THE 4TH WORLD CONSTRUCTION SYMPOSIUM - 2015

Sustainable Development in the Built Environment: Green Growth and Innovative Directions
12-14 June 2015 - Colombo

SYMPOSIUM
PROCEEDINGS

12th – 14th JUNE 2015

GALADARI HOTEL COLOMBO

THE 4TH WORLD CONSTRUCTION SYMPOSIUM
SUSTAINABLE DEVELOPMENT IN THE BUILT ENVIRONMENT: GREEN GROWTH & INNOVATIVE DIRECTIONS

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THE 4[TH] WORLD CONSTRUCTION SYMPOSIUM 2015

Theme:

Sustainable Development in Built Environment: Green Growth & Innovative Directions

Editors

Dr. Y. G. Sandanayake
Dr. N. G. Fernando
Dr. G. I. Karunasena

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

Edited by Dr. Y. G. Sandanayake, Dr. N. G. Fernando and Dr. G. I. Karunasena

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We are very thankful to the authors who have submitted papers for this symposium, as if not for them, we could not hold this event. Our special thanks 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, key note speaker, session chairs, session coordinators, paper presenters, industry presenters, members of panel discussion and investor forum, awards selection committees, BEPAM Journal Editor-in-Chief, Emerald Publisher and the committee and other invitees for their commitment and contribution to the symposium.

We are also thankful for the organisations that have provided sponsorships. Last but not least, all our colleagues in the organising committee and symposium secretariat are especially thanked for devoting their time and effort to make 'The 4th World Construction Symposium 2015' a success.

Editors
The 4th World Construction Symposium 2015

Sri Lanka
June 2015

PREFACE

The 4th World Construction Symposium 2015 held on 12 - 14 June 2015 in Colombo, Sri Lanka is jointly organised by the Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit (BEMRU), Department of Building Economics, University of Moratuwa. International Council for Research and Innovation in Building and Construction (CIB) is the main sponsor of the event. Liverpool John Moores University, United Kingdom, Centre for Innovation in Construction and Infrastructure Development (CICID), The University of Hong Kong, Indian Institute of Technology Madras (IIT Madras), CIB - TG 72 (Public Private Partnership), CIB - W092 (Procurement Systems) and Colombo School of Construction Technology (CSCT) are the associate partners of the Symposium. The main theme of this international symposium is *'Sustainable Development in Built Environment: Green Growth & Innovative Directions'*. The symposium provides a special forum for academic researchers and industry practitioners to share their knowledge, experience and research findings on green growth, innovative directions and sustainable future in construction industry.

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

We received number of abstracts and full papers for the symposium covering the above themes from both local and foreign authors. All full papers went through a rigorous double-blind peer-review process by local and world renowned reviewers with respect to the originality, significance, reliability, quality of presentation and relevance, prior to selection. Priority was given to the quality and standard of papers rather than the number of papers presented at the symposium. It is our firm belief that the publication that emerged from this symposium is the result of the tireless effort of all authors, reviewers, symposium organising committee members, partners, sponsors and that it would pave way for advancement of knowledge in sustainable development in built environment.

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PAPERS

A CONCEPTUAL LEAN-BASED FRAMEWORK FOR IMPROVING THE ENVIRONMENTAL PERFORMANCE OF READY-MIXED CONCRETE PRODUCTION PROCESSES

Anna George Nellickal, Andukuri Vijaya Rajendra and Sivakumar Palaniappan*

Building Technology and Construction Management,
Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India

ABSTRACT

The Ready-Mixed Concrete (RMC) industry is one of the fastest growing construction sectors and plays an important role towards infrastructure development. The RMC industry is expected to rise from INR 155-160 billion in 2009 - 2010 to INR 395 - 400 billion in 2014 – 2015 in India. The use of RMC for construction has proved to be advantageous due to its assured quality, accuracy in the mix proportion, faster construction, less workforce and improved workspace utilization. The RMC industry life cycle consists of five major phases namely manufacturing of raw materials, transportation of raw materials to batching plant, batching plant operations, delivery of concrete to site and site activities for placing and compaction. Significant amounts of resources such as materials, energy and water are used during these five phases. The transportation of raw materials and concrete is considered as one of the major sources of energy use and emissions. This study investigates the application of lean concepts for improving the environmental performance of RMC industry operations. First, the current status of RMC industry is presented. Second, a detailed study of resources used during various phases of RMC industry is summarized based on case studies carried out in Chennai. Third, lean concepts relevant for construction to minimize or eliminate non-value adding activities and wastes are discussed. Finally, this study presents a conceptual framework based on lean thinking to improve the environmental performance of RMC industry. This framework can be used to evaluate alternate RMC production scenarios and enhance the decision-making process for better production and environmental performance.

Keywords: *Lean Construction; Ready-Mixed Concrete Production; Sustainable Construction.*

1. DEVELOPMENT OF RMC INDUSTRY IN INDIA

The construction industry in India has been traditionally labour-oriented. This is mainly due to the lack of capital investment, availability of cheap and abundant labour and the highly fragmented nature of the construction sector in the earlier days. However, slowly towards the 1980's, the country saw the advent of liberalisation principles into its economy and this paved the way for large-scale investments in the industrial, infrastructure and agricultural sectors. This led to the increased pace in the mechanisation of the construction industry and to the advent of RMC in India (Jain, 2002).

The use of RMC in the construction industry is significantly advantageous because of many reasons. It assures good quality concrete as well as precise mix proportions of the various raw materials in concrete. It also leads to faster construction, lesser number of labourers, reduced congestion at the work site and improved workspace utilisation (Indian Cement Review, 2014).

Concrete is the most widely used material in the world next to water and in the present scenario, the ready-mixed concrete industry is one of the fastest growing sectors in India. The size of the RMC industry has grown from INR 155-160 billion in 2009-2010 to INR 395-400 billion in 2014-2015 (Goyal, 2012). The main reasons for this exponential growth of the RMC industry in the last few years is

* Corresponding Author: E-mail - sp@iitm.ac.in

attributed to the rapid growth in the development of the infrastructure sector, technological advancements and the increase in the per capita consumption of cement and concrete in India.

Ready-mixed concrete arrived in India as early as the 1950’s but its use was limited only to large construction projects such as dams, long-span bridges, multi-storey complexes, etc. Its use was mainly made possible with the help of captive plants which were outsourced from other countries as RMC plants were yet to make an impact in the Indian construction sector. In 1974, a techno-economic feasibility study was conducted by the Central Building Research Institute (CBRI), Roorkee, India, which recommended the setting up of RMC plants in the major metropolitan cities of India (Verma *et al.*, 1978). This study led to the establishment of the first RMC plant in 1987. However, the plant did not contribute much to the construction industry as the use of RMC for construction purposes was yet to arrive commercially (Alimchandani, 2007). The first commercial RMC plant was set up in Pune in 1993. In the following year, the Associated Cement Companies Ltd. set up plants in Mumbai and Navi Mumbai. The next decade saw the setting up of a large number of RMC plants in India, predominantly in the metropolitan areas (Jain, 2002).

As per the earliest efforts to count the RMC plants in India, the total number of plants accounted to 27 and was mainly concentrated in the major cities of India (Jain, 2000). In 2001, the number increased to 47 (Jain, 2002) and further increased to 147 by 2005 (Ranganath, 2005). In 2013, the all India commercial statistics of RMC plants amounted to a total of 857 and the latest statistics show that as per January 2015, the total number of RMC plants is 1135 (Manjunathal *et al.*, 2015). Figure 1 shows the rise in the number of RMC plants in India. The development and growth of RMC industry in India and the major milestones are summarized in Table 1.

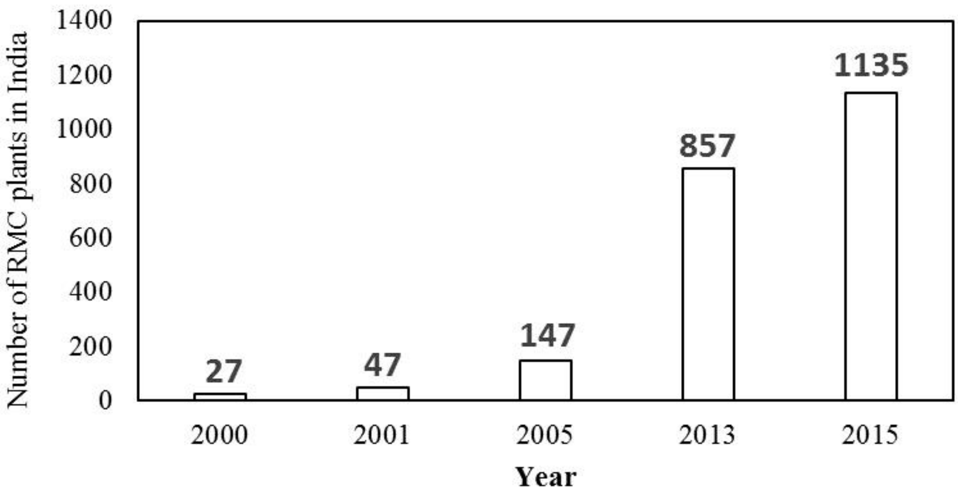


Figure 1: Growth of RMC Plants in India

Also, the Ready-Mixed Concrete Manufacturers’ Association (RMCMA) was formed in 2002. It is a non-profit organisation comprising the leading RMC producers in India. The association aims to increase the use of RMC across India as well as to enhance sustainability aspects and conduct research in this field (RMCMA, 2014).

Most of the plants have been set up in the seven large cities of India and they account for 30 - 60 % of the total concrete used in these cities. On an all India basis, RMC accounts for only about 5 % of the total concrete used. However, its use is rapidly increasing in spite of the 12 - 20 % higher cost as compared to the traditional approach of site-mixed concrete (Alimchandani, 2007). On an average, the total concrete market in India is estimated at about 300 million cubic meters annually. Out of this, the RMC plant produced share is about 35 million cubic meters (Goyal, 2012), which is around 12 % of the total concrete production.

Table 1: Major Milestones in the Development and Growth of RMC in India

Year	Event
1950	Introduction of captive plants in India, limited to large-scale construction projects
1974	CBRI recommends setting up RMC plants in major cities of India
1987	Establishment of first RMC plant in India, though it did not contribute commercially
1993	The first commercial RMC plant is set up in Pune
1994	ACC Ltd. Set up two new plants in Mumbai and Navi Mumbai
2000	Earliest efforts to count the RMC plants in India - 27 plants
2001	A total of 47 plants located in the major metropolitan areas
2002	Formation of Ready-Mixed Concrete Manufacturers' Association (RMCMA)
2005	Number of RMC plants increased to 147
2012	Total RMC market estimated at 35 million cubic meters
2013	The total number of plants increased to 857
2015	Estimated number of RMC plants in India - 1135

The use of RMC and the number of RMC plants in India is increasing to such an extent that efforts have to be made to reduce the impact on the environment due to its production processes. This study investigates the application of lean concepts for improving the environmental performance of RMC industry operations. The current status of RMC industry is presented and a detailed study of resources used during the various phases of RMC industry is summarised. The lean concepts relevant for construction to minimize or eliminate non-value adding activities and wastes are discussed. Finally, a framework based on lean thinking is presented to improve the environmental performance of RMC industry.

2. PROCESS MAP FOR RMC PRODUCTION

Four case studies were carried out to develop a detailed understanding of RMC production processes from the extraction of raw materials to activities carried out at site. The RMC plants that were visited are located within 100 kilometres of Chennai, the capital city of Tamil Nadu state in India. Based on these visits, the RMC production related processes are grouped into five major phases namely manufacturing of raw materials, transportation of raw materials to batching plant, operations at the batching plant, delivery of concrete to site using transit-mixer trucks and site operations. Figure 2 shows the details of these phases and the resources used in each phase such as water, fuel, electricity, consumables, equipment, vehicles, instruments and human workforce. The details of the five phases are described below.

2.1. MANUFACTURING OF RAW MATERIALS

The raw materials used for ready-mix concrete production are cement, sand, coarse aggregates, water, admixtures and flyash. Energy is used for manufacturing cement at the cement plant through extraction of raw materials, processing, clinker production, grinding and packaging. Cement is produced mainly from limestone and clay along with smaller amounts of gypsum. Coal and coke are used for burning cement clinkers and oil is used for lubrication. Sand is usually obtained from the river sources. Usually, 20 mm and 12/10 mm coarse aggregates are used for concrete production. Manufactured sand is used in some cases when the river sand is not available. Flyash is obtained as a by-product from thermal power plants.

The admixtures are produced from a wide variety of chemicals. Water is usually obtained from a natural source.

2.2. TRANSPORTATION OF RAW MATERIALS TO BATCHING PLANT

The raw materials required for ready-mixed concrete production are transported to the batching plant using trucks. Cement and flyash are stored in huge silos at the batching plant. The coarse and fine aggregates are stored in their respective storage yards. The admixtures are transported to the plant in cylindrical barrels which are connected to the batching plant mixer. Water is brought to the plant in tankers and are filled in the water tanks.

2.3. BATCHING PLANT OPERATIONS

The batching plant is usually fully automated and is run by diesel or electricity. The major sources of energy consumption include the diesel generator, site office operations, loader used for handling aggregates from the storage yard to automated belt conveyor and trucks used by staff members. The batching plant is able to produce different grades of concrete as well as special types of concrete such as self-compacting concrete. The mix proportions are already stored into the automated control systems of the batching plant. The mixer used in the plant is either a pan mixer or a twin shaft mixer.

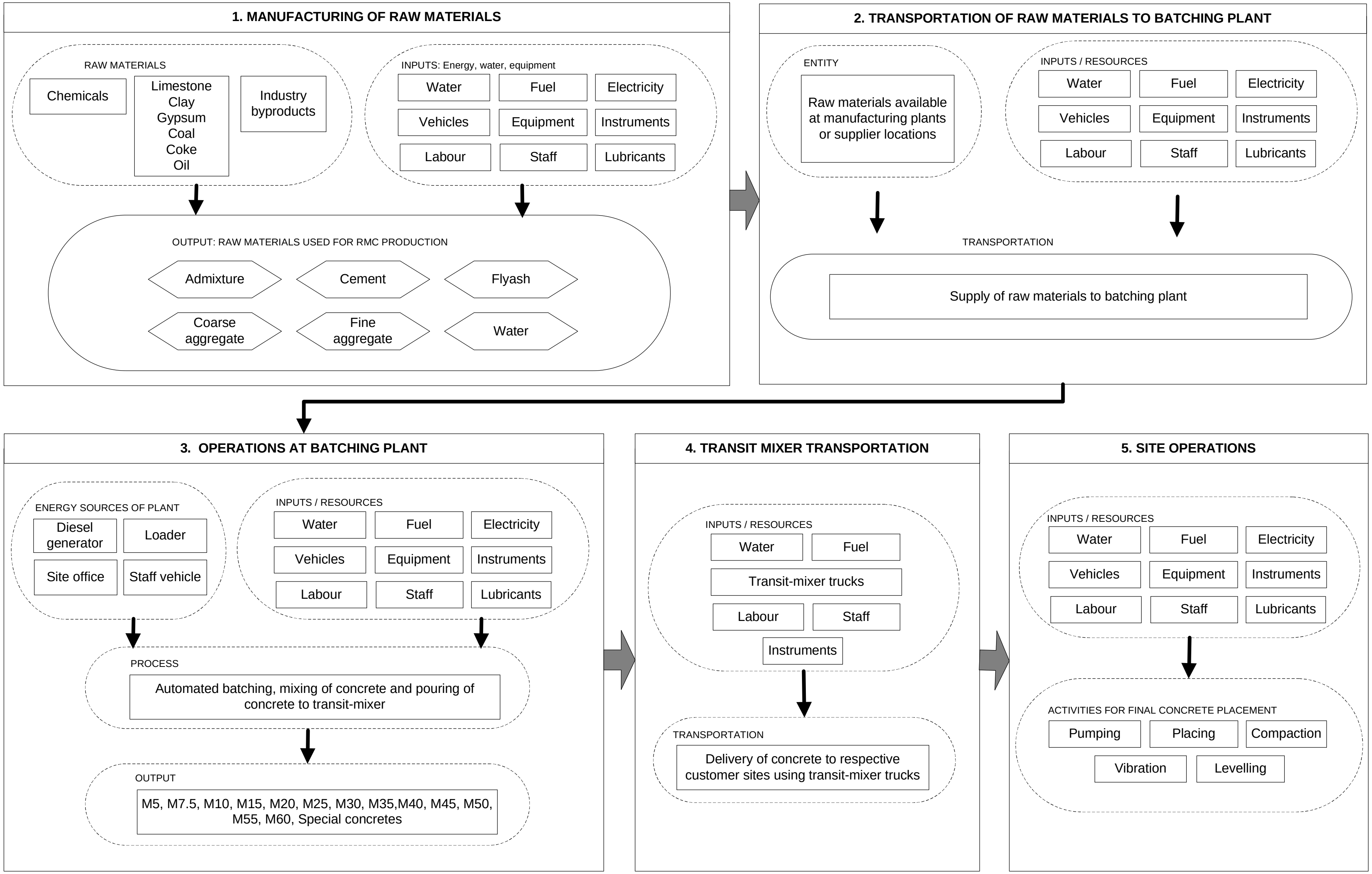


Figure 2: Process Map of RMC Production

2.4. TRANSPORTATION OF RMC USING TRANSIT MIXER

The batched concrete is fed into the transit-mixer trucks which are transported to the respective customer sites. The total capacity of the transit mixers are 7 cum. The final mixing of the concrete is performed in the rotating drums of the transit-mixer trucks. For the best properties of concrete to be maintained, the concrete should reach the site within a maximum time of 2 hours from the time of batching. Traffic usually hinders the smooth transportation of transit-mixer trucks, especially in the major cities.

2.5. SITE OPERATIONS

Once the transit mixer reaches the customer site, the concrete is then pumped to the required location using a concrete pump. The placed concrete is further levelled and compacted for its effective placement. The surface is then given the final finishing using appropriate tools to get a smooth appearance of concrete before the curing is done. In most cases in India, the RMC supplier takes care of pumping the concrete at site while most of the other activities are under the control of the building contractor.

3. REVIEW OF LEAN CONCEPTS AND TOOLS

Lean thinking was originally developed in the 1930's from the idea of elimination of waste in production systems. It was introduced by Henry Ford and was popularly known as the Toyota Production system. Lean thinking was finally simplified into five main principles: specify value, identify the steps in the value stream, continuous flow, pull production and pursue perfection for continuous improvement (Womack and Jones, 1996). Over production, over-processing, rework, excess inventory, waiting, transportation and excessive motion are the major sources of waste. Once the source of waste is identified, lean approach uses various concepts and tools for the elimination of wastes, thereby making the system more productive. Some of the lean concepts/ tools are discussed below (Marhani *et al.*, 2013):

- Just-in-Time (JIT): It is a Japanese philosophy applied in manufacturing which involves having right items of right quality and quantity at the right place and right time.
- Continuous improvement: It is a systematic approach to gradual, orderly and continuous improvement of a production system.
- Total Quality Management (TQM): The management of quality at every stage of operations from planning to design through continual process monitoring for process improvement.
- Work Standardisation: Standardisation of work ensures that each job is organised and carried out in the most effective manner for the elimination of waste.
- Total Productive Maintenance (TPM): TPM is a set of tools, which when implemented in an organisation as a whole gives the best utilization of machines with least disruption of production.
- Value Stream Mapping (VSM): It is a lean-management tool for analysing the current state and designing a future state for a series of events after detecting and eliminating the non-value adding activities. It also optimizes the value adding activities.
- Huddle Meetings: Start-of-the-day meetings of all personnel to review the work to be done that day.
- 5S (Workplace organisation): One of the most effective tools for continuous improvement is 5S which consists of sort, straighten, sweep and clean, systemise and standardise for effective waste reduction.

3.1. LEAN CONSTRUCTION

In 1992, the lean manufacturing principles were introduced into the construction industry by Koskela (1992) for better productivity. Lean construction is believed to be particularly useful on complex, uncertain and quick projects. The main objective is to maximize the value and minimise waste (Lean Construction Institute, 2012). This allows companies to reduce cost, eliminate waste and deliver projects in time (Lim, 2008). A new flow planning and controlling system, known as the Last Planner System (LPS) introduced fundamental changes in the way construction projects are planned and controlled (Ballard, 2000; Ballard and Howell, 1997). In LPS, the sequences of implementation sets up an efficient schedule planning framework through a pull technique, which shapes work flow, sequence, and rate; matches work flow and capacity; develops methods for executing work; and improves communications between trades. Table 2 presents a review of lean construction case studies which used Last Planner System and other lean concepts such as Value Stream Mapping.

Table 2: Summary of Lean Construction Case Studies

Project	Country	Benefits	Implementation Phase (Technique)	Reference
Hospital building project	USA	Increased work plan reliability	Construction phase (LPS)	Ballard (2000)
Hospital building project	USA	Improved work planning ability	Design phase (LPS)	Hamzeh *et al.* (2009)
Medical center project	Chile	Efficient identification and measurement of waste resources	Construction phase (VSM)	Rosenbaum *et al.* (2013)
New town development	USA	Better resource levelling and Improved work planning ability	Design phase (LPS)	Ballard *et al.* (2009)
Housing project	Ecuador	Improved project performance and increased work plan reliability	Construction phase (LPS)	Fiallo and Revelo (2002)
Apartment buildings	Israel	Reduced batch size, Work in Progress (WIP) is controlled, reduced cycle times	Construction phase (VSM)	Sacks and Goldin (2007)
Residential building	Brazil	Improved look-ahead planning	Construction phase (LPS)	Kemmer *et al.* (2007)
Central bus station project	Peru	Reduced project delivery time and production time	Design phase (LPS)	Arbulu *et al.* (2006)
Subway project	South Korea	Improved informational transparency and reduced procurement cost	Construction phase (LPS)	Kim and Jang (2005)
Airport building	UK	Reduced cost	Supply chain management (LPS)	Ballard *et al.* (2007)
Parking garage	USA	Increased profit	Construction phase (LPS)	Salem *et al.* (2005)
School building	Denmark	Reduced batch size	Construction phase (LPS)	Nielsen and Thomassen (2004)
Administration building	Saudi Arabia	Improvement in quality of work practice, enhancement in managerial practices	Construction phase (LPS)	Sehaimi *et al.* (2009)
Industrial bridge construction	Sweden	Reduced cost, physical loads and improved safety	Construction phase (LPS)	Simonsson and Emborg (2007)
Industrial building	Brazil	Improved supply chain integration	Construction phase (LPS)	Sterzi *et al.* (2007)

4. FRAMEWORK FOR THE APPLICATION OF LEAN CONCEPTS IN THE RMC INDUSTRY

This section depicts that the application of lean principles in the different phases of RMC industry could greatly influence the time, cost and the environmental performance of the production processes. A framework is presented based on the visits undertaken to RMC plants in Chennai. Figure 3 presents a lean-based framework for improving the environmental performance of RMC industry. The framework suggests that lean concepts can be used for improving the production performance as well as the environmental efficiency. The five phases of RMC production are taken into consideration and activities that enhance the environmental and production performance are presented. Each proposed action is linked with a lean concept recommending that the lean thinking in the RMC industry can lead to better production and environmental benefits.

4.1. MANUFACTURING OF RAW MATERIALS

The energy consumption and emissions due to manufacturing of raw materials can be reduced by applying the relevant lean concepts. The raw material inventories should be maintained such that they are available only when required keeping the over-production of the materials at check. The over-processing of raw materials should be eliminated by all means as this leads to additional usage of energy. The quality and safety should be under check and defects should be eliminated to avoid rework. Moreover, in keeping with the concept of sustainability from the design stage itself, the use of locally available raw materials and recycled materials should be encouraged.

4.2. SUPPLY OF RAW MATERIALS TO BATCHING PLANT AND TRANSPORTATION OF RMC BY TRANSIT MIXERS

The use of large capacity trucks for raw material transportation to the batching plant as well as the usage of optimum number of trucks will keep a check on the number of trips to the batching plant, which in turn will conserve the fuel consumption substantially. The trucks should be managed in such a way that the waiting time and queuing of each truck should be minimised as much as possible as this will decrease fuel wastage. Moreover, the proper maintenance and repairs of all vehicles and equipment should be carried out regularly. The skill of the driver is also an important factor related to the fuel use of transit truck mixers.

4.3. BATCHING PLANT OPERATIONS

The performance of batching plant can be improved through the application of lean concepts which could reduce the impacts on the environment. One of the main requirements is to schedule the batching of concrete according to the customer needs. This could be done by setting of adequate milestones for each RMC company to reach their target production. Weekly work plans along with start-of-the-day meetings will be helpful to plan ahead for better efficiency of the plant. It will also lead to increased knowledge and communication among the workforce at the batching plant. Incorporating the use of safety and mobile signs could lead to better team effort during batching plant operation. The use of the loader for aggregate transportation should be controlled in order to maintain the number of times it is used, thereby reducing the fuel consumption.

4.4. SITE OPERATIONS

The operations at the site include the usage of a large number of equipment and vehicles. These should be maintained regularly in order to improve the overall efficiency of site activities. During the vibration of concrete, care should be taken such that it is not over-compacted. Regular safety and quality checks should be ensured for improving the productivity rate and reducing the defects. Also, in case of exceeding the transit mixer delivery time, the usage of higher grade concrete for lower grade strength requirement is also followed as it will not lead to the wastage of batched concrete.

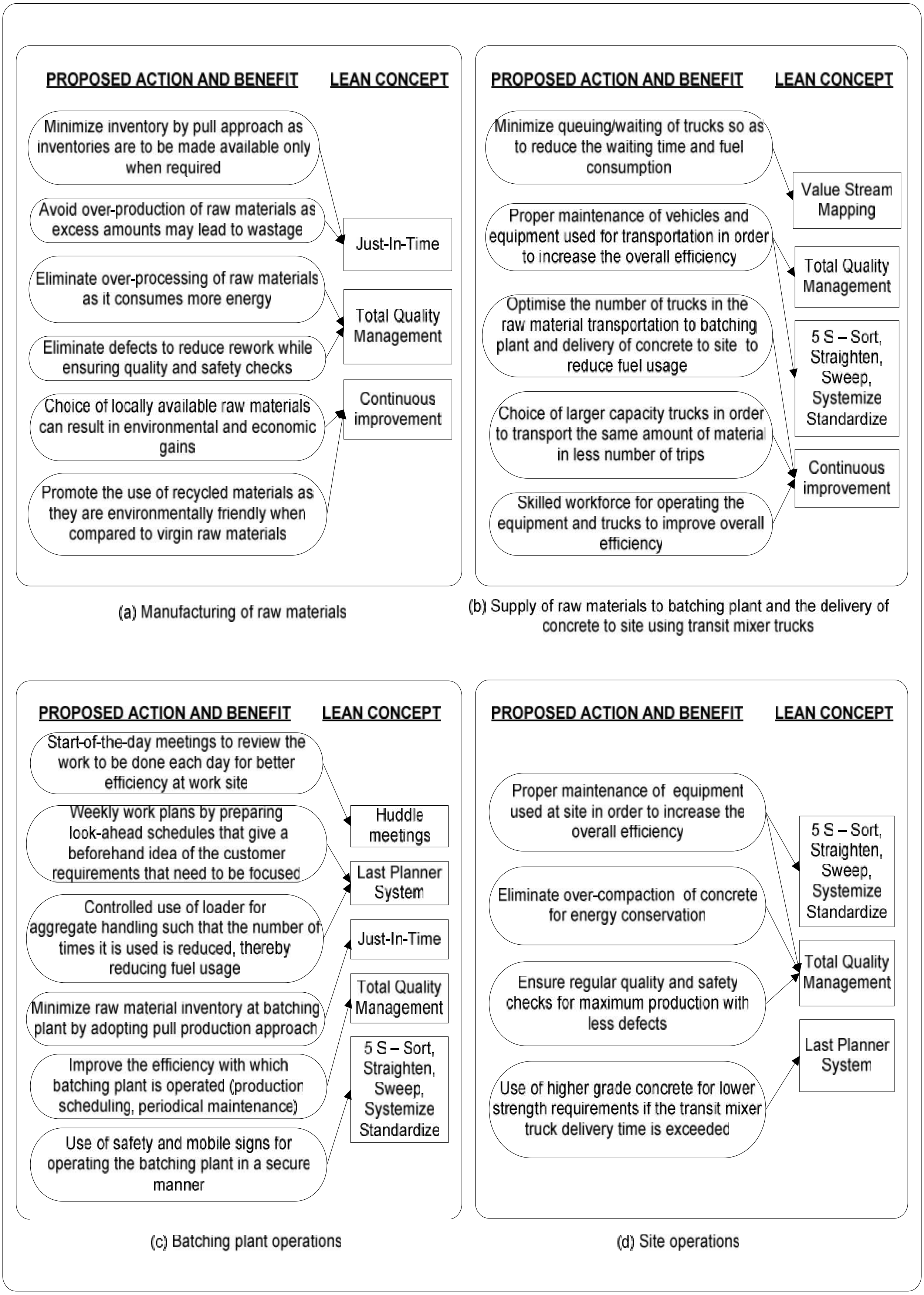


Figure 3: Lean-based Framework for Improving the Environmental Performance of RMC Industry

5. CONCLUSION

This study presents a review of the status of RMC industry in India and a process map documenting the details of major phases of RMC industry from raw materials production to site operations. Due to the growing demand of RMC and the increased environmental concern today, a lean-based framework is presented for improving the environmental performance of the RMC industry. Further studies can focus on gathering field data related to energy use and developing a simulation model for evaluating alternate production and construction scenarios to assess the performance in terms of cycle time, energy footprint and carbon footprint. The simulation-based model will also be useful to study the effect of lean concepts on production performance.

6. REFERENCES

Alimchandani, C.R., 2007. The Indian Experience of Ready Mixed Concrete (RMC). In: 32nd *Conference on Our World in Concrete & Structures,* Singapore 28–29 August 2007. CI-Premier PTE LTD.

Arbulu, R., and Soto, J., 2006. A Design Case Study: Integrated Product and Process Management. In: *14th Annual Conference of the International Group for Lean Construction (IGLC-14),* Santiago, Chile.

Ballard, G., 2000. *The Last Planner System of Production Control*. School of Civil Engineering, Faculty of Engineering, University of Birmingham, UK.

Ballard, G. and Howell, G.A., 1997. Shielding Production: An Essential Step in Production Control. *Journal of Construction Engineering and Management*, 124(1), 11-17.

Ballard, G., Hammond, J. and Nickerson, R., 2009. Production Control Principles. In: *17th Annual Conference of the International Group for Lean Construction (IGLC-17),* Taipei, Taiwan.

Ballard, G., Liu, M., Kim, Y.W. and Jang, J.W., 2007. *Roadmap to Lean Implementation at the Project Level*. Construction Industry Institute (CII), Research Report, Austin, Texas.

Fiallo, C.M. and Revelo, P.V.H., 2002. Applying the Last Planner System to a Construction Project- Case study in Quito Ecuador. In: *10th Annual Conference of the International Group for Lean Construction (IGLC-10),* Granmado, Brazil.

Goyal, C.R., 2012. Concrete :Ready-Mixed Concrete- Readies Itself To Take Over The Industry. July 2012, The Masterbuilder, 58-64.

Hamzeh, F.R., Ballard, G. and Tommelein, I.D., 2009. Is the Last Planner System Applicable to Design? - A Case Study. In: *17th Annual Conference of the International Group for Lean Construction (IGLC-17),* Taipei, Taiwan.

Indian Cement Review, 2014 [online]. Available from: http://www.indiancementreview.com/News.aspx?news=Ready-Mix-Concrete-India-Sector&nid=oQru6pPQGJYexnRHE+cMng [Accessed 3 December 2013].

Jain, A.K., 2000. RMC: A Durable And Cost-effective Construction Material. *The Indian Concrete Journal*, 3(4).

Jain, A.K., 2002. Ready-mixed Concrete Growth Prospects in India. In: *27th Conference on Our World in Concrete & Structures*, Singapore 29–30 August 2002. CI-Premier PTE LTD, 255-262.

Kemmer, S.L., Heineck, L.F.M., Novaes, M.V., Alexandre, C., Mourão, M. A. and Alves T.C.L., 2007. Medium Term Planning- Contribution Based on Field Application. In: *15th Annual Conference of the International Group for Lean Construction (IGLC-15),* East Lansing, Michigan.

Kim, Y.W. and Jang, J.W., 2005. Case study - An Application of Last Planner to Heavy Civil Construction in Korea. In: *13th Annual Conference of the International Group for Lean Construction (IGLC-13),* Sydney, Australia.

Koskela, L., 1992. *Application of The New Production Philosophy to Construction.* Center for Integrated Facility Engineering, Stanford University, Stanford, California, Technical Report No. 72.

Lean Construction Institute, 2012. *What is Lean Construction?* [online]. Available from: http://www.leanconstruction.org [Accessed 13 February 2014].

Lim, V.L.J., 2008. *Lean Construction: Knowledge and Barriers in Implementing into Malaysia Construction Industry*. Project Peport, Universiti Teknologi Malaysia.

Manjunathal, L.R., Ravishankar, M. and Aswath, M.U., 2015. Growth and Development of Ready-Mixed Concrete Industry in India. In: *Seminar Document: Quality Assurance and Innovations in Ready-Mixed Concrete*, Bangalore 24-25 February 2015. 99-106.

Marhani, M.A., Jaapar, A., Bari, N.A.A. and Zawawi, M., 2013. Sustainability through Lean Construction Approach: A Literature Review. *Procedia- Social and Behavioral Sciences*, 101, 90- 99.

Nielsen, A.S. and Thomassen, M.A., 2004. How to Reduce Batch Size?. In: *12th Annual Conference of the International Group for Lean Construction (IGLC-12)*, Copenhagen, Denmark.

Ranganath, R.V., n.d. *Ready-Mixed Concrete* [online]. BMS College of Engineering. Available from: http://elearning.vtu.ac.in/12/enotes/Adv_Conc_Stru/Unit5-RVR.pdf [Accessed 10 March 2014].

RMCMA, 2014. *Ready Mixed Concrete Manufacturers' Association* [online]. Available from: http://www.rmcmaindia.org/ [Accessed 22 January 2014].

Toledo, R.M. and González, V., 2013. Improving Environmental and Production Performance in Construction Projects using Value-Stream Mapping: A Case Study. *Journal of Construction Engineering and Management*, 140(2), 1-11.

Sacks, R and Goldin, M., 2007. Lean Management Model for Construction of High-Rise Apartment Buildings. *Journal of Construction Engineering and Management*, 133(5), 374-384.

Salem, O., Genaidy, J.S.A. and Luegring, M., 2005. Site Implementation and Assessment of Lean Construction Techniques. *Lean Construction Journal*, 2(2), 1-21.

Sehaimi, A., Tzortzopoulos, P. and Koskela, L., 2009. Last Planner System: Experiences from Pilot Implementation in the Middle East. In: *17th Annual Conference of the International Group for Lean Construction (IGLC-17)*, Taipei, Taiwan.

Simonsson, P. and Emborg, M., 2007. Industrialization in Swedish Bridge Engineering: A Case Study of Lean Construction. In: *15th Annual Conference of the International Group for Lean Construction (IGLC-15)*, East Lansing, Michigan.

Sterzi, M.P., Isatto, E.L. and Formoso, C.T., 2007. Integrating Strategic Project Supply Chain Members in Production Planning and Control. In: *15th Annual Conference of the International Group for Lean Construction (IGLC-15)*, East Lansing, Michigan.

Verma, C.L., Jain, S.K. and Rehsi, S.S., 1978. Techno-Economic Feasibility Study for the Production of Ready-Mixed Concrete in India. *The Indian Concrete Journal*, 54(10), 257-259.

Womack, J.P. and Jones, D.T., 1996. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. New York: Simon and Schuster.

A FRAMEWORK FOR THE EVALUATION OF INDOOR ENVIRONMENTAL QUALITY (IEQ) PERFORMANCE IN APPAREL INDUSTRY BUILDINGS IN SRI LANKA

M.G.D.T. Vijerathne* and L.D. Indunil P. Seneviratne
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In the modern world, many people spend large portion of their time in built environments. Accordingly, significance of built environments' performance is increasing over past two decades. It draws the attention towards the concept of Indoor Environmental Quality (IEQ) to determine how well built environments are performing as IEQ performance directly affects occupants' health, comfort, satisfaction and ultimately for a productive work environment. Moreover, IEQ concept can be considered as an integral part of total building performance approach.

Today in Sri Lankan industrial sector, especially apparel manufacturing sector grows upward in speedily. For this rapidly development, performance of the built environment is vital as it is having direct relationship with occupants' productivity. At the present, various approaches to evaluate IEQ performance has being developed. However, it is evident that there is no holistic approach. Similarly in Sri Lanka, there is no comprehensive framework applied in industrial buildings to evaluate IEQ performance. This necessitates the important of developing a holistic IEQ evaluation approach which would greatly benefit to the industrial sector.

Survey methodology is used in the research and RII is employed as a data analysing tool to validate the IEQ indicators which have been identified in literature review and modified in preliminary survey. Further, it is established the most significant indicators based on their importance towards IEQ performance in apparel industry buildings with AHP tool. The developed framework comprised with four main IEQ indicators as thermal comfort, indoor air quality, acoustic quality and lighting quality. This framework focused on holistic approach to measure IEQ performance which will allow acceptable built environment while processing continuous improvements.

Keywords: *Building Performance; Built Environment; Indoor Environmental Quality (IEQ); IEQ Indicators; Industrial Buildings.*

1. INTRODUCTION

The indoor environment quality (IEQ) performance of buildings directly or indirectly affects the buildings operation and its occupant's satisfaction and productivity (Heinzerling *et al.*, 2013). At present, the concept of an acceptable IEQ is considered as an integral part of the total building performance approach, however it is not fully appreciated yet (Wong *et al.*, 2008).

According to Sinou and Kyvelou (2006), there is an emerging issue of poor IEQ related factors negatively impact on industrial building occupants. As the investments on industrial buildings become popular and large numbers of people were attached to the industrial work settings, it was arisen the demand for IEQ improvement to reduce impact of poor IEQ conditions on building occupants (Bannet, 1984).

According to Sinou and Kyvelou (2006), nowadays several methods are in practice for evaluating IEQ performance of buildings. It is further verified by Adebiyi *et al.* (2007) as there is no generally agreed model for IEQ evaluation. Consequently, a critical need exists to develop an IEQ performance evaluation

* Corresponding Author- E mail - dimuthuvijerathne@gmail.com

framework to define acceptable IEQ levels for buildings and to provide standard way of doing continuous improvement of IEQ (Kumar and Fisk, 2002).

Similarly in Sri Lanka, there is no comprehensive framework applied in buildings to evaluate IEQ performance and the situation is same with other countries as there is no high concentration on some IEQ factors in building performance (Mallawaarachchi and Silva, 2012). Industrial buildings also have not been considered the evaluation of total IEQ performance, even though some of buildings have concentration on few IEQ measurements. Therefore, this research focused to develop a framework to evaluate for total IEQ performance of industrial buildings in Sri Lanka.

2. LITERATURE REVIEW

People spend almost 90% of life time in built environment when the world is in the developed part of it (Klepeis *et al.*, 2001). Main relationship between buildings and people is that, buildings are for people and people are the facilitators of built environments (Barrett, 1992 cited Amaratunga and Baldry, 1998). Furthermore, Barrett (1992 cited Amaratunga and Baldry, 1998) emphasised that, the environments create by buildings provides the temperature, humidity, lighting and ventilation which necessary for people to live and work productively.

In the present, the concept of IEQ is growing as a new and very useful concept of the building performance and quality (Catalina and Iordache, 2011). It is because of people spending most of their time in built environments and various aspects of the indoor environment affect its occupant's wellbeing and performance (Prakash, 2005). Further, the quality of the indoor environment reflects on the health, comfort and productivity of occupants in built environment (Singh, 1996).

Thermal comfort, lighting quality, acoustic quality and indoor air quality are the most important indicators of IEQ (Mahbob *et al.*, 2011). All these four indicators of the indoor environment interact with each other and make impact on the overall indoor comfort and energy consumption of the building (Catalina and Iordache, 2011). Figure 1 illustrated the main indicators relating to the concept of IEQ performance.

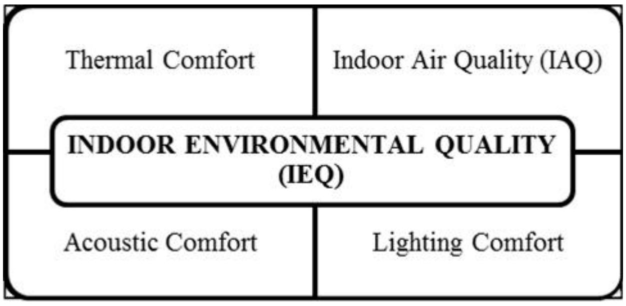


Figure 1: Main Indicators of IEQ

Industrial sector, basically apparel manufacturing industry has an important place in economy of Sri Lanka while it has become the largest export industry in Sri Lanka since the year 1986. It is also the largest net foreign exchange earner of the country and also the biggest industry in Sri Lanka (Dheerasinghe, 2006). Moreover, apparel manufacturing industry is the leading manufacturing industry in Sri Lanka up to now and it has emerged as the country's main export earner and the largest single employment provider (Saheed, 2005). There are 830 garment factories in Sri Lanka, of which 157 are small, 438 are medium, and 235 are large. The industry produces around 500 million units of garments per annum of which woven garments account for 55% and knitwear 45 % (Saheed, 2005).

Heerwagen (2000) stated that, there is a direct effect of IEQ on factory workers performance. According to the present surveys, IEQ plays an important role and it has a strong and direct correlation with work efficiency and also earlier scientific studies conclude that 16% of worker's performance can be increased, if the building occupants are comfortable with their indoor environment (Mahbob *et al.*, 2011). Most of the industrial building owners and responsible persons such as health and safety executives, maintenance engineers applied some techniques to evaluate the building performance and yet, those methods are conducted in their own customized ways (Rathnayaka, 2010). Furthermore, Rathnayaka (2010) stated that, maximum benefits of those evaluations are doubtful, due to that reason.

3. RESEARCH METHODOLOGY

The quantitative approach with the survey methodology was selected for this research and three steps were adopted to develop the IEQ performance evaluation framework.

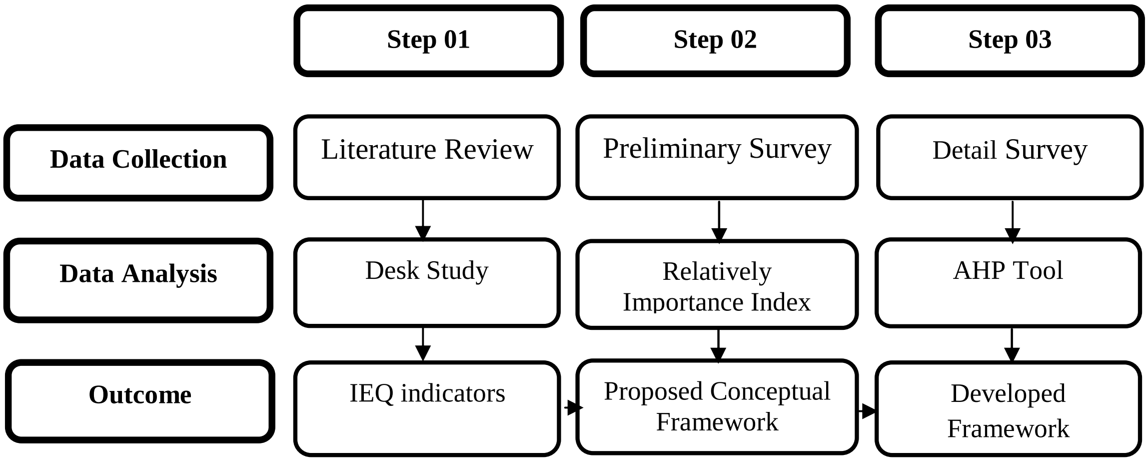


Figure 2: Steps in the Research Methodology

Step 1 - A comprehensive literature review was carried out in order to explore the concept of IEQ, IEQ performance evaluation techniques and tools, current IEQ performance condition in Sri Lankan apparel manufacturing sector and IEQ related indicators through referring books, journal articles and unpublished dissertations.

Step 2 - Preliminary survey was carried out among ten (10) industry experts and analysed using Relatively Importance Index (RII) in order to serve the most significant IEQ indicators to derive with a conceptual framework for the development of holistic framework to evaluate IEQ performance in apparel manufacturing industry in Sri Lanka.

Step 3 - Based on the Analytical Hierarchy Process (AHP) tool which provided the facility of prioritization of factors, the questionnaire was prepared by using the data gathered from preliminary questionnaire survey. Since the data collection was mainly aim at professionals in garment manufacturing field in Western Province, questionnaires were distributed among 30 respondents as large size of sample may be impractical as there is a great tendency to provide arbitrary answers (Wong and Li, 2007). Moreover, AHP survey with 30 number of respondants sample size has been conducted in previous researches (Sato, 2003).

Detail questionnaire survey was carried out among thirty (30)IEQ related industry experts and analysed using Analytical Hierarchical Process (AHP) in order to validate and prioritize the preliminary survey findings. The Proposed developed framework consisting of four IEQ main indicators and its twenty seven sub indicators (Figure 3) were developed using the literature review and preliminary survey findings.

4. GENERIC FRAMEWORK FOR EVALUATING IEQ PERFORMANCE

Indicators which are related to IEQ were identified referring twenty researches which were done based on the IEQ performance evaluation which had been discussed in literature review. In this identification, sub indicators were identified basically in major four key indicators, namely indoor air quality, lighting quality, thermal comfort and acoustic quality. It had listed 12 indicators which are related to indoor air quality, 11 indicators which are related to lighting quality, 6 indicators which are related to thermal comfort and 5 indicators which are related to acoustic quality. Hence, altogether 34 indicators were identified (Refer Table 1).

Apart from the IEQ indicators which were identified in the literature review, respondents had identified 15 additional indicators and seven (7) indicators were removed, two (2) indicators were combined as one and three (4) indicators were modified while three (3) were split in to two. In order to identify the importance of the indicators for evaluating the IEQ performance, it was necessary to rank the indicators according to their importance and remove the indicators which are having a less importance. To determine the relative importance of IEQ indicators, the results obtained from preliminary survey were transformed to importance indices based on the RII value. Table 2 shows the RII values and the ranking position of each identified IEQ indicators according to their level of importance in evaluating total IEQ performance.

Table 1: RII Prioritization of IEQ Sub Indictors

	Indoor Environmental Quality (IEQ) Indicator	**RII**
	Indoor Air Quality (IAQ)	
1	Fresh Air Supply	0.92
2	CO_2 Concentration	0.88
3	Relative Humidity (RH)	0.84
4	Perceive Air Quality	0.80
5	Hazardous Chemical	0.80
6	Fabric Dust	0.76
7	Micro Organism (Fungus, Bacteria etc.)	0.72
8	Ventilation Rate	0.68
9	Natural Odour	0.48
10	Chemical Organ Odour	0.48
11	Volatile Organic Compound	0.48
12	Water Vapour Pressure	0.48
13	Relative Air Velocity (Mean)	0.48
	Lighting Quality	
1	Illumination Uniformity	0.84
2	Lighting Power Density (LPD)	0.80
3	Light Intensity	0.80
4	Natural (Day) Lighting	0.76
5	Direct Glare	0.76
6	Flicker Rates	0.68
7	Indirect (Reflected) Glare	0.68
8	Wall Colour	0.48
9	Nr of Lights according to the SqrFeets	0.48
10	Colour Variation	0.48
11	Distance between the Floor Level and Light Source	0.48
12	Direction of the Occupant Regarding Light Source/Bulb	0.44
	Thermal Comfort	
1	Operative Nature (light, medium, low work load of the occupant)	0.72
2	Machine Nature	0.72
3	Dry Bulb Temperature	0.68
4	Building Conductivity	0.68
5	Factory Layout	0.68
6	Wet Bulb Globe Bulb Temperature Index (WBGT Index)	0.64

	Indoor Environmental Quality (IEQ) Indicator	RII
7	Occupants Metabolic Rate	0.64
8	Wet Bulb Temperature	0.48
9	Mean Radiant Temperature	0.48
10	Construction Material	0.48
11	Air Temperature	0.44
	Acoustic Quality	
1	Equipment and Mechanical Noise	0.76
2	Sound Absorption	0.68
3	Outdoor Traffic Noise (Insulation)	0.68
4	Overhearing Private Conversation	0.68
5	Building Size	0.64
6	Plant Room and Other Related Noises	0.64
7	Sound Pressure Level	0.48
8	Excessive Echoing of Voices/Sounds	0.44
9	Used Material for The Construction	0.44

The insignificant factors were disregarded which have the RII value lesser than 0.5. To gain a better result from AHP analysis, it was removed the 8th indicator of IAQ as it was advised to limit the main and sub factors in number seven on the basis of Miller's theory (Perera and Sutrisna, 2010).

According to the result of RII analysis, six indicators under the key indicator of IAQ, five indicators which were under the key indicator of lighting quality, four indicators which were under the key indicator of thermal comfort and three indicators which were under the key indicator of acoustic quality were identified as less importance indicators.

5. DEVELOPED FRAMEWORK FOR IEQ EVALUATION

Each IEQ related sub indicator was prioritized by using the AHP tool with the data which was obtain through the AHP questionnaire survey which was contained pairs of key and sub indicators. Those indicators were compared based on their relative importance with the intention of improving the effectiveness of IEQ performance evaluation framework for the apparel manufacturing facility. The ultimate objective of the adaptation of AHP tool was to obtain performance scores for each and every indicator for the prioritisation. This tool is consisted three interrelated steps as air wise calculation, normalised calculation and finally, consistency calculation as the judgment of the respondents may not be consistent.

Performance scores or the relative weights were obtained through the normalisation of pair-wise comparisons. Indicators which were used to develop the conceptual framework were developed with the results obtained in preliminary survey by using RII calculation to conduct the pair wise comparison. Therefore, it can be developed the generic framework for evaluate IEQ performance of apparel manufacturing facility can be developed with final data findings of the AHP tool. Indicators which were prioritized are presented in Table 2. Validity and consistency of the data set which was used to develop the framework has been confirmed by the lower consistency ratio than the given acceptable value of 1.0. Based on that fact, it can be justified that, this framework can be utilised for evaluating the IEQ performance of apparel manufacturing facility.

In Table 2, first column named 'Rank' indicates the relevant ranks of IEQ sub indicators under relevant main indicators according to their performance scores. Overall performance scores were obtained by multiplying the performance score for relevant sub indicator by the performance score which is allocated for the main indicator of relevant sub indicator. 'Overall Rank' was prioritized by referring overall performance scores. The overall performance scores of the all IEQ sub indicators were added up to 1.00

while overall performance scores of the IEQ sub indicators within the relevant main indicator were added up to the performance score of relevant main indicator.

Table 2: Prioritized IEQ Indicators

Rank	Indoor Environmental Quality (IEQ) Indicator	Performance Score	Overall Performance Score	Overall Rank
1	**Indoor Air Quality (IAQ)**	**0.368**		
1.1	Fresh Air Supply	0.302	0.111	1
1.2	CO_2 Concentration	0.151	0.055	5
1.3	Relative Humidity (RH)	0.116	0.043	9
1.4	Perceive Air Quality	0.117	0.043	8
1.5	Hazardous Chemical	0.178	0.066	4
1.6	Fabric Dust	0.091	0.033	14
1.7	Micro Organism (Fungus, Bacteria etc.)	0.045	0.017	23
2	**Lighting Quality**	**0.296**		
2.1	Illumination Uniformity	0.071	0.021	20
2.2	Lighting Power Density (LPD)	0.124	0.037	11
2.3	Light Intensity	0.183	0.054	6
2.4	Natural (Day) Lighting	0.150	0.044	7
2.5	Direct Glare	0.106	0.031	15
2.6	Flicker Rates	0.291	0.086	2
2.7	Indirect (Reflected) Glare	0.074	0.022	19
3	**Thermal Comfort**	**0.229**		
3.1	Operative Nature (light, medium, low work load of the occupant)	0.296	0.068	3
3.2	Machine Nature	0.157	0.036	12
3.3	Dry Bulb Temperature	0.130	0.030	16
3.4	Building Conductivity	0.120	0.027	17
3.5	Factory Layout	0.150	0.034	13
3.6	Wet Bulb Globe Bulb Temperature Index (WBGT Index)	0.098	0.022	18
3.7	Occupants Metabolic Rate	0.049	0.011	25
4	**Acoustic Quality**	**0.107**		
4.1	Equipment and Mechanical Noise	0.348	0.037	10
4.2	Sound Absorption	0.194	0.021	21
4.3	Outdoor Traffic Noise (Insulation)	0.124	0.013	24
4.4	Overhearing Private Conversation	0.067	0.007	27
4.5	Building Size	0.166	0.018	22
4.6	Plant Room and Other Related Noises	0.102	0.011	26

Among four main indicators ‘IAQ’ main indicator obtained the highest performance score (0.37) and ‘Lighting Quality’ (0.30) obtained the second highest performance score while ‘Thermal Comfort’ (0.23) and ‘Acoustic Comfort’ (0.11) respectively obtained the third and fourth highest scores. Overall rank in accordance with the overall performance scores of the IEQ sub indicators are presented in the Table 2.

According to the figures presented in the Table 2 ‘Fresh Air Supply’, ‘Flicker Rate’, ‘Operative Nature (light, medium, low work load of the occupant)’, ‘Hazardous Chemical’, ‘CO_2 Concentration’ and ‘Light Intensity’ indictors have obtained the highest overall performance scores exceeding 0.05. Therefore the foresaid IEQ sub indicators can be identified as the most significant indicators to evaluate the overall IEQ performance of the apparel manufacturing factory. According to the presented figures the highest important indicator which is ‘Fresh Air Supply’ is approximately sixteen times greater than the least important sub indicator which is ‘Overhearing of Private Conversation’. It shows the criticality of the highest important indicator when comparing with the least important indicator.

Further, sub IEQ indicators which are obtain performance scores lower than 0.03 can be identified as moderately important indicators which are ‘Natural (Day) Lighting’, ‘Perceive Air Quality’, ‘Relative Humidity (RH)’, ‘Equipment and Mechanical Noise’, ‘Lighting Power Density (LPD)’, ‘Machine Nature’, ‘Factory Layout’, ‘Fabric Dust’, ‘Direct Glare’ and ‘Dry Bulb Temperature’. Performance score below 0.03 can be identified as the least important indicators which are namely ‘Building Conductivity’, ‘Wet Bulb Globe Bulb Temperature Index (WBGT Index)’, ‘Indirect (Reflected) Glare’, ‘Illumination Uniformity’, ‘Sound Absorption’, ‘Building Size’, ‘Micro Organism (Fungus, Bacteria etc.)’, ‘Outdoor Traffic Noise (Insulation)’, ‘Occupants Metabolic Rate’, ‘Plant Room and Other Related Noises’ and ‘Overhearing Private Conversation’.

The framework was developed on the basis of findings of the literature review, findings of the preliminary questionnaire survey and then finalised with the finding of AHP survey. As IEQ performance can be identified as one of the integral parts of total building performance IEQ performance is presented as a subset of total building performance (Refer Figure 3).

Literature review identified that the main and sub indicators which are influence on IEQ performance in the built environment. Then, those indicators were modified and ranked according to the relatively importance while ignoring the less importance indicator by applying the RII tool. Furthermore, relatively higher importance indicators were prioritized with the AHP survey on the basis of importance of each indicator to the apparel manufacturing sector in Sri Lanka. Those prioritized indicators were presented in respectively under the four main indicators in the framework.

Framework illustrated that the importance of proper IEQ performance evaluation as occupants’ satisfaction, increasing the productivity of occupants. The importance of IEQ evaluation was derived from the literature review as considerable number of researchers have being emphasised it. Moreover, this IEQ performance evaluation framework can be applied to measure the adequacy of current practice and through the measured results organisations can use for continuous improvements of IEQ performance within apparel manufacturing facility. This application of the IEQ framework was focused on developing this framework with the intention of mentioned application as achieving ultimate objective of this research.

This framework can be used in the design and operation stage of an apparel manufacturing facility to maintain proper IEQ performance. Industry practitioners who are engaged with IEQ performance related activities as Facilities Managers, Health and Safety Executives, Maintenance Managers/ Engineers, Sustainable Officers, Factory Inspection Engineers will be the beneficiaries of this framework.

During the evaluation of IEQ performance within the workplace the evaluator can use this framework to identify the indicators which have to be highly concerned. Moreover, this framework can be used to identify most significant indicators as this framework has being prioritized the indicators based on their importance. This can be referred to decide the indicators which should be significantly taken into consideration among various IEQ indicators.

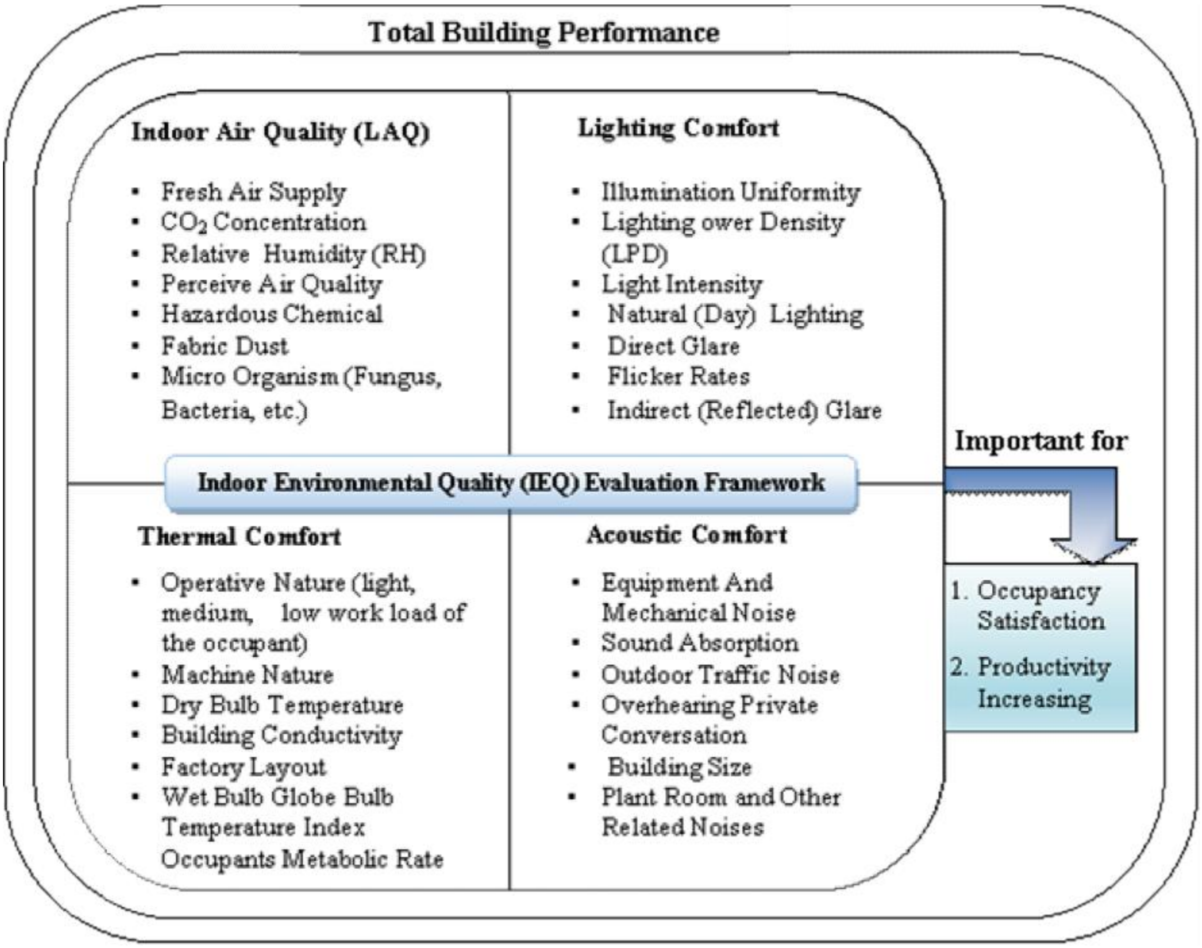


Figure 3: Developed Framework for Evaluating IEQ Performance

6. CONCLUSIONS

A conceptual framework was proposed compromising of four main indicators and fourth five sub indicators to evaluate IEQ performance of apparel manufacturing industry in Sri Lanka. With the research findings of preliminary survey and interviews, the researcher proposed a conceptual IEQ evaluation framework for the industrial buildings of Sri Lanka: Apparel industry.

Based on the AHP survey outcome, the generic IEQ performance evaluation framework had been developed with performance scores which represented the relative importance of each main and sub IEQ indicators. These performance scores provided opportunity to consider the significance of each and every IEQ main or sub indicator from another IEQ main or a sub indicator respectively. Moreover, overall performance scores of IEQ indicators were calculated as to pave the path to prioritise IEQ sub indicator of each main indicator with each other.

This research facilitate for a successful structured framework to evaluate the IEQ performance as providing a good solution and pave the path for continuous improvements action towards occupancy satisfaction and productivity with identifying significant IEQ indicators for the overall IEQ performance of the industrial buildings, basically the apparel manufacturing sector within Sri Lankan context.

7. REFERENCES

Adebiyi, K.A., Charles, O.E. and Waheed, M.A., 2007. Safety Performance Evaluation [online]. *Disaster Prevention and Management*, 16(2), 178-187. Available from: http://www.emeraldinsight.com/0965-3562.html [Accessed 8 February 2014].

Amaratunga, D. and Baldry, D., 1998. Appraising the Total Performance of Higher Educational Buildings: A Participatory Approach towards a Knowledge Based System. In: *Construction and Building Research Conference, RICS*. 140-154..

Bannet, D., 1984. *Production System Design* [online]. London: Butterworth and Co. Publishers. Available from: http://www.emeraldinsight.com/0965-3562.html [Accessed 8 Febuary 2014].

Catalina, T. and Iordache, V., 2011. IEQ Assessment on Schools in the Design Stage. *Building and Environment*, 49(1), 129-140.

Dheerasinghe, R., 2003. Garment Industry in Sri Lanka Challenges, Prospects and Strategies. *Staff Studies* [online], (2), 33-72. Available from: http://ss.sljol.info/articles/abstract/10.4038/ss.v33i1.1246/

Heinzerling, D., Stefano, S. and Webster, T., 2013. Available Indoor Environmental Quality Assessment Models: A Literature Review. *Building and Environment*, 70(1), 210-222..

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

Kumar, S. and Fisk, W.J., 2002. IEQ and the Impact on Building Occupants [online], *ASHRAE Journal*, 44(4), 50-52. Available from: http://energy.lbl.gov/ie/viaq/pubs/ashrae_april2002.pdf [Accessed 18 February 2014].

Klepeis, N.E, Nelson, W.C., Ott, W.R., Robinson, J. P., Tsang, A. M. and Switzer, P., 2001. The National Human Activity Pattern Survey (NHAPS): A Resource for Assessing Exposure to Environmental Pollutants. *Expo Anal Environ Epidemiol*, 11(3), 231-252..

Mahbob, N.S., Kamaruzzaman, S.N., Salleh, N. and Sulaiman, R., 2011. *A Correlation Studies of Indoor Environmental Quality (IEQ) towards Productive Workplace*. Report No. 28, 434-438. Singapore: IACSIT Press..

Mallawaarachchi, H. and Silva, L.D., 2012. *Green Framework to Improve Indoor Air Quality in Buildings: Reducing the Impact of Sick Building Syndrome on Office Workers in Sri Lanka: A Literature Review*. Unpublished Dissertation (B.Sc). University of Moratuwa, Moratuwa, Sri Lanka.

Perera, N. and Sutrisna, M., 2010. The Use of Analytic Hierarchy Process (AHP) in the Analysis. *The Built and Human Environment Review*, 3(1), 29-48..

Prakash, P., 2005. *Effect of Indoor Environmental Quality on Occupant's Perception of Performance* [online]. Thesis (M.Sc.). University of Florida, Florida. Available from: http://escholarship.org/uc/item/0wb1v0ss [Accessed 23 June 2014].

Rathnayaka, R., 2010. *Development of Post Occupancy Evaluation Framework to Evaluate the Factory Building Performance*. Unpublished Dissertation (B.Sc). University of Moratuwa, Moratuwa, Sri Lanka.

Saheed, A.H., 2005, June 30. Lanka's Apparel Industry Maintains Dominant Status in Industrial Sector [online]. *Sunday Observer*, Available from: http://www.LankaNewspapaers.com [Accessed 12 February 2014].

Singh, J., 1996. Review: Health, Comfort and Productivity in the Indoor Environment [online]. *Indoor and Built Environment*, 5, 5-12. Available from: http://ibe.sagepub.com/content/5/1/22.

Sinou, M. and Kyvelou, S., 2006. Present and Future of Building [online]. *Management of Environmental*, 17(5), 570-586. Available from: http://dx.doi.org/10.1108/14777830610684530 [Accessed 22 February 2014].

Wong, L.T., Mui, K.W. and Hui, P.S., 2008. A Multivariate-Logistic Model for Acceptance of Indoor. *Building and Environment*, 1(2), 1–6.

A GUIDE FOR PERFORMANCE EVALUATION PROCESS FOR INTERNATIONALLY FUNDED COMMUNITY DEVELOPMENT PROJECTS IN SRI LANKA

Ruwani Perera* and Gayani Karunasena
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In today's world, many development efforts are implemented as Community Development (CD) projects. Their unique nature and qualitative objectives raise a special challenge in performance evaluation as performance evaluation of CD projects is affected by several factors. Thus, this research was aimed at developing a guide for performance evaluation of CD projects implemented by Non-Government Organizations (NGOs) in Sri Lanka to streamline the process.

As identified in literature review, four major impact areas from in and out of the CD project environment and five major stages of performance evaluation process were identified. Five CD projects were selected as case studies and interviews were conducted to gather data.

The research identified existing and proposed strategies applied by NGOs. According to the findings, majority of CD projects have not practiced all identified stages by giving the same weight for each of them.

The identification of lessons learnt and best fit practices are important factors, while responsible officers should carefully select representative stakeholder groups to share the evaluation findings in different ways.

Keywords: *Community Development Projects; Guide; Impact Areas; Performance Evaluation Process; Strategies.*

1. INTRODUCTION

The internationally funded Community Development (CD) projects play a significant role in developing or filling the gaps in community. The ultimate goal of CD projects differs from commercial and industrial projects (Kamrul and Indra, 2009). Based on social disparity prevailing in some developing countries, both public and private sectors are involved in development initiatives with the support of donor agencies. CD efforts cater to development of rural, urban and estate poor in developing countries. These projects are implemented by the public sector entities of recipient governments under agreements with relevant donor agencies (Kularathna, 2009). Sometimes, the implementing party may be a non-governmental organization (NGO) or a private professional body (Crawford and Bryce, 2003).

In Sri Lanka, currently the development initiatives are taken by both public and private sectors. Private institutes and NGOs directly involve with some development projects with the support of their respective donors parallel to services delivered by the government to the civil society. There are different types of development programmes aimed at improving living conditions of plantation communities and residents of urban slums and shanties that are implemented as CD projects in Sri Lanka (Kularathna, 2009). Rural and urban poor and estate sector communities face different kinds of living challenges in their day to day lives and living patterns. Hence, the attention of many NGOs is focused on sufferings of these communities.

*Corresponding Author: E-mail - ruwaninimasha_perera@yahoo.com

The operating environment and culture of the host country also make CD projects different from traditional business projects (Blunt and Jones, 1992). The life cycle of CD projects implemented by these NGOs and private institutions are generally the same, but they have their own nature of the project environment. At the same, unique characteristics of CD projects help to build the complex project environment in the CD project implementation.

A CD project consists of some hard elements to concern the soft issues in human society (Crawford and Bryce, 2003). It has caused less visible and less measurable of its deliverables and its project performance. Basically, there are three stakeholder parties involved in CD projects as the funding agency, the implementing unit and the target beneficiaries (Youker, 1999). Hence, the overall performance of the CD project depends largely on the role of key major stakeholders who are from different cultures and have different expectations within the CD project environment. Therefore, when measuring the project success through the performance, the evaluation process is different from project to project or organization to organization.

Still there is no developed universal agreed project performance to CD projects' project performance. Some organizations and persons have developed the guidelines for performances evaluation. But, due to unique project environment of CD projects, these may also be affected by many impacts. The literature regarding the performance evaluation is comparatively less than the other international level and national level studies in CD project management filed. The findings from the international world or other countries may not be similar to the implementation pattern of Sri Lankan context. Further, there is lesser number of available literature studies for performance evaluation of CD projects in Sri Lankan context.

This research paper has formulated its aim to propose a guide for performance evaluation process for internationally funded CD projects in Sri Lanka. To achieve this aim, the research methodology has been developed based on the above mentioned four objectives.The literature review section examined the nature of internationally funded CD projects and major impact areas consists ins and outs of the CD project environment. At the same time, this review has also revealed the available standards and guidelines for measuring CD project performance. This research examined the available project performance evaluation processes of five internationally funded CD projects, implemented by the NGOs in Sri Lanka under the interview process. The selection criteria for selected cases were nature of project response, time factor of the project and regional disparity. In the analysis part, the research was analysed under major three areas identified through the data collection stage. First, it identified the influence level for each step of five major stages in performance evaluation process through the impact areas. Second, identified the existing strategies applied them to prevent from impact areas. Third, proposed strategies were identified for preventing the impacts through the lesson learns. The major data analysing technique was content analysis. Finally, through this research, it was possible to develop a guide for project performance evaluation of internationally funded CD projects implemented by NGOs in Sri Lanka.

2. LITERATURE REVIEW

Based on the findings of literature survey, it has been identified the practical situation and impact areas in CD projects' performance evaluation process. Further, the existing standards and guidance for performance evaluation process have been identified when considering the professional and institutional framework.

2.1. AVAILABLE GUIDANCE

Considering the affected impact areas and unique nature of CD projects, some people and institutions have attempted to develop some guidelines and standards for conducting the impact evaluation process for CD projects in an effective way.

Touwen (2001) has identified mainly six essential parts of performance evaluation process in the hand book for projects: development, Management and fundraising. Zaarinpoush (2006) has indicated four fundamental methods and steps for conducting evaluations in the book called "Project Evaluation Guidance for non-profit organisations". Accordingly, the Organisation for Economic Co-operation and Development (OECD) - Development Assistance Committee (DAC) Network on international development evaluation has developed a glossary of key terms in evaluation and results-based management to help to clarify concepts and to promote consistent use of common terms in these areas. Hughes and Nievwenhuis, (2005) has presented further fundamentals for conducting evaluations through the book “A project Managers’ Guide to Evaluation”. The United Nations Evaluation Group (UNEG) (2005) has introduced nine areas of norms, ethical principles and standards.

Further, UNEG has developed a guideline including several steps for conducting evaluation for its operated projects. As part of its mandate, UNEG formed a Task Force on Evaluation of Normative Work in response to an increased call for such evaluations and a dearth of relevant resources.

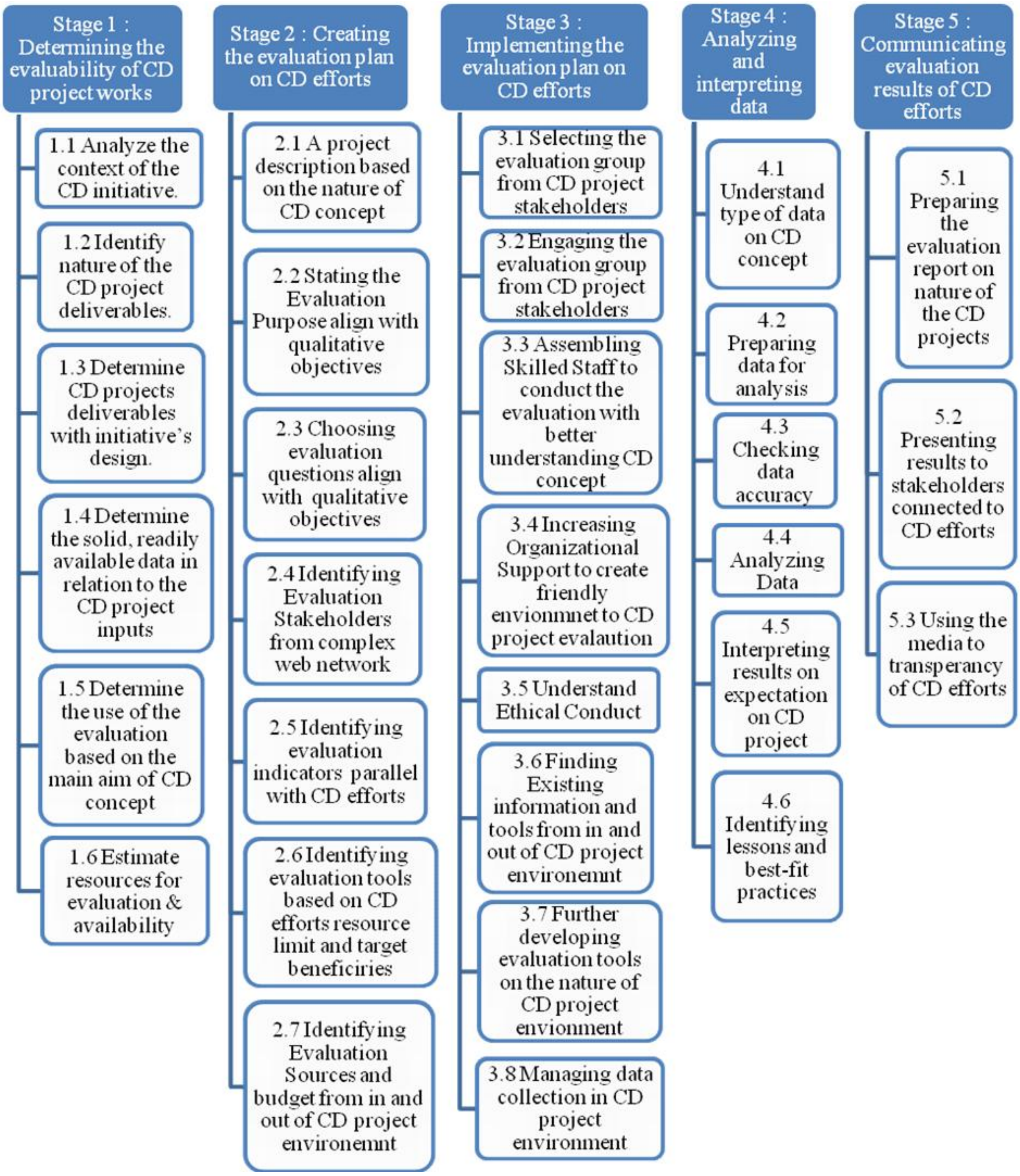


Figure 1: Project Performance Evaluation Process

By considering the above available guidelines of various professionals and organisations regard to project performance evaluation, they can be categorized into five major stages of the process as shown in Figure 1.

Basically four impact areas in both internal and external project environment influence the performance evaluation process as impacts related to CD project nature, impacts related to nature of the organisation, impacts related to external environment and impacts related to target beneficiaries.

The effects of qualitative objectives of CD projects influence measurement of the project performance (Derricourt and Oakley, 1988). The CD project contains some hard elements by concerning the soft issues of the human society (Crawford and Bryce, 2003). Based on the tangible and intangible inputs, challengeable environment is created for coordinating and evaluating project performance (Khang and Moe, 2008).

The well-defined evaluation process is led to measure the accuracy of project performance with technical sound (Touwen, 2001). Further, the involvement of external party made a pressure to conduct the qualitative measurement parallel to the qualitative objectives of CD projects (Derricourt and Oakley, 1988).

The requirements of donor led to generate the priority areas of performance evaluation of CD projects. Many organisations including NGOs have their privacy to operate humanitarian work in development field. Therefore, the organisation's culture and policies are unique to each organisation to organisation and it affects the performance evaluation plan and its implementation process of CD projects.

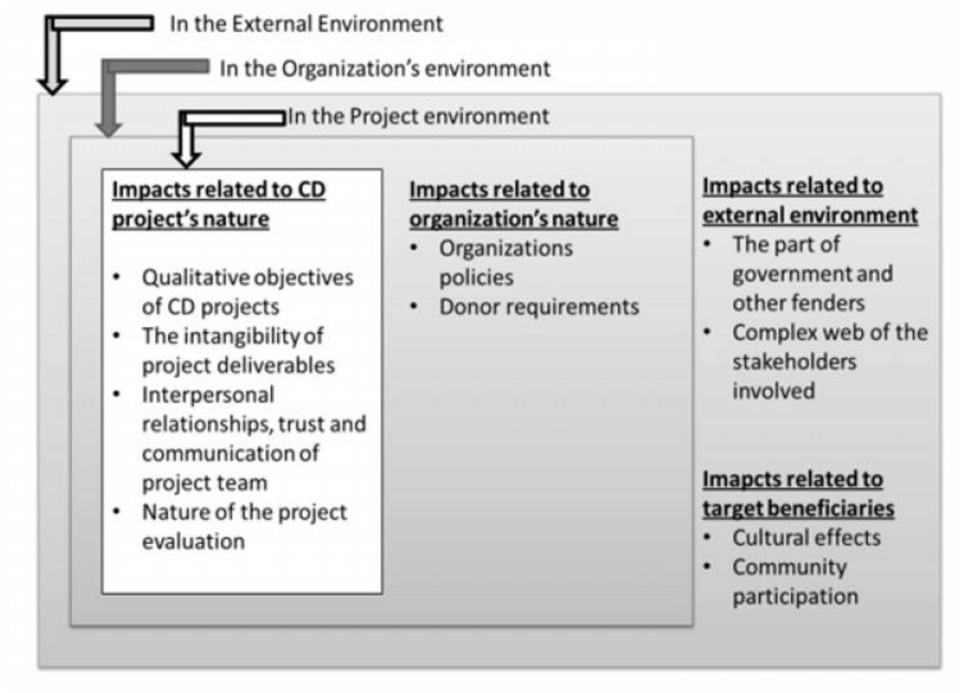


Figure 2: Impact Areas in Internal and External CD Project Environment for Performance Evaluation Process

Diallo and Thuillier (2005) highlighted the unique characteristics of CD projects and identify the influence of interpersonal relationships, trust and communication on project success. Most of the organisations attempt to fulfil the project team of a project through their permanent employees or human resources and they are developed through the culture of the organisation.

The Oakley and Derricourt (1988) have expressed that the measuring the results of CD projects as important due to the requirements of the government party and other development funding agencies. The implementing party should provide the transparent progress of CD projects: whether it should achieve its qualitative objectives with the available financial and human resources (Derricourt and Oakley, 1988). Furthermore, many kinds of stakeholders involve functioning of the CD projects. This group creates a complex network environment in the CD project. In the CD project's implementation process, the involvement level of target beneficiary group may be differed throughout the entire project life cycle. Community participation is difficult to define merely in terms of specific, material objectives.

Correspondingly, the cultural issues of the host country may be act as a challenge for achieving the goals of the project due to its differences from country to country and continent to continent (Kamrul and Indra, 2009). Also, this may adversely affect the project performance evaluation process of CD projects.

3. RESEARCH METHOD

In this research, the main research question is "What kind of strategies can be applied for minimising the influencing impact areas for performance evaluation in CD projects?". This study is concerned with the performance evaluation processes of selected five CD projects under the interview process as mentioned in Table 1. Therefore, this research followed the multiple-case design in designing the research.

Table 1: Interviewees' Profile

Case	Description of the Nature of CD Project	Interview Code	Responsible Interviewees
Case One	Integral human development	CAS1	M & E Coordinator
Case Two	Disaster responses and community development	CAS2	Project Manager
Case Three	Transformational development	CAS3	Project Manager
Case Four	Transformational development	CAS4	M & E Coordinator
Case Five	Transformational development	CAS5	Project Officer

As the major unit of analysis, the study selected the CD projects implemented by five NGOs in Sri Lanka. Interviewees were selected by considering several criteria as time duration of the project life cycle, nature of project response and regional disparity.

Based on the findings of literature review survey, the interview profile was designed basically under three areas:

- How impact areas affected the CD projects' performance evaluation process?
- What kinds of strategies were already applied by them to prevent the impact areas?
- What kind of strategy can be proposed through the lesson learnt in the evaluation processes to protect the impact areas?

4. DATA ANALYSIS

Table 2 shows the impact areas affected the CD projects' performance evaluation process, strategies already applied by them to prevent the impact areas and strategies that can be proposed through the lesson learnt in the evaluation processes to protect the impact areas.

Table 2: Data Analysis

Stages	Impacts	Strategies in Use	Strategies Proposed
Stage One	▪ Unviability of baseline or assessment findings ▪ Not practice the monitoring mechanism ▪ Staff transfers (Irregular hand-over process) ▪ The past CD project input data missed or not recorded in a systematic way	▪ CD Project input tracking Table ▪ Baseline survey ▪ Periodic monitoring ▪ Availability of key assessment & design docs. ▪ CD Project decisions meeting minutes and reports ▪ Discussion with senior	▪ Organisation's vision, mission and core values ▪ Capacity Building events ▪ Proper handing over process ▪ Knowledge transferring ▪ Periodic reporting with stakeholders ▪ Records with government sector on staff transfers

Stages	Impacts	Strategies in Use	Strategies Proposed
	▪ Lack of data on project implementation process ▪ Behaviour of stakeholders ▪ partners' contribution ▪ Effects of Intangible objectives and organisation culture	management & CD project team ▪ Evaluation requirements of donor & other stakeholders ▪ Aware organisation members regarding the evaluation	▪ Monitoring mechanism in community ▪ Impact, sustainability criteria ▪ Applying lessons learnt ▪ Initial meetings with community to find resources
Stage Two	▪ Not thoroughly consider the stakeholders interest & evaluation questions ▪ Influence of organisational mechanism ▪ Unstable condition in the CD project location ▪ Not forming a balance and appropriate evaluation representative sample group. ▪ Missing the stakeholder analysis session ▪ Influence of CD project's qualitative objectives, its less visible CD project input deliverables and complex nature of the target beneficiaries. ▪ Some consist essential elements were hidden and some displayed a big picture than the reality in the complex CD project environment ▪ Not identify regular steps for the evaluation process	▪ Key Documents related to the CD project ▪ Identifying donor and stakeholders requirements ▪ Behaviour of beneficiaries ▪ Setting both qualitative and quantitative questions ▪ Better understanding on organisation policies ▪ Developing evaluation questions and criteria to generate lesson learnt, alternatives and best fit practices ▪ Coordinating with community leaders or re-preventatives ▪ Maintain monitoring mechanism ▪ Developing the evaluation tools considering the data analyzing ▪ Developed tools to find the sensitive and qualitative achievements in CD project beneficiaries	▪ The CD project purpose aligned with organisation policy ▪ The evaluation questions and criteria same in the assessment phase, measuring at beginning ▪ Developing one or more questions for every CD project outcomes ▪ Stakeholders' profile ▪ Periodic meetings ▪ Potential evaluation stakeholders ▪ Priorities indicators ▪ Better understanding ▪ Review session with evaluation groups ▪ Make sure availability resources ▪ Correct identification of formal and informal evaluation tools ▪ Clearly identifying steps, activities ▪ Use the results of the first stage
Stage Three	▪ Not form a real evaluation group as a representative sample ▪ Less familiar with organisational culture them ▪ Not following the professional ethics by external party ▪ Lack of knowledge on CD project environment ▪ Mot much consider to get the support from other staff in organisation and to aware all ▪ Enumerators not follow the professional evaluation ethics in data collection stage. ▪ The poor engagement level of stakeholders and evaluation group ▪ Not consider the sample size, available resources	▪ Aware all information and background of the CD project ▪ Evaluation TOR for external qualified party ▪ Evaluation group respects the culture of the organisation ▪ The evaluation group and external party should be formed based on the representatives sample of the stakeholders ▪ Re-ensure technical knowledge ▪ Knowledge regarding the CD project environment and organisation culture ▪ Aware on evaluation process, expected outcomes ▪ Understanding the cultural and customs of target beneficiaries	▪ Aware the nature of the CD project beneficiaries, respect their culture, protect the privacy ▪ Conducting periodic meeting sessions ▪ Get un bias decisions ▪ Protect the evaluation ethics and standards ▪ Identify strengthen of staff ▪ Considering the cultural patterns of stakeholders ▪ Developing realistic and measurable tools ▪ Sample size of tools with the budget and available resources ▪ Conducting pilot survey

Stages	Impacts	Strategies in Use	Strategies Proposed
	and time factor when developing evaluation tools ▪ Not following the pilot survey	▪ Consider the ideas of evaluation group ▪ Encourage active participation of community and stakeholders ▪ Developing data collection plan ▪ Trained and qualified enumerators	
Stage Four	▪ Poor designed evaluation tools ▪ When entering the data, not follow to re-check the filter the raw data and information. ▪ Responses level of target beneficiaries ▪ The recording pattern of enumerators ▪ large gap between the expected outcome and the received value ▪ Not use trained data entry persons ▪ Not give a weight to identify lessons and best-fit practices	▪ Filtering raw data and information in a systematic way ▪ Well-trained data entry persons ▪ Having well-defined evaluation outcomes ▪ Getting the clear value through the data analyzing for outcomes ▪ Clearly identify the best practices and lessons learnt	▪ Availability of strongly developed qualitative and quantitative data tools ▪ Checklist to reassure availability of collected data and information ▪ Providing evaluation findings for lessons learnt and best practices for management decision making purpose ▪ Generating lesson learnt and best practices of community engagement
Stage Five	▪ Not follow and consider the particular content of the report based on the expectations of the different stakeholders ▪ Not consider the requirements of stakeholders ▪ Missing stakeholders for evaluation meeting did not follow this step to communicate the results ▪ Not follow regular results communication methods	▪ Considering the all requirements of stakeholders ▪ Considering all aspects of CD project outcomes and evaluation purpose	▪ Ensure stakeholders &community participation for the evaluation meeting ▪ Considering the organisation policy ▪ Calling media ▪ Conducting the meeting from mother language ▪ Stakeholders'…….?

4.1. STAGE ONE - DETERMINE THE EVALUABILITY OF CD PROJECT WORKS

Stage 1.1: All cases agreed that the step for analysing the context of CD project initiatives was difficult, due to the impacts related to the nature of target beneficiaries and their complex living environment. Without having a baseline or assessment findings and if they do not practice the monitoring mechanism throughout the project life cycle in a proper way without a large scale survey. An interviewee expressed that he had followed the proper monitoring mechanism for all aspects of target beneficiaries. Further, they had conducted a baseline survey to understand all aspects of all beneficiaries in the CD project location in the beginning of the CD project. Majority of cases have identified the need for conducting baseline survey before starting the CD project they have emphasised the importance for establishing the proper monitoring system throughout the project.

Stage 1.2: Two cases mentioned that the nature of the organisation policies such as staff transfers and terminations, the past CD project input data may be missed or not recorded in a systematic way. Interviewees expressed that they maintained the CD project input tracking table in systematic way. Some cases had proposed to maintain the project input tracking table and referring the project expectations to identify the nature of the CD project inputs. Every team member must thoroughly understand the vision, mission and background situation of the organisation.

Stage 1.3: The step-determining the CD project deliverables with its project design was affected in most cases due to the lack of data and information related to project implementation process from the initial phase. Some cases usually refer the documents related to project design documents, assessment results and other basic information documents. Most cases suggested that need for referring to the past CD project records, design documents throughout the CD project implementation process.

Stage 1.4: Information related to implementation process is absent in some cases. Some interviewees attempted to maintain the tracking table for the CD project deliverables. Further, due to the nature of target group, they considered the proper monitoring mechanism. Interviewed cases stated that there was a need for maintaining documents and reports related to the CD project implementation.

Stage 1.5: Some responders mentioned that responsible persons including the senior management have not participated determining the accurate time for the evaluation while considering the requirements of donor and other major stakeholders. Further, some mentioned that, they had no idea to conduct the evaluation due to lack of directions mentioned in CD project proposals. Under the step - determining the use of the evaluation, some interviewees shared that they conducted a proper discussion with senior management and responsible persons in the CD project team to identify expected results through the evaluation. Further, some of them shared that they had given more focused to the requirements of donor and other stakeholders when determine the uses of the evaluation. As mentioned in early part, interviewees agreed that the conducting the discussion with the senior management and project team was more important to determine the uses of the proposed evaluation due to the nature of the CD project background. Further, they proposed a very good point; to get the community leaders' ideas on the need and uses of the evaluation. They will support to develop more prospects among the target beneficiary groups.

Stage 1.6: The identification of the available resources in and out of the CD project environment were not easy due to intangible objectives and unique nature of the CD project and complexity of the CD project location which aimed the community. Under the step - estimating and the available resources for the evaluation, responders suggested the better awareness on the evaluation to enhance the ability of project team as well as the organisation to find the available resources in and out of the CD project environment. According to the ideas provided by interviewees, they had not attempted to give sufficient weight for this stage. Sometimes, the steps of this stage were only done in the mind of responsible evaluator or the results of this stage were not written.

4.2. STAGE TWO - CREATING THE EVALUATION PLAN ON CD EFFORTS

Stage 2.1: Based on the available data collected in the previous stage and their experience regarding the ongoing project implementation process of CD projects, they are able to complete this step in sufficient manner. All responders agreed that the need for availability of the project description based on the nature of CD efforts including all the key requirements and elements of the CD project before preparing the evaluation plan.

Stage 2.2: When setting the evaluation purpose, lots of requirements of stakeholders to be considered. But, some expressed that they were not able to consider such requirements thoroughly. At the same time, considering the operational mechanism also influenced this step as a barrier. Some interviewees expressed that they did not consider much about the nature of proposed questions. The stating the evaluation purpose aligns with its qualitative objectives is the most serious job. Therefore, they had clearly identified the requirements of donor and stakeholders on this evaluation. Further, responders highlighted that the need for identifying the most sensitive areas on the behaviour of the beneficiaries which should be addressed and answers through the evaluation when stating the purpose of the evaluation aligned with its qualitative objectives.

Stage 2.3: The expected results were varied based on the unstable condition in the CD project location and it affected the identification of evaluation questions when considering the nature of the CD project and its location. Similarly, in choosing the evaluation questions aligned with its qualitative objectives, interviewees had used some strategies for ensuring the better understanding of the organisation policies as well as considering the need for generating lessons learnt and best fit practices. Parallel to the designed evaluation purpose, the evaluation questions should be developed both qualitative and quantitative questions considering the soft objectives of the CD projects.

Stage 2.4: Without proper preparation, some expressed that they faced difficulty to form a balance and appropriate evaluation representative sample group. Most of them have missed the stakeholder analysis session to assign the duties and responsibilities. Parallel with this step, most cases attempted to identify the evaluation stakeholders from complex web and one interviewee expressed that they maintained the stakeholder profile. All responders proposed that the need of the representation of the community leaders when identifying the evaluation stakeholders from the complex web environment.

Stages 2.5 and 2.6: These two steps were difficult jobs due to the CD project's qualitative objectives, its less visible CD project input deliverables and complex nature of the target beneficiaries. All interviewees expressed that they faced lots of difficulty in setting the indicators and its relevant tools in the design stage. Furthermore, interviewees mentioned that they had maintained a monitoring system beginning to measure the progress of indicators which were built in the assessment survey. The resource limit and target beneficiaries are identified or developed based on the neediness of the evaluation. In this process, the identification of the evaluation tools based on the nature of CD efforts, resource limit and target beneficiaries should be capable to find the sensitive and qualitative achievements in the CD project beneficiaries as well as the CD project location.

Stage 2.7: Some consist essential elements were hidden and some displayed a big picture than the reality in the complex CD project environment. Further, some were not able to identify regular steps for the evaluation process to allocate the financial resources for implementing them at a correct time and in a proper way. Also, some organisation policies affected the identification of the sources through in and out of the CD project due to generated constrains and some pressures from the organisation policy and organisation culture. Most responders agreed that they had used past CD project designed documents to find the evaluation sources through the implementation process. Further they had attempted to clearly identify and prioritized the steps of the evaluation process including the data collection step, to prepare the evaluation budget in an effective manner.

4.3. STAGE THREE - IMPLEMENTING THE EVALUATION PLAN ON CD EFFORTS

Stages 3.1 and 3.2: Some of them were not able to form a real evaluation group as a representative sample of all stakeholders who linked with the CD project in direct or indirect way. The bias decisions were taken by them and it also affected the real outcomes of the entire evaluation. Some interviewees expressed that they had followed a particular step when selecting the external evaluation party. They had engaged to call bid and selected suitable external qualified party who provided the better responses for evaluation TOR.

Stage 3.3: Majority of the interviewees shared that some staff of the external party, who engage in data collection step had not followed the professional ethics in their job and it had created some issues and conflicts among the community members. Most of interviewees proposed that to conduct a polite survey for re-ensuring the level of technical knowledge of them. This will be supported to minimise the errors in the data collection in the CD project.

Stage 3.4: Most of the interviewees indicated that this step was not much considered in the process to get the support from other staff in organisation and to aware all of them regarding the process of the evaluation. Most of the interviewees expressed that they attempted to improve the sufficient and more knowledge by using CD project related documents, publications of the organisation, vision, mission and policy statement of the organisations as well as the nature of cultural background of the CD project location. Some stated that they attempted to get the mother organisation support through conducting the initial meeting for all staff members regarding the evaluation process, scheduled plan and its expected outcome.

Stage 3.5: Interviewees expressed that they do not attempt to create an additional step to promote the evaluation ethics for evaluation team. One interviewer mentioned that they faced difficulty in the data collection step, because some of the enumerators in the external staff had involved in creating some conflict between the community members, by not following the professional evaluation ethics and it also affected the entire results of the evaluation. Majority of responders expressed that the need for applying ethical values by CD project team among the target beneficiaries in the CD project implementation process as well as the evaluation process. The CD project team is generally familiar with the nature of the target beneficiaries and they should be responsible for respecting the culture and customs of the target beneficiaries.

Stage 3.7: The redeveloping the evaluation tool matrix on the nature of CD project environment should be further developed in this stage with the valuable ideas of evaluation group and stakeholders based on the complex CD project environment. But, the poor engagement level of stakeholders and evaluation group members were influenced to build weak evaluation tool matrix with their valuable ideas. Further, some evaluation group members were not able to re-design the realistic evaluation tools considering the sample size, available resources and time factor created an issue in the performance evaluation process. Some interviewees expressed that their evaluation group further developed the evaluation tools based on the newly received resources from the community in the periodic review meetings.

Stage 3.8: All interviewees mentioned that this was the most critical step in the evaluation process. First, the nature of the designed evaluation plan influenced to run the effective data collection flow for the process. Some interviewees expressed that most of them had not attempted to conduct pilot a survey before starting the data collection, therefore, they were not able to identify the issues and wasted the resources in the process. Further, as mentioned earlier, the role in the enumerators in the data collection process was also influenced in getting the accurate data from the selected sample group among the target community. Under the data collection management step, interviewees proposed a well-defined data collection plan and importance for managing it in an effective way while having the strong qualitative and quantitative data measurement tools. Further, they have suggested that the neediness for encouraging the community and relevant stakeholders to their active participation in the data collection step.

4.4. STAGE FOUR - ANALYSIS AND INTERPRETING DATA

Stage 4.1: The nature of the CD projects is more related with the qualitative objectives, but the results can be expressed through both qualitative and quantitative value based on the requirements of donor and other stakeholders. Some interviewees responded that they faced a challenge under this step due to poor designed evaluation tools.

Stage 4.2: Most of the interviewees expressed that, they faced difficulty when data entering step, because, they did not follow this step deeply, to filter the raw data and information. Some interviewees have suggested that the raw data and information should be carefully filtered to identify the errors which were recorded in the data collection stage.

Stage 4.3: One interviewee expressed that he missed this step and it was caused by creating a large gap between the expected outcome and the received value. At the same time, due to the responses level of target beneficiaries as well as the recording pattern of enumerators, also occurred some mistakes in the data collection.

Stage 4.4: All of them mentioned that they had used trained data entry persons for data entering and analysing part related to the developed evaluation indicators. Some interviewees expressed that they had used the well trained data entry persons for entering and analyzing the data for each evaluation tools and evaluation indicators.

Stage 4.5: Interviewers stated that this step was affected by the poor design of the evaluation purpose. Further, they had given more consideration for establishing clear well-defined evaluation outcomes in the evaluation design stage after considering the qualitative outcomes of CD project.

Stage 4.6: Considering the step of identifying lessons learnt and best-fit practices, interviewees expressed that they do not attempt to give a weight to identify lessons and best-fit practices from the evaluation results.

4.5. STAGE FIVE - COMMUNICATING EVALUATION RESULTS ON CD EFFORTS

Stage 5.1: Some of them mentioned that they did not follow and considered a particular content of the report based on the expectations of the different stakeholders in the CD project environment. They had not attempted to give priority to consider the requirements of the donor, community and government sector. Some interviewees expressed that the need for conducting the evaluation presentation in mother tongue, for it assures more participation and involvement of the community.

Stage 5.2: Interviewees expressed that some of stakeholders missed in this stage and it was caused to miss the opportunity to experience the output of the whole CD project contribution. Some interviewees expressed that they used a stakeholder profile to identify the requirements of them separately and developed presentation flow for more emphasis their requirements how fruitful from the results of the CD project's progress.

Stage 5.3: Majority of interviewees saw this as an additional step which might spend lots of money with their limited financial resources. Moreover, most of interviewees agreed that the importance of using media to publish the evaluation results. They suggested to link with the communication unit of the mother organisation.

5. CONCLUSION

The aim of this research was to develop a guide for performance evaluation of foreign funded CD projects implemented by NGOs in Sri Lanka. The research emphasised the need for developing a guide for performance evaluation due to the lack of available literature and a developed standard guideline in Sri Lankan context. Further, the nature of the CD project and its unique characteristics create challenges in managing and evaluating a CD project parallel to its expected outcomes. The literature review session further identified the unique characteristics of CD projects and their applicability in international and national contexts while considering the performance evaluation in CD projects. Furthermore, this research identified the how performance evaluation process was affected by several impact areas from internal and external CD project environment. The research found basically four impact areas: nature of the CD project, nature of the organisation, nature of the external environment and nature of target beneficiaries. Moreover, the research examined the available developed standards and guidelines for performance evaluation process for CD projects developed by professionals and institutions and finally it was able to develop a common guideline including five major stages: determination of the ability to evaluate the CD project works, creating the evaluation plan on CD efforts, implementing the evaluation plan on CD efforts, analysing and interpreting data and communicating the evaluation results on CD efforts. Under the case study method, the research examined the selected five performance evaluation processes of CD projects of which they had done impact evaluation at the completion stage of the CD project through the interview process. The interview profile had designed considering basically three questions.

- How impact areas were affected by the CD projects' performance evaluation process?
- What kind of strategies already applied by them in the impact areas?
- What kind of strategies can be proposed through the lessons learnt in conducting evaluation processes to the impact area?

Considering the ideas of interviewees, the research identified that how different stages and steps of the performance evaluation process affected by identified four impact areas. At the same time, it also examined different kinds of strategies that are already applied by them to minimise these impacts to conduct a successful evaluation process and to present different proposed strategies generated through the lessons learnt of the past evaluation experiences. By using these proposed and existing strategies generated in NGOs, finally the proposed guide has been developed considering each steps and stages of the performance evaluation process of CD projects.

6. RECOMMENDATIONS OF THE RESEARCH

The proposed strategies for more effective stages are summarised in Table 3.

Table 3: Proposed Strategies

Stage	Strategy
Stage One **Determination of evaluability of CD project work**	▪ Better understanding on organisation's vision, mission and core values ▪ Regular Capacity Building events ▪ Knowledge transferring and handing over
Stage Two **Creating the evaluation plan on CD efforts**	▪ Correct identification of evaluation tools ▪ Developing more questions for every outcome ▪ Stakeholders' profile Priorities evaluation indicators
Stage Three **Implementing the evaluation plan on CD efforts**	▪ Sample size of tools with the budget and available resources ▪ Developing realistic and measurable tools ▪ Conducting a pilot survey
Stage Four **Analysing and interpreting data**	▪ Providing evaluation findings for lesson learnt and best practices for management decision making purpose ▪ Generating lesson learnt and best practices of community engagement
Stage Five **Communicating the evaluation results**	▪ Ensure stakeholders and community participation for the evaluation meeting ▪ Calling media ▪ Considering the organisation policy ▪ Conducting the evaluation meeting in mother tongue ▪ Maintain a stakeholders' profile

Due to the unique characteristics of the CD projects and its complex nature ins and outs of the project environment create some impacts and threats for implementing the evaluation process in an effective way. Before starting the performance evaluation process to measure the impacts in the completion stage of the CD project, they should be careful to build a strong foundation for the performance evaluation. At the same time, they should attempt to maintain a successful CD project implementation process throughout the CD project life cycle. CD projects have their own evaluation process, but considering the strategies and proposed guidelines including the steps of five stages will definitely support to achieve successful and fruitful results in the performance evaluation process while ensuring their quality throughout the process for any foreign funded CD projects implemented by NGOs in Sri Lanka.

7. REFERENCES

Batten, T., 1957. *Communities and Their Development.* Oxford University Press, London.

Boehm, B.W. and Ross, R., 1989. Theory-W Software project management principles and examples. *IEEE Trans Software Eng 1989,* 15(7), 902-916.

Bonch, R., forthcoming.*Conducting randomized experiments.* CA: Sage.

British Standards Institute, 2003. BS ISO 10005:2005.*Quality Management systems-GuCDed-lines for quality Management in projects*. London: BSI.

Cary, L., 1973. *Community Development as a Process,* Columbia: University of Missouri Press.

Cawley, R., 1989. From the Participants' Viewpoint: A Basic Model of the Community Development Process. *Journal of the Community Development Society*, 20(2), 101-111.

Cooke-Davies, T., 2002. The "real" success factors on projects. *Int J Project Manage*, 20(3), 185-190

Crawford, I.M., 1997. *Marketing Research and information systems* [online]. Available from:http://www.fao.org/docrep [Accessed 25 May 2014].

Crawford, L. and, P., 2003. Project Management monitoring & Evaluation: methods for enhancing the efficiency and effectiveness of a CD project implementation. *Int J Project Manage,* 21(1), 363-373.

Diallo, A. and Thuillier, D., 2004. The success dimensions of International development projects; the perceptions of African project coordinators. *Int J Project Manage,* 22(1), 19-31.

Dissanayake, D.M.S.S.L., 2003. Rural community development, lessons from the Japanese experience: an exploratory study, *The Distant Neighbour, Faculty of Graduate Studies,* University of Colombo. 317-338.

Gunasekara, D.S.K., 2010.*Constrains and challenges of NGO managed Community Development project in Sri Lanka.* Unpublished Dissertation (M.Sc.). University of Moratuwa, Sri Lanka.

Kamrul, A. and Indra, G., 2010. Analysis of cost and schedule performance of international development projects, *Int J Project Manage*, 28(1), 68-78.

Khang, D.B. and Moe, T.L., 2008. Success criteria and factors for International development projects: a lifecycle based framework. *Project Management Journal,* 39(1), 72-84.

Kularathna, W.G., 2009. Community Development in Sri Lanka. *Sri Lankan Journal of Librarianship and Information Management,* 2(1), 1-4.

Touwen, A., 2001.*Development Managing and Fundraising* [online]. Geneva :International Federation of University Women Available from: http://www.ifuw.org [Accessed 25 May 2014].

Wanigarathna, R.D., 2003. *Intergration Mechanism in Social Development.* Focus; Social Development.

Youker, R., 1999. Managing International Development projects: Lesson Learned. *Project Manageemnt Journal,* 4(2), 1-3.

Zarinpoush, F., 2006.*Fundamental Methods and Steps for conducting Project Evaluation* [Online].Canada:Imagine Canada. Available from: http://sectorsource.ca/sites/default/files/resources/files/projectguide_final.pdf [Accessed 25 May 2014].

A REVIEW OF THE BENEFITS AND THE HINDRANCES TO THE SUSTAINABLE CONSERVATION OF HERITAGE BUILDINGS IN MALAYSIA

Dodo Mansir*
Department of Real Estate and Facilities Management, University Tun Hussein Onn, Malaysia

Narimah Kasim
Department of Construction Management, University Tun Hussein Onn, Malaysia

ABSTRACT

Malaysia has an array of Heritage Building's (HB's) most of which have been standing for centuries that are exceptionally valued from the point of view of Architecture and History. Valuable as they are, these HB's are thus assets legally declared to be strictly protected (otherwise termed conservation) according to statutory guidelines. The National Heritage Act among others is a statutory document guiding conservation of HB's in Malaysia superintended by The Ministry of Culture, Arts and Heritage. This study reviewed the benefits and hindrances to the sustainable conservation of HB's in Malaysia. This study shows that while there are enormous benefits reaped from conservation of HB's, there also exist hindrances to the conservation process that could be attributed to planning and implementation at a policy, program and project level. These hindrances ultimately poses challenges to conservation of HB's thereby making conservation of HB's in Malaysia unsustainable. A way forward lies in the need for immediate action to addressing such challenges through sustainable processes, principles and policies. One that strives to strike a balance between environmental, economic, social cultural benefits for all generations. One that is sustainable. As such, a prompt need for Malaysia to benchmark world's best practices in the conservation of HB's that will address notable challenges was recommended. Furthermore, owners of HB's (public and private) must make continuous implementation of the results on such best practices a core priority thus making the conservation process sustainable.

Keywords: *Heritage Buildings; Malaysia; Sustainable Conservation.*

1. INTRODUCTION

Idrus *et al*. (2010) define a Heritage Building (HB) as a building built in the past which has high historical and architectural value and require continuous care and protection to preserve its aesthetic, archaeological, spiritual, social, political, and economic values. These values signify a unique identity specific to a society. In another definition given by Section 2(1) of The National Heritage Act (NHA) of Malaysia (2005), a HB is a building or group of separate or connected buildings which because of their architecture, their homogeneity or their place in the landscape possess outstanding universal value that are striking from the point of view of history, art or science. These definitions describe a HB to being unique, distinctive and exceptional which makes it an asset immensely valued. To pass for a HB however, two criteria must be fulfilled. First, a building must be legally declared to be protected under the approval of a government and secondly, it (the building) must be published in a government gazette.

There exists an array of HB's across Malaysia showcasing Malaysia's unique history that is attributed to its almost five centuries (1511-1957) of colonial rule by the Portuguese, Dutch and British. A feat to this uniqueness in HB's is notable in historic sites and cities across the country. For instance, Melaka and George Town are historic cities in Malaysia having in stock iconic HB's among other outstanding

* Corresponding Author: E-mail - mansirdo14@yahoo.com,

features that propelled their being enlisted as World Heritage Sites by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in 2008 (Ahmad, 2009; Idrus *et al.*, 2010).

The International Council on Monuments and Sites (ICOMOS, 1999) which is a comprehensive global guideline on HB conservation defines conservation as all processes of looking after a place (buildings and monuments among others) aimed at retaining its cultural heritage. Conservation of HB's may according to circumstances be in either of the following forms: maintenance; restoration; reconstruction; adaptation; and stabilization (Article 14 of France, 1999; Part I; Section 2 of Malaysia, 2005). A commonly accepted definition of sustainable conservation is still evolving among practitioners of HB conservation (Abungu, 2012). Irrespective of this, sustainable conservation seeks to address the harmonious integration of all three indices of sustainable development (which are environmental, economic and social) into conservation (Jackson *et al.*, 2011; Knih, 2012; Wara, 2012; Ramachandra and Abu, 2014). From another source, sustainable conservation is driven by four major indices which are: social; economic; environmental; and cultural (Spangenberg*et al.*, 2002). Although some authors consider the cultural dimension of sustainability to being a sub-item of the social dimension, other authors (Kenny, 2006; Abu, 2014) have argued that the social construct does not fully regard culture to being important however, in fields of study on cultural heritage, scholars feel that only upon considering culture as a full-fledged construct will it be given due regard.

The environmental index to sustainability usually addresses factors which concerns matters such as air quality, water quality, sanitation, drainage, energy consumption, embodied energy, use of environmentally friendly materials, among others. The economic index usually addresses optimising resource consumption, quality of life, economic development, property value. The social construct addresses social equity, health equity, community development, social capital, social support, human rights, labour rights, social responsibility, social justice, cultural competence, community resilience, and human adaptation. The cultural index addresses the complexity of contemporary society, issues related to norms and values among others.

Kamal *et al.* (2007) are of the opinion that conservation is relatively new in Malaysia as compared to countries like United Kingdom, China and other countries. Works of Amir and Robiah (2007) concluded that there are weaknesses in the approach of conservation adopted for HB's in Malaysia. Furthermore, Mohd-Isa *et al.* (2011) further reported that most problems emanating from conservation of HB's in Malaysia is because conservation is not being deemed as holistic. All these assertions clearly show that conservation in Malaysia is yet to gain full sustainable accord because there exist some gap in its full exploration relative to the sustainability indexes earlier presented. As such, this forms the underpinning basis for this research. Hence, this study aims at reviewing the benefits accrued from the conservation of HB's on one hand and the challenges hindering the sustainable conservation of HB's in Malaysia on another hand with a view to suggesting ways forward.

2. HERITAGE BUILDINGS IN MALAYSIA AND THE REGULATIONS FOR THEIR CONSERVATION

The architectural ensemble of buildings in Malaysia represents an outstanding example which illustrates significant stages in human history. Malaysia has a number of HB's that are publicly and privately owned that have outstanding architectural and heritage interest. All declared HB's in Malaysia must however fulfil Criteria 67 (2) of NHA (2005) which according to the Malaysia (2007) are:

1. Historic interest: buildings that have illustrated important aspects of Malaysia's social, economic cultural and religious history,
2. Architectural interest: buildings that are important for styles in their architectural design, decoration and craftsmanship,
3. Close historical association: buildings associated with the life or work of a nationally important person or organisation,
4. Townscape value: buildings that have contributed to the scenery of the townscape or landscape,

5. Group value: An ensemble of buildings denoting a particular architectural style of a certain era,
6. Age and rarity: buildings that are old and rare compared to its historical equals,
7. Physical features: buildings layout, material or location reflecting its original design,

Malaysia has an array of HB's ranging from administrative buildings, royal palaces, religious buildings (mosques, churches and temples), fortresses and residential buildings that have been around for centuries and showcase its diverse history. Table 1 depicts some among other HB's in Malaysia that are still standing.

Table 1: Category of Heritage Buildings in Malaysia

Type of Building	Building	Year Built
Administrative	Stadthuys Building	1650s
	Melaka Waterworks Department Building	1750s
	Sultan Abdul Samad Building	1897
	High Court Building Penang	1905
Religious	St. Pauls Church	1512
	Cheng HooonTeng Chinese Temple	1645
	Sri Poyyatha Indian Temple	1710
	Kampong Hulu Mosque	1726
	Christ Church	1741
	Godess of Mercy Temple	1800
	Nagore Shrine	1800
	Kapitan Keling Mosque	1802
	Acheen Street Malay Mosque	1808
	St. George Church	1818
Institutional	Penang Free School	1821
	Yin Oi Medical Hall	1886
Residential	Dutch Style Terraced Houses	1700's
	Early Shop-Houses	1800's
	Munsyi Abdullah Residence	1850's
	Goh Chan Lau Residence	1880
	Transitional Styled Shop-Houses	1890's
Others	Porta De Santiago	1511
	Dutch Cemetery	1750's
	Fort Cornwallis	1787
	Town Hall and City Hall	1850
	Victoria Memorial Clock Tower	1897

All matters related to HB's and their conservation in Malaysia are backed by the National Heritage Act (Act 645) of Malaysia enacted in 2005. Other legislations that have a direct link to the conservation of HB's in Malaysia according to Idrus*et al.* (2010) are:

1. Antiquities Acts (1976), Act 168;
2. Town & Country Planning Act 1976 (Act 172);
3. Uniform Building By-Laws 1984;
4. Street, Building & Drainage Act (Act 133) 1974;
5. Local Government Act (Act 171)1976;
6. Urban Development Corporation Act 1971 (Act 46);
7. Federal Territory Planning Act 1982 (Act 267);
8. Town and Country Planning Act 1995 (Revised) (Act A933);
9. Melaka Enactment No.6 1988; and
10. Johore Enactment No.7 1988.

The Department of National Heritage and The Department of Museums and Antiquities are units under the Ministry of Culture, Arts and Heritage in Malaysia. They are the custodians of HB's in Malaysia and are responsible for preserving and maintaining them through implementing and enforcing the provisions stipulated in the National Heritage Act 2005 (Act 625). A core objective of both departments is to conserve, preserve, and protect Malaysia's HB's through research, documentation, and enforcement, and encourage awareness. The aforementioned regulatory bodies use aforementioned legislations to designate, gazette and protect all HB's in Malaysia. Furthermore, they equally use these regulations for planning, implementing and controlling all conservation practices.

3. CONSERVATION OF HERITAGE BUILDINGS AND IT'S IMPACT IN MALAYSIA

Malaysia has a lot of HB's all over the country. Conservation of HB'sin Malaysia began in the 70's (UNESCO, 2009; Mohd-Isa *et al.*, 2011). It gained prominence and witnessed its acceptance in the 80's when Malaysia became a member of UNESCO's Convention (1988) concerning the protection of the world cultural and natural heritage (Harun, 2005; Ahmad, 2010)**.** This led to a great demand in the practice of conserving HB's in Malaysia in the 90's and during that time as **(**Ahmad, 2009) posits, conservation of HB's became an important National Agenda. According to Mohd-Isa *et al.* (2011), conservation of HB'sin Malaysia flourished in the 21st century especially when Melaka and GeorgeTown historical cities were enlisted as UNESCO's World Heritage Site in 2008. Such enlisting was a tremendous achievement to Malaysia's natural and cultural heritages because it led Malaysia to becoming a hub that promoted heritage tourism. From these strides, the conservation of HB's in Malaysia was given high priority. Mohd-Isa *et al.* (2011) reported that in total, RM100 million was spent for the purpose of conservation of HB's under the 9th Malaysian Plan (2006-2010) alone. Subsequent budgets have also been made to conserving HB's across Malaysia. All these feats to the conservation of HB's have accrued several benefits to Malaysia. The subsequent sub-sections discuss these benefits.

3.1. EMPLOYMENT BENEFIT

The technologies of conservation of HB's are still low thus it is deemed to be more labour intensive compared with development of new buildings (Avakyan, 2013). In another study, Tully (1993) and Langston *et al.* (2008) report that conservation generates 25% more employment than new building construction. These studies show that conservation relies more on labour than it does on materials. This means that effectively conserved HB's will eventually harbours employment of the local community. In Malaysia, Said *et al*. (2013) posited that conservation of HB's have yielded employment opportunities to the youth. It is thus obvious that conservation of HB's brings in it employment benefits that ultimately have a positive impact on the socio-economy of a society and nation at large.

3.2 SOCIO-ECONOMIC BENEFIT

Elahi (2008) posits that just as individuals amass economic capital, they also strive to obtain cultural capital accumulated through possession of HB's among other heritage items or objects. Heritage Buildings thus serve as a capital to communities, neighbourhoods, regions and a country at large. In Malaysia, HB's have generated revenue in tens of billions of Malaysian Ringgit (Bhuiyan*et al.*, 2013). Figure 1 shows the revenue generated from tourism in Malaysia.

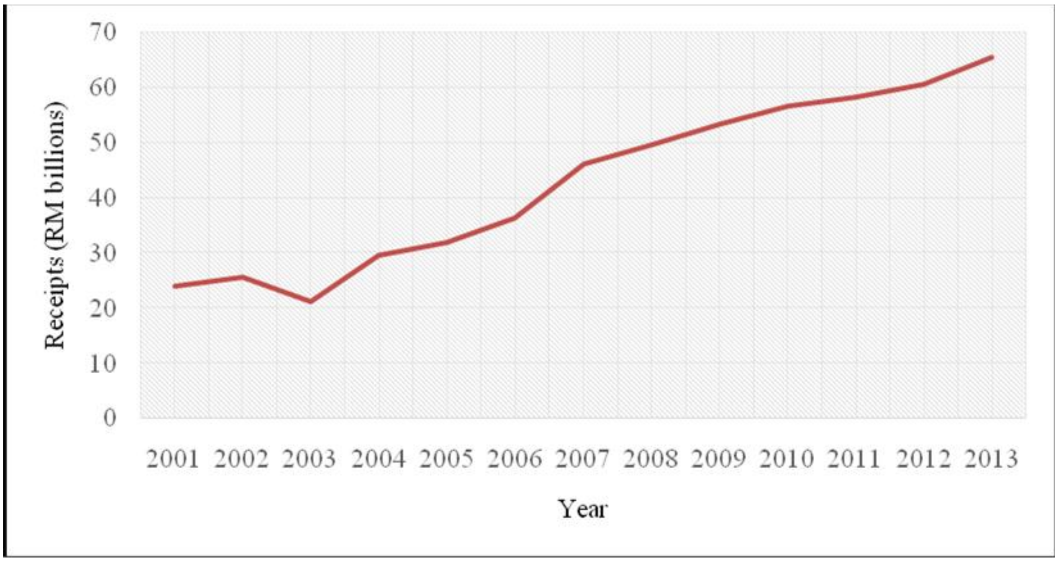


Figure 1: Revenue Generated from Tourism in Malaysia
Source: Adapted from Bhuiyan *et al.* (2013)

In all the 13 years captured in the diagram, the trend in revenue generation only witnessed a decline in the period 2002-2003. All other years recorded an increase in revenue generated by tourists in Malaysia with HB tourism significantly contributing to such revenue stream. These generated revenues have played significant roles towards enhancing the socio-economic conditions of the societies these HB's are located. For instance, conservation in itself results to job creation. Similarly, effective conservation also results to tourist attraction which subsequently results to revenues (through taxes and other spendings). According to Bhuiyan *et al.* (2013), Malaysia Tourism Transformation Plan under the Economic Transformation Program (ETP) intends to achieve the target of RM168 billion in revenue by 2020. This will indeed have a positive impact on the socio-economic development to the cities harbouring HB's and Malaysia at large.

3.3. HERITAGE TOURISM BENEFIT

A study by Rypkema (2008) showed that heritage tourists stay longer, visit twice as many places and spend 2.5 times more than other visitors. Avakyan (2013) makes the assertion that the more a HB is conserved, the more a new tourism product emerges for both domestic and international visitors. Thus, conservation of HB's aids in boosting tourism. In Malaysia, conservation of HB's has made Malaysia to become a tourist hub which according to Ahmad (2009) has made tourism to become the second most important sector in Malaysia's economy. Figure 2 shows the tourist arrival to Malaysia.

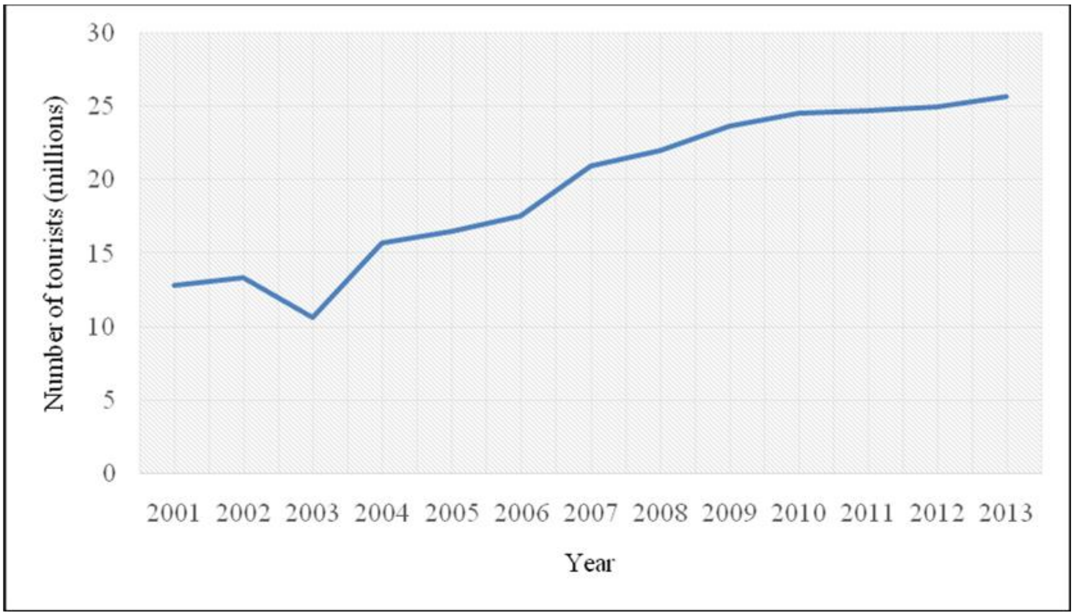


Figure 2: Tourist Arrivals in Malaysia
Source: Adapted from Bhuiyan *et al.* (2013)

As is shown in Figure 2.13, in all the 13 years captured in the diagram, the trend in tourist arrival in Malaysia only witnessed a decline in the period 2002-2003. All other years recorded an increase in tourist arrival in Malaysia with HB tourism significantly contributing to such revenue stream. According to Bhuiyan*et al.* (2013), Malaysia Tourism Transformation Plan under the Economic Transformation Program (ETP) intends to achieve the target of 36 million tourists by 2020. If this forecast is met, it will indeed have a positive impact to Malaysia.

3.4. PROPERTY VALUE BENEFIT

Studies have shown that property values within conserved HB districts appreciate in value at faster rates than the overall real property local market. For example, a study in Canada found that HB's performed better in the marketplace over the last 30 years due to conservation efforts (Rypkema, 2008). In another study, Forsyth (2007) reports that pre-World War buildings in the UK are worth on average 20% more than equivalent in value to more recent houses. In a cultural value specific context, Hareven and Langenbach (1981) are of the opinion that HB's have taken on increasing value as it acts like a bridge between the past and the present, providing elements of collective memory and connection to urban settings. In Malaysia, Ch'ng *et al*. (2013) posits that benefits in conserving HB's may be reflected in the lease or resale value of adjoining property which ultimately provides good income incentive for the property owner. This results from the fact that HB's and buildings in their surrounding usually carry a premium which makes them more desirable than their equivalents in non-HB present premises. Conservation of HB's as such has significant positive effects on property values (residential and businesses alike) around the area a HB is located.

3.5. SMALL BUSINESSES INCUBATION

Rypkema (2008) claims that the presence of effectively conserved HB's in districts as opposed to other non-HB presence districts encourage the natural incubation of small businesses. The work of Listokin *et al.* (1998) elaborates on this by discussing various examples of conservation of HB's as a vehicle for Small and Medium Enterprise (SME) development. An effect to business incubation can be witnessed in the springing up of industries that produce goods and services used for the conservation and running of the HB's. The induced effects here are the expenditures made by the residents, workers and visitors among others either involved with the conservation or running of the HB's. In Malaysia, incubated businesses (that can be seen upon visit) resulting from conservation includes: small-scale independent retailers, artisan-type workshops, and other traditional and localised activities.

3.6. SOCIO-CULTURAL BENEFIT

Conserving HB illuminates the identity, memory, event, and also inspiration of a local community. According to Hasbollah and Baldry (2014), through conservation, the cultural values of heritage buildings (CVHB) are expected to have a prolonged effect on the socio-culture of a society. In another study, Avakyan (2013) points out the importance of conservation within the context of increasing globalization, where there is a growing need to conserve the past for the continual strengthening of national cultural identity. In other studies, Ashworth *et al.* (2007) found that HB's serves to fill the voids of socio-cultural functions. Forrest and Kearns (2001) and Elahi (2008) also noted that HB's can lead to the creation of a strong sense of belonging. Malaysia enjoys distinctive multicultural architectural heritage with strong Islamic, Chinese and Western influences all of which are portrayed in the HB's (Sodangi *et al.*, 2014). HB's in Malaysia thus serve as the cultural identity of the country and its people. Socio-cultural benefits derived from conservation of HB's as such include improving the kinship bond between its heterogeneous society through learning and appreciating the numerous multi-cultures. Other social benefits derived from the conservation of HB's include: safeguarding authenticity, enjoyment of the building's aesthetic values, improving the sense of place factor, and crime reduction.

3.7. ENVIRONMENTAL BENEFIT

The environmental benefits of HB's as such cannot be overemphasised. Elsorady (2014) claims that one quarter of all the things dumped in landfills are construction debris. In another study, Forsyth (2007) found that demolition of buildings in the UK accounts for 24% of the total annual waste produced. It can thus be right to say that the continuous usage of existing buildings when compared to constructing new buildings saves waste and reduces the need for new building materials. In Malaysia, Sodangi *et al*. (2014) asserts that conservation of HB's promotes sustainable development. This can be affiliated to the fact that HB's reduces energy usage associated with demolition, reduction of material waste and disposal thereby preserving embodied energy. Furthermore, many HB's employ massive construction in their external envelope, which can reduce energy consumption in heating and cooling. In Malaysia, almost all HB's are constructed using a range of eco-friendly materials that typically display a useful life well in excess of their more modern counterparts (e.g. use of solid stone walls, timber floors among other eco-friendly materials). Conservation of HB's thus has enormous environmental benefits.

3.8. NON-PRICED BENEFIT

Some benefits reaped from conservation of HBs cannot be quantified nor priced. For instance, compared to recent buildings, most HB's have superior build quality with craftsmanship that can hardly be duplicated. Randle (2012) posited that HB's offer character, life and vibrancy, or indicate the decline and abandonment of an area. Due to such distinctiveness, HB's are highly valued for their own sake. Furthermore, conservation of HB's enhances the landscape scenery and most times makes HB surroundings pass for entertainment hubs (Ley and Olds, 1988; Elsorady, 2014). Conserving HB's equally contributes to a society's wellbeing by protecting its cultural resources. To cap this up, conservation of HB's in Malaysia has accorded mutually beneficial relationship between stakeholders and the local community by increasing the bond of kinship among its diverse multi-cultural nationals.

4. HINDRANCES TO SUSTAINABLE CONSERVATION OF HB'S IN MALAYSIA

A review of literature shows that several researches have reported numerous challenges to conservation of HB's in Malaysia. These studies indeed qualify the assertions that 'despite all the positive efforts, there are still major challenges and issues in dealing with the conservation of HB's in Malaysia' (Zakiyudin, 2001; Amir, 2002; Amir and Robiah, 2007; Mohd-Isa *et al.*, 2011). For instance, in a study by Woon and Lim (2010), they found the following challenges to the conservation of HB's in Malaysia:

1. The lack of information on the cost of items;
2. Complexity of the method of conservation;
3. Difficulty in sourcing the required material;

4. Lack of standardised documents pertaining to conservation work to ease costing;
5. Lack of understanding in conservation works on the part of Quantity Surveyors which ultimately leads to difficulty in preparing a cost budget;
6. Modification or adaption of information or standards from new construction works to be used for conservation works;
7. Inadequate knowledge on special works to be considered when preparing a cost budget for conservation works such as archaeological excavation, scientific testing and analysis and other preliminary works; and
8. The existing cost analysis format and tools are not suitable for conservation projects because of the differences in part of the scope of work between conservation and new building works.

In another study by Harun (2011) titled "Heritage Building Conservation in Malaysia: Experiences and Challenges", she reports several issues that pose as challenges to conservation in Malaysia which are:

1. Non-standardised conservation plan and conservation process: The decision on conservation is sometimes made based on assumptions which results to non-standard practice;
2. Lack of skill workers and conservator challenges: There is lack of labour and technical expertise in conservation methods and techniques. This is a major problem because almost all conservation projects require an understanding of and analysis of building defect diagnoses. There is also the issue of testing and treating building material, choosing appropriate tools and the methods to conserve the building. All these pose great challenge to the conservator who oversees the conservation project;
3. Choice and sourcing of material. There is a problem in getting materials that could pass for replicates of the original material during conservation. Regardless of this, the challenges are not only to get the original materials but the contractor needs expertise in interpretation of the needs of the project. New material that is compatible with the original must be sought and tested for strength, texture, scale and form among others before finally being applied; and
4. Conservation guidelines for conservation works: Appropriate conservation guidelines usually serve as an important tool for the conservator and building contractors. Although National Heritage Act 2005 gives emphasis to the care of listed buildings and declaration of National Heritage, however these regulations are yet to be accompanied with guidelines and technical manual for conservation works.

From the study by Said *et al*. (2013), they enumerate the challenges that affect conservation of HB's and their immediate surroundings to being: intensive and uncontrolled development pressures; insufficient legislations and enforcement; changing lifestyles and consumption patterns of city dwellers; expectation of new tourists; public awareness; environmental degradation; non transparent local initiatives; poor provision of grants and technical advice; and insufficient law and enforcement.

Ch'ng *et al.* (2013) are also of the opinion that conservation of HB's in Malaysia is faced with challenges such as:

1. Low-investment incentives and capital gains which has resulted in low conservation efforts and subsequent dilapidation and neglect of HB's;
2. Absence of a workable conservation market; and
3. Low public support.

Sodangi *et al.* (2014) found that among the 16 best practice criteria for conserving HB's in Malaysia they studied, the most challenging are: approaches to conservation; attitude of stakeholders towards conservation; integration of corporate strategy to the objectives of conservation; prioritisation of conservation works to new construction works; and monitoring of the conservation works.

These studies among others collectively not only confirm but also showcase the challenges to conservation of HB's in Malaysia. An inference to be drawn from all these factors hindering the sustainable conservation of HB's in Malaysia is that they can be categorised to factors that are planning specific, implementation specific or those that are a combination of both. Planning specific hindrances here refer to adequacy and robustness of guidelines, stakeholder engagement (particularly to human capital development relative to awareness and skill acquisition) and perhaps resource sourcing. Those that are implementation specific refer to ethics on conservation practice, safeguarding authenticity and integrity. Similarly, these hindrances can be viewed from the perspective of policies, programmes and project levels of conservation. Ultimately, these hindrances have farfetched effect on the environmental, economic, social and cultural wellbeing of the buildings and their immediate environment.

5. The Way Forward

According to Harun (2011),for conservation of HB's to be successful, it must be supported by relevant stakeholders inclusive of building owner, professional and competent technical people, the academia and the community among others. Such success may however only be feasible when best practices to the whole conservation process of HB's are opted for and adopted. A process that will create a paradigm shift to the existing status-quo must be opted for. That which is sustainable.

Comparing the afore-presented target of Malaysia Tourism Transformation Plan on one hand and the challenges existing in the conservation of HB's in Malaysia on another, it may be convenient to state that there is need for immediate action to addressing such challenges. Similarly, considering the afore-presented enormous benefits reaped from the conservation of HB's on one hand and the challenges existing in the conservation of HB's in Malaysia on another, there is indeed a dire need to addressing these challenges. Combating these challenges efficiently however calls for conservation processes, principles and policies that will not only bring forth success in improving the challenges, but one that is sustainable. Although Abungu (2012) asserts that a commonly accepted definition of sustainable conservation is still evolving among practitioners of HB conservation, Jaafar *et al.* (2015) stressed that sustainable conservation must strive to strike a balance between economic, environmental, and social benefits. Malaysia must thus put in place a sustainable conservation programme that emphasises social and economic development in such a way as to avoid damaging the environment for future generations. After all, sustainable conservation may be said to be an enabler for a building that is rich in historical values to withstand the test of time from one generation to another.

6. Conclusions and Recommendations

This review paper on one part showed the positive impact on the effort in conserving HB's in Malaysia and on the other, the challenges to conservation of HB's. It may be concluded that these challenges clearly depict problems in the conservation of HB's which ultimately show that there is a gap in the sustainable conservation of HB's in Malaysia. The researchers recommend that there is need for studies on world's best practices in the conservation of HB's that will fill such notable gaps. Furthermore, owners of HB's (public and private) must make continuous implementation of the results on such best practices a core priority thus making the conservation process sustainable.

7. References

Abu, R., 2014. *Community Development and Rural Public Libraries in Malaysia andAustralia.* Thesis (PhD). Victoria University,Melbourne, Australia.

Abungu, G., 2012. The Convention Today for a Better Future: Emerging Issues onSustainable Development and Disaster Prevention/Recovery.*The Closing Event of the Celebration of the 40th Anniversary of the World Heritage Convention*. Kyoto 6-8 November 2012. 52-56. Available from: file:///C:/Users/user/Downloads/activity-726-1.pdf [Accessed 12 December 2014]

Ahmad, A.G., 2010. *PemuliharaanBangunanWarisan di Malaysia PengalamandanCabaran*. Minden: PenerbitUniversitiSains, Malaysia.

Ahmad, G.A., 2009. *Urban Conservation in Malaysia.* Safeguarding Cultural Heritage.

Amir F., 2002. *Conservation Maintenance Management*. Sheffield Hallam University, United Kingdom.

Amir, F. and Robiah, A. R., 2007. Conservation Maintenance Management of Historic Buildings in Malaysia: A callfor Establishing a Framework.*Seminar KebangsaanRupa Bandar Malaysia, MengekalWarisanMembinaIdentiti*. Malaysia 28-29 November 2007. Perak.diLumut: Perak.

Ashworth, G.J., Graham, B.and Turnbridge, J.E., 2007. *Pluralising Pasts: Heritage, Identity and Place in multicultural societies*. Pluto Press: London.

Avakyan, M.G., 2013. *Adaptive Reuse of Historic Churches in New York City: the Opportunities and Challenges for Community Development*. Thesis (MSc). Columbia University in the City of New York.

Bhuiyan, H.A., Siwar, C. and Ismail, M.S., 2013. Tourism Development in Malaysia from the Perspective of Development Plans. *Asian Social Science,* 9(9),11-18.

Ch'ng, S.K., Khoo, L.S. and Lim M.Y., 2013. Preference Information and Experimental Heritage Conservation Auctions. *Journal of Cultural Heritage Management and Sustainable Development,* 3(1),82-94.

Elahi, F., 2008. *Economic Revitalization or the Creative Destruction of Heritage: A Case Study of Port Dalhousie at a Cusp*. Thesis (MSc). University of Waterloo.

Forrest, R. and Kearns, A., 2001. Social Cohesion, Social Capital and the Neighbourhood. *Urban Studies,* 38(12), 2125-2143.

Harun, S.N., 2011. Heritage Building Conservation in Malaysia: Experience and Challenges. *ProcediaEngineering,* 20,41-53.

Harun, S.N., 2005. *AmalanKerjaPemuliharaanBangunanBersejarah di Malaysia*.Thesis (Ph. D.). UniversitiSains Malaysia. Available from: http://versys.uitm.edu.my/prisma/view/viewPdf.php?pid=4206 [Accessed 12 december 2014].

Hareven, T.K.and Langenbach, R., 1981. *Living Places, Work Places and Historical Identity*. Blackwell Press: London.

Hasbollah, R.H. and Baldry, D., 2014. Conserving Cultural Values of Heritage Buildings from the Facilities Management Perspective in Malaysia. J*ournal of Facilities Management,* 12(2),172-183.

Idrus, A., Khamidi, F. and Sodangi M., 2010. Maintenance Management Framework for Conservation of Heritage Buildings in Malaysia. *Journal of Modern Applied Science,* 4(11),66-77.

Jackson, K., Pierre, J. and Jolley, M., 2011. *Strategic Methods in Community Engagement for UNESCO Biosphere Reserves*. Thesis (MSc). Blekinge Institute of Technology, Karlskrona, Sweden.

Jaafar, M., Noor, M.S.and Rasoolimanesh, S.M., 2015. Perception of Young Local Residents toward Sustainable Conservation Programmes: A Case Study of the Lenggong World Cultural Heritage Site.*Tourism Management*, 48, 154-163.

Kenny, S., 2006. *Developing Communities for the Future*. 3rd ed. CengageLearning:Australia.

Knih, D., 2012. *Community Engagement as Conflict Prevention: Understanding the Social License to Operate*. Thesis (MSc). University of Victoria.

Ley, D. and Olds, K., 1988. Landscape as Spectacle: Worlds' Fairs and the Culture of heroic Consumption.*Environment and Planning,* 6, 191-212.

Listokin, D., Listokin, B, and Lahr, M., 1998. The Contributions of Historic Preservation to Housing and Economic

Development.*Housing Policy Debate,* 9(3), 431-478.

National Heritage Act. Act 645, 2005.Malaysia: The Commissioner of Law Revision.

Malaysia, 2007. Nomination Dossier for the Historic Cities of the Straights of Melacca [online].Avilable from: file:///C:/Users/user/Downloads/Malaysia%20%20Malacca.pdf [Accessed 12 December 2014].

MohdI. F.A., Zainal-Abidin Z. and Hashim E.A., 2011. Built Heritage Maintenance: AMalaysian Experience. *The2nd International Building Control Conference Penang* [online], 20, 213-221. Available from: http://versys.uitm.edu.my/prisma/view/viewPdf.php?pid=37543 [Accessed 12 December 2014].

Ramachandra, A. and Abu Mansor, N. N., 2014. Sustainability of Community Engagement in the Hands of Stakeholders. *Education and Training,* 56(7),588-598.

Randle, K., 2012. *The Evolution of the Built Environment of Heritage Communities: Comparative Case Study of St. Jacobs and Creemore.* Thesis (Master's). University of Waterloo Ontario, Canada.

Rypkema, D.D., 2008. Heritage Conservation and the Local Economy. *Global Urban Development*[online],4(1). Available from: http://www.globalurban.org/GUDMag08Vol4Iss1/Rypkema.htm [Accessed 12 December 2014].

Said, Y.S., Aksah, H. and Ismail D.E., 2013. Heritage Conservation and Regeneration ofHistoric Areas in Malaysia.*Procedia social and behavioural science*, 105, 418-428.

Sodangi, M, Khamdi, F.M., Idrus, A., Hammad, B.D. and Umar, A.A., 2014. Best Practice Criteria for Sustainable Maintenance Management of Heritage Buildings in Malaysia. *Procedia Engineering,* 77,11-19.

Spangenberg, J.H., Pfahl, S., and Deller, K., 2002. Towards Indicators for Institutional Sustainability: Lessons from an Analysis of Agenda 21. *Ecological Indicators*, 2, 61-77.

Tully, E., 1993.*Construction Employment Multipliers to take Account of Price Increases between 1983 and 1992.* Science and Technology: Canberra.

UNESCO, 2009. *A Protocol for Best Conservation Practice in Asia: Professional Guidelines for Assuring and Preservation the Authenticity of Heritage Sites in the Context of the Cultures of Asia.* UNESCO: Bangkok.

Wara, U.S., 2012. *Cultural Heritage Conservation and Sustainable Urban Community in Dhaka: Case Study with MirpurBenarashiPalliandShakhari Bazaar*. Thesis (Master's). The University of Hong Kong.

Woon, L.W. and Lim, Y.M., 2010. Elemental Cost Format for Building Conservation Works in Malaysia. *StructuralSurvey*, 28(5), 408 – 419.

Zakiyudin, Z.A., 2001. Study of Conservation Methods Adopted in Malaysia. M. Sc. UniversitiTeknologi Mara, Malaysia.

A STUDY ON APPLICABILITY OF BAMBOO FIBRE REINFORCED MYCELIUM BONDED SAWDUST MATERIAL FOR PARTITION WALL

O.D.P.C. Vithanage* and S.R. Chandrathilake
Department of Building Economics, University of Moratuwa, Sri Lanka

R.U. Halwathura
Department of Civi Engineering, University of Moratuwa, Sri Lanka

ABSTRACT

In building construction there is a need of alternative materials which are low cost, high efficiency and environmentally responsible. This research presents an innovative solution for partition walls. The solution is produced by using sawdust, mycelium and other ingredients which are normally used in mushroom cultivation. In this material the mycelium acts as a natural glue to bind sawdust particles. Also bamboo fibre was introduced to increase the strength of the innovative material. The panel making process was done by four steps as preparing mixture, preparing mould to grow mycelium, getting mushroom cultivation and compressing and drying the panel. To find the standard of the properties of the material, compression strength parallel to surface and water absorption tests were done by using the test specimens of the new material. All the tests were conducted according to the ASTM D 1037 (1978) standard to keep the test results at a standard level. The compression strength test showed that the optimum amount of bamboo fibre proportion in order to get the maximum compressive strength. Other than that ultimate compressive strength, yield strength, density, specific strength and Young's modulus were calculated too. The properties of new material were compared with Gypsum and MDF panels to find the position in the market. In this process mushroom is harvested as a by-product which leads to make a link between food industry and construction industry. This material fulfils the requirements of partition walls and can be applied as a green solution in partition wall construction.

Keywords: *Bamboo Fibre; Mycelium; Partition Wall.*

1. INTRODUCTION

In construction industry there is a vast range in use of materials (Marotte, 2005). According to Ecovative's Mushroom Materials (2013), researchers continually do experiments, on low cost environmentally responsible materials which can be developed from natural things. To find out environmental friendly effective materials researchers turned to develop materials with vegetable fibres including bamboo, industrial waste, soil and agricultural wastes (Ghavami, 2004). Ecovative's Mushroom Materials (2013) illustrated that the researchers do researches on fungus in order to develop such materials. Mycelium, the vegetative part of fungus is rapidly grown on sawdust (Arulnandy *et al*., 2008). Ecovative's Mushroom Materials (2013) elaborated that the mycelium, a natural self-assembling glue which is grown on agricultural waste. At present the people use mycelium for producing medicine, producing food, healing landscapes, pest control, increasing plant productivity, packaging and insulation material (The Power of Fungi, Mushrooms and Mycelium, 2012). Arulnandy *et al*. (2008) stated that people use sawdust as the media for mycelium in order to cultivate mushrooms in food industry. Naturally mushrooms are grown on wooden particles as well as on bamboo successfully (Oyster Mushrooms Growing on Bamboo Rraft, 2011). Ghavami (2004) found that bamboo fibre can be used for tensile loading applications. There is a possibility of using bamboo fibre with mycelium as a reinforcement material because bamboo helps mycelium to grow well.

In this research mycelium bonded material and bamboo fibre are combined in order to make bamboo fibre reinforced mycelium bonded sawdust material. Mycelium bonded material has properties of flame

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

retardant, thermal insulation, impact absorbent, flexibility and light weight as a packaging material (Ecovative's Mushroom Materials, 2013). Applying the above mentioned materials to make a wall panel may be end up with combination of above mentioned properties. According to Ecovative's Mushroom Materials (2013) mycelium bonded material is a non toxic environmentally responsible material. So this combination may give a green building material that timely requisite to the world. The aim of this research paper is to test and develop partition wall panels using bamboo fibre reinforced mycelium bonded sawdust material.

2. PARTITION WALL AS A BUILDING ELEMENT

Partition wall is one of the non-structural building elements (Munir, 2012). It is a non load-bearing wall designed for the purpose of separating a space (Civil Engeneering Terms, 2011). The partition walls can be mainly classified as fixed and movable. Partition walls may be constructed of bricks, blocks, steel, concrete, clay blocks, Glass blocks and timber.

2.1. MATERIALS USED FOR PARTITION WALL PANELS

Partition wall panels are made of various kinds of materials. They can be categorized under natural materials and manmade materials. Some of the natural materials are clay, wood, and straw. The man made materials are glass, metal and concrete. Several man-made products are more or less synthetic. In current market there are many types of materials available for partition walls. These materials have been designed to fulfil the different kinds of user requirements such as price and durability. Different types of materials have their inherent properties. In this research an innovative building material for partition walls is based on mycelium.

2.2. MYCELIUM

Mycelium is the vegetative portion of the fungus (Arulnandy *et al*., 2008). Fungi kingdom consists of yeast, mildews and mushrooms (American Heritage Science Dictionary Online, 2005). Campbell (2008) declared that the parts of mushrooms can be identified separately as follows.

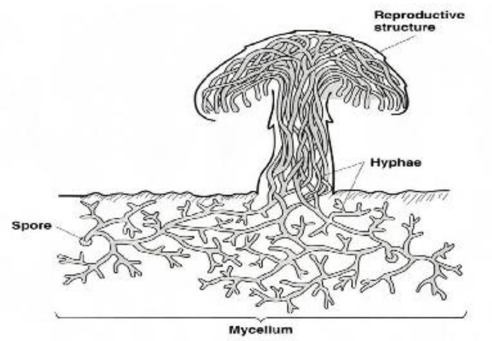


Figure 1: Sketch of Mushroom Indicating Hyphae and Mycelium
Source: Campbell (2008)

There are slender tubes named hyphae that spread like a network (Campbell, 2008). Stamets (2005) mentioned that the hyphae feed off the dead or living organisms. Through the hyphae a fungus absorbs nutrients from the environment (Stamets, 2005). According to the Stamets (2005) the hyphae have been linked as a network which is called as mycelium. The visible part of mycelium is named as mushrooms (American Heritage Science Dictionary Online, 2005).

2.3. USAGE OF MYCELIUM

Mycelium is significantly used in mushroom cultivation. Other than that Mycelium is linked with food industry, agricultural industry, and other manufacturing industries. It is also used to make ethanol and to make some medicine. Ecovative's Mushroom Materials (2013) emphasised that mycelium is used to prepare packing materials. Agricultural waste is a good media for growing mycelium.

3. RESEARCH METHODOLOGY

Research approaches are classified into two categories as quantitative and qualitative. Quantitative approach tends to relate to positivism and seek to collect actual data and to study relationships between facts. Experimental researches and survey researches come under quantitative approaches. This research can be categorized under experimental approach.

4. DESCRIPTION OF EXPERIMENTAL STUDY AREA

The process of preparing the panel was done by major four steps as preparing mixture, preparing mould to grow mycelium, getting mushroom cultivation, compressing and drying the panel. In this research a partition wall panel was prepared with saw dust which was bonded with mycelium. As this was a new concept there was not a predetermined process of preparation this kind of panel. It is necessary to design a process of preparing a bamboo fibre reinforced mycelium bonded sawdust panel. In the mushroom cultivation industry, the cultivators grow mushrooms using containers which are called as cultivation bags. When preparing these cultivation bags cultivators insert some kinds of germ which are called as mushroom seeds in normal context. After about four weeks the bags get full of white in colour due to growth of mycelium. This mycelium seems to be used as a binding material in construction work. By keeping this as a base concept the process of bamboo fibre reinforced mycelium bonded sawdust panel was derived. One kilogram of mixture consists of 1kg of Sawdust, 100g of Brown cover of rice (by-product of threshing), 20g of $CaCO_3$, 2g of $MgSO_4$, 100ml of Water and 2g of Mushroom seeds which are used to get optimum mushroom harvest.

4.1. PROCESS OF PREPARING MYCELIUM PANEL

Step 1 - Preparing mixture	
Mix the sawdust, brown cover rice, bamboo fibre, $CaCO_3$, $MgSO_4$ and water together.	Put the mixture in to the polythene bag and close by fixing a cotton wool prop
Keep the mixture bags for 24 hours at the room temperature.	Sterilize prepared bags by steaming.
Step 2 - Preparing mould to grow mycelium	
Prepare the moulds using hard board.	Sterilize the polythene bag by steaming.
Insert the polythene bag with the cotton cloth into the mould.	Insert the cotton cloth into the sterilized polythene bag as a cover of the panel.
Fill the bag with pre prepared saw dust mixture.	Compact saw dust mixture using a rod.
Put a ring around the mouth of the bag and close the mouth of the bag with cotton wool.	Put seeds of mushroom (germ) in to the bag.
Cover the ring with a paper.	Keep the mould in a dry, dark place for weeks to grow mycelium
Step 3 - Get mushroom cultivation	
Remove the cotton wool and cut the mouth of the bag.	Harvest mushroom cultivation for about 5 times within 7-10 days intervals.
Step 4 - Compressing and drying the panel	
Remove the mycelium grown panel from mould and place it in between above prepared steel plates.	Prepare two steel plates which can be tied each other by screws.
Compress the structure which contains mycelium panel by using mechanical compressor.	To keep the plates in same position after compression, tight the plates with screws.
Damage the polythene bag to remove moisture properly.	Keep this structure about 3 days which allows mycelium to make new bonds.
Put the structure into an oven or a dryer about 24 hours for drying.	Get the structure out from the oven and remove the plates.

Figure 2: Process of Preparing Mycelium Panel

4.2. FIXING PANEL TO THE STRUCTURE TO FORM A PARTITION WALL

After preparing bamboo fibre reinforced mycelium bonded sawdust panel the water proofing coat can be applied. Panels can be fixed to the wood or steel frames with help of the screws. Screws should be placed about every four inches. Two panels need to be fixed on either side allowing a space in between them. The space can be left empty or filled with heat insulation material. Jointed areas should be covered with water proofing tape and relevant finishes should be applied. As this bamboo fibre reinforced mycelium bonded sawdust panel mainly contain decaying ingredients, it is possible to use to prepare compost.

5. TEST DATA COLLECTION AND ANALYSIS

Data analysis focused on how the strength of the panel material varies according to the bamboo fibre content. In order to standardization the test results, it was necessary to use standard test methods. For this innovative material, a similar type of standard testing method had been used. After getting the test results calculations were done and figured out the values through graphs. To show the market validity which can be achieved by this panel, strength, cost and weight parameters were compared with existing panels.

5.1. STANDARDIZATION OF PROPERTIES OF THE PANEL

ASTM D 1037 (1978) contains general methods for evaluating the engineering and design properties of wood-base fibre and particle panel materials. As this bamboo fibre reinforced mycelium bonded sawdust panel contains wood-base particles (sawdust) and bamboo fibre this standard testing method can be applied.

5.2. TEST 1 - COMPRESSION STRENGTH PARALLEL TO SURFACE (ASTM D 1037)

Scope

The goal of the test 1 was to identify the strength of bamboo fibre reinforced mycelium bonded sawdust panel and how the strength of the panel material vary depend on the bamboo fibre content. Test panels were made of 1kg mixture of above ingredients and different quantities of bamboo fibre (10g, 20g, 30g and 40g). Using the above mentioned process panels were prepared 24mm thickness and let them to the full growth of the mycelium. After harvesting the mushrooms for 5 times, they are 50% compressed until they got 12mm thickness using compression machine. After that specimens were dried in an oven for 24 hours at 100℃ temperature.

Test Specimens

The laminated specimens were prepared by using two panels applying epoxy resin in between them. After curing the applied resin for 8 hours the panels were sawed in to the size of 1x4 inches with the smooth right angle surfaces. Fifteen test specimens were prepared as generally minimum three figures should be taken to find out the average figure of compressive strength of different bamboo fibre contented material. Other than that, test specimens of Gypsum and Medium-density fibreboard (MDF board) were also prepared.

Test Procedure

Test specimen was kept in the centre of the testing machine in a vertical plane. Clamps of 3 inches in length were fixed to the two long edges of the specimen to keep plane vertically without bending. The load was applied at a uniform rate of head travel of the testing machine at the speed of 0.020 inches per minute. This test was focused on calculating values of ultimate compressive strength.

Calculations

The test graphs show the results of the tests which indicate the changes in length of the specimen due to externally applied forces. In this research analysis ultimate compressive strength, specific strength and modulus of elasticity are calculated with help of the test results.

5.2.1. *FINDING THE ULTIMATE COMPRESSIVE STRENGTH OF MYCELIUM PANEL*

Table 1 shows the average ultimate compressive strength against the content of bamboo fibre in the test specimens. Three sets of sample specimens have been tested to find out the average ultimate compressive strength of bamboo fibre reinforced mycelium bonded sawdust panel.

Table 1: Ultimate Compressive Strength of Mycelium Panel Specimens

	Sample set-1		**Sample set-2**		**Sample set-3**		**Average**
Bamboo fibre content (g)	Maximum force applied (N)	Ultimate compressive strength (N/m^2)	Maximum force applied (N)	Ultimate compressive strength (N/m^2)	Maximum force applied (N)	Ultimate compressive strength (N/m^2)	Ultimate compressive strength (N/m^2)
0	1435	2224254	1405	2177754	1742.5	2700880	2367629.74
10	1910	2960506	1730	2681505	2045	3169756	2937255.87
20	2265	3510757	1740	2697005	2630	4076508	3428090.19
30	2265	3510757	2125	3293757	2627	4071858	3625457.25
40	1630	2526505	2120	3286007	2142	3320107	3044206.09

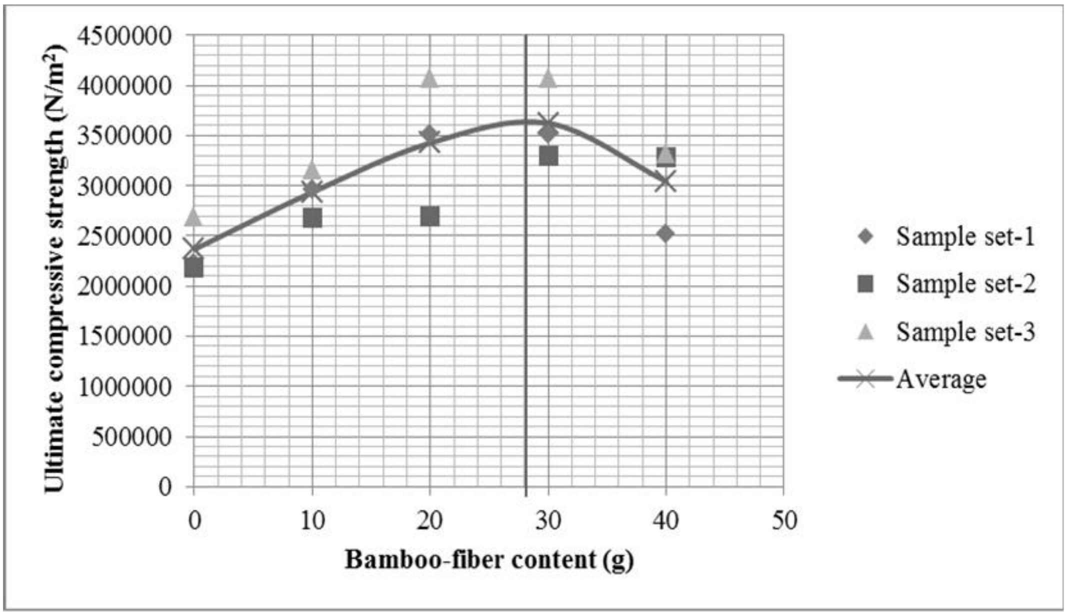


Figure 3: Ultimate Compressive Strength of Mycelium Panel Specimens

From Figure 3, it can be identified 28g is the optimum amount of bamboo fibre that can be used to 1kg of mixture in order to get the maximum compressive strength. So the fibre mixture ratio for this specific panel is 0.028 that gives the maximum strength.

5.2.2. *COMPARISON OF THE ULTIMATE COMPRESSIVE STRENGTH WITH OTHER MATERIALS*

The average ultimate compressive strengths of Gypsum and MDF test specimens were compared with the ultimate strength of bamboo fibre reinforced mycelium bonded sawdust panel which contains 28g of bamboo fibre in the 1kg of mixture as suggested in Figure 3.

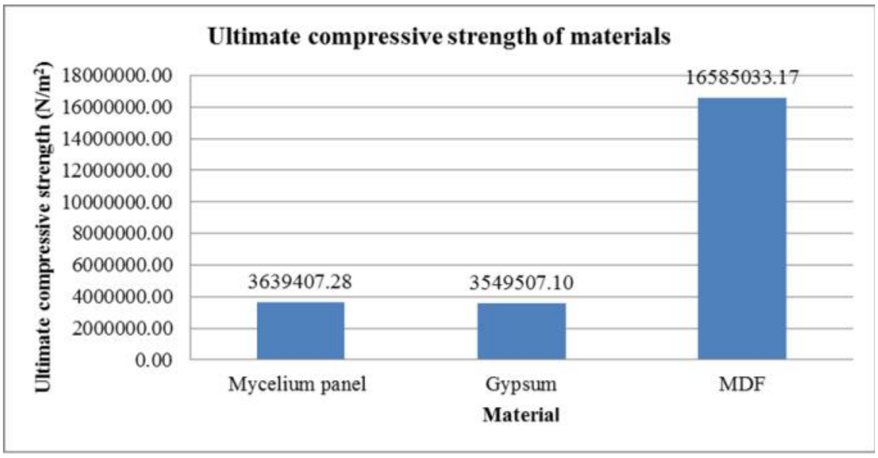


Figure 4: Ultimate Compressive Strength of Mycelium, Gypsum and MDF Panels

Figure 4 shows that ultimate compressive strength of the bamboo fibre reinforced mycelium bonded sawdust panel is higher than Gypsum panel and lower than MDF panel.

5.2.3. Comparing Yield Strength Combined with Density of Materials

Yield strength can be defined, in materials science, as the stress at which a material begins to plastically deform (Corrosionpedia, 2014). Before the yield point, the material will deform elastically and will return to its original shape when the applied stress is removed (Corrosionpedia, 2014). Yield strength is very important when designing a component and selecting a material.

Table 2: Yield Strength and Density of Mycelium, Gypsum and MDF Panels

Material	Yield Strength (N/m^2)	Yield Strength (MPa)	Density (kg/m^3)
Mycelium panel	3345230.25	3.35	732.59
Gypsum	3098253.10	3.10	755.63
MDF	15293520.00	15.29	787.82

5.2.4. Finding out the Specific Strength of Mycelium Panel

The specific strength of a material is the yield strength divided by its density (Peirson, 2005). The SI unit for specific strength is Pa/(kg/m3), or Nm/kg. Increasing of the specific strength, point out that the specific material has high strength while reducing the weight (Peirson, 2005).

Figure 5 shows the specific strength of bamboo fibre reinforced mycelium bonded sawdust panel, Gypsum panel and MDF panel.

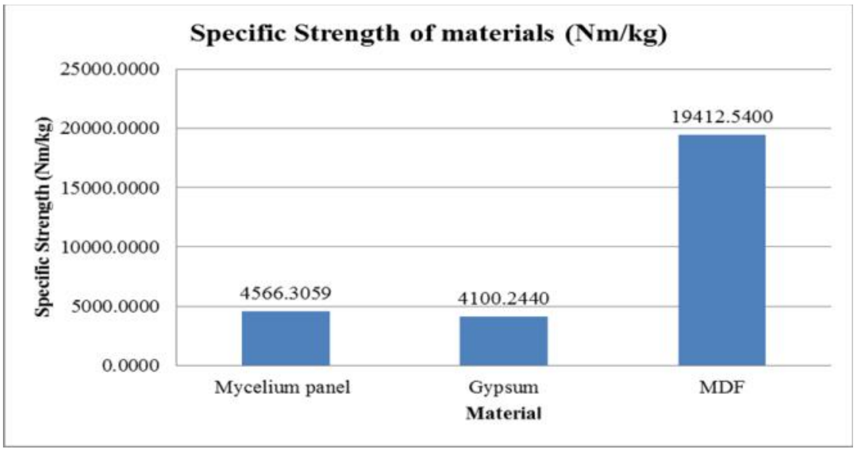


Figure 5: Specific Strength of Mycelium, Gypsum and MDF Panels

5.2.5. *MODULUS OF ELASTICITY OF MYCELIUM PANEL*

The modulus of elasticity or Young's modulus enables to calculate the change in the dimension of a specimen under tensile or compressive loads (Mcnaught and Wilkson, 1997). It predicts how much a material specimen extends under tension or shortens under compression. As the test 1 is a compression test stress-strain curve is drawn based on that results. Young's modulus is calculated from that stress-strain curve shown in Figure 6.

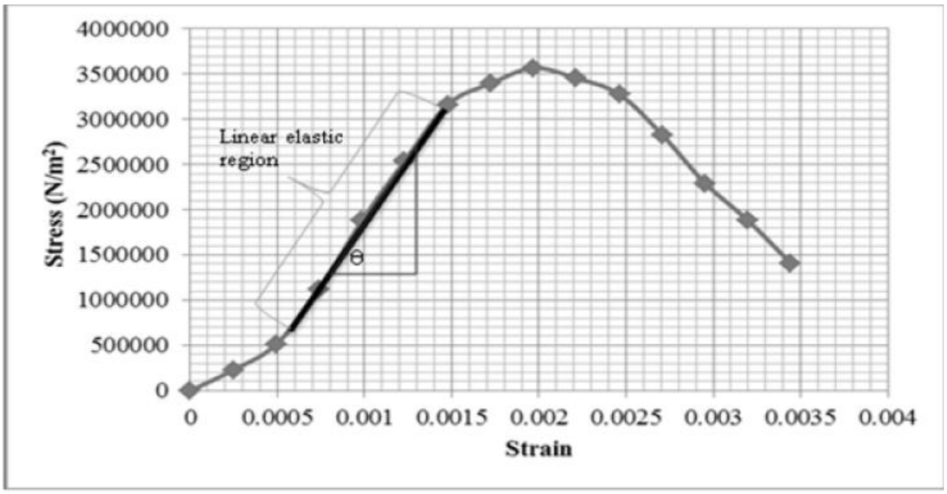


Figure 6: Stress-Stain Curve of Mycelium Panel

Young's modulus = 1400000/0.0005 = 2.8 x 10^9 N/m^2 = 2.800 GPa

Figure 6 is drawn for the bamboo fibre reinforced mycelium bonded sawdust panel which contain 30g of bamboo fibre inserted in 1kg of above prepared mixture. The optimum amount of bamboo fibre is 28g according to Figure 3. Figure 6 has been drawn for the panel which contains 30g bamboo fibre instead of the panel which contains 28g bamboo fibre as they are similar approximately. So, the Young's modulus of panel which contains 28g bamboo fibre is around 2.8 GPa.

5.2.6. *COMPARING YOUNG'S MODULUS OF MYCELIUM PANEL WITH OTHER MATERIALS*

The Young's modulus is in essence the stiffness of a material (Mitchell and Green, 1999). It is important when selecting material for construction work. The table shows the Young's modulus of bamboo fibre reinforced mycelium bonded sawdust panel, Gypsum panel and MDF panel. Figure 7 shows the Young's modulus of bamboo fibre reinforced mycelium bonded sawdust panel is in between Gypsum and MDF panels.

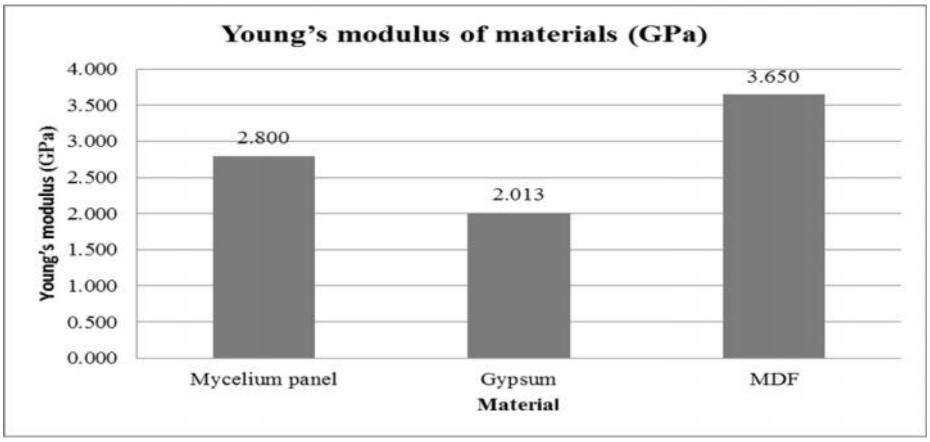


Figure 7: Young's Modulus of Mycelium, Gypsum and MDF Panels.

5.3. TEST 2 - WATER ABSORPTION (ASTM D 1037)

Scope

This test was done to decide water absorption level of bamboo fibre reinforced mycelium bonded sawdust panel and to compare it with the water absorption levels of the other panels. Test panels were prepared according to above procedure which was used in test 1. Other than that Gypsum and MDF panels were also used to compare the water absorption levels. This test was conducted according to the ASTM D 1037 (1978) standard.

Test Specimen

The test specimens were cut from bamboo fibre reinforced mycelium bonded sawdust panel in 6x6 inches (152x152 mm) in size according to ASTM D 1037 (1978) standard. The edges of the specimen should be smooth. Other than that, tests specimens were taken from Gypsum and MDF panels to compare the water absorption level of the materials.

Test Procedure

The different specimens were taken according to their content of different amounts of fibre in bamboo fibre reinforced mycelium bonded sawdust panel and test specimens of Gypsum and MDF panels. Then the specimens were weighed accurately to the nearest decimal before submerged them in water. The specimens were submerged horizontally under 1 inch of water. After 10 minutes submerged specimens were taken out and drained for 10 minutes and measured the weight of the specimens. The same specimens were submerged in the water again and measured the weight of each specimen after 10 minutes. The researcher repeated the same procedure and measured the weight of the specimens at specified time durations.

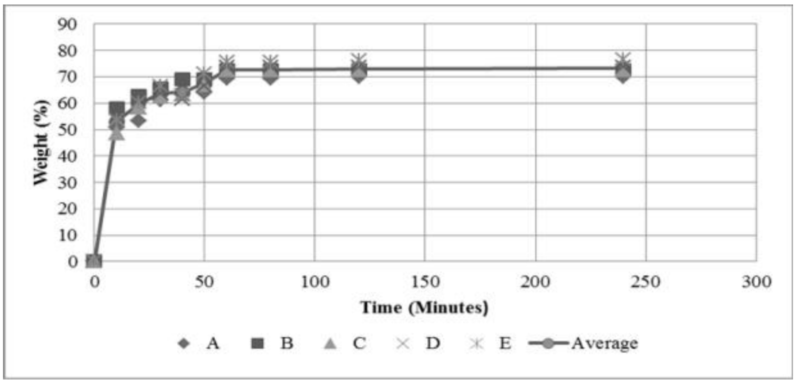
Calculations

Measuring the water absorption levels of test specimens according to the bamboo fibre content of the mycelium panel and comparing the average water absorption level of mycelium panel with the Gypsum and MDF were done under this calculation.

5.3.1. WATER ABSORPTION OF MYCELIUM PANEL

Figure 8 show the increase in weight percentages of the different specimens during the submersion. Initially the weight was increased but after about 60 minutes it becomes to a constant amount. Table 3 shows the weight of the different test specimens of bamboo fibre reinforced mycelium bonded sawdust panels. According to Table 7, the weight of the test specimens were shown in a percentage as it is required by ASTM D 1037 (1978) standard.

Though the bamboo fibre contents were different in each specimen, the water absorption pattern and the amount of water absorbed were nearly the same. According to these results it can be concluded that the water absorption of bamboo fibre reinforced mycelium bonded sawdust panel is not depend on bamboo fibre content. After 60 minutes, increment of the weight was stopped and the percentage of weight became to a constant value in all bamboo fibre reinforced mycelium bonded sawdust panel specimens.



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Fibre Content
A – 0 g
B – 10 g
C – 20 g
D – 30 g
E – 40 g

Figure 8: Young's Modulus of Mycelium, Gypsum and MDF Panels.

5.3.2. *COMPARISON OF WATER ABSORPTION OF MYCELIUM PANEL WITH OTHER MATERIALS*

The same test procedure was done for test specimens of Gypsum and MDF panels. The average amount of water absorption bamboo fibre reinforced mycelium bonded sawdust panel specimens was compared with the amount of water absorption of Gypsum and MDF panels. The amount of water absorption is shown by increasing weight of the panel specimens. To draw Figure 9, the weight percentages are considered instead of the weight of the panel specimens.

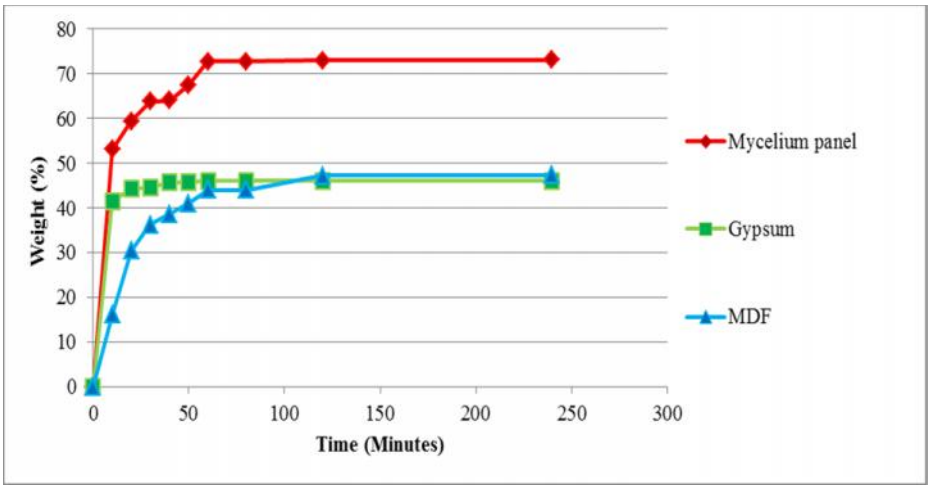


Figure 9: Water Absorption Percentage of Mycelium, Gypsum and MDF Panels.

According to the observations of the Figure 9 bamboo fibre reinforced mycelium bonded sawdust panel specimen took about 60 minutes to come to the maximum water absorbed level (73%). Gypsum and MDF specimens took 40 minutes and 120 minutes respectively to come to the maximum water absorbed levels (46% and 47%). After 120 minutes bamboo fibre reinforced mycelium bonded sawdust panel shows the highest water absorption level when compared to Gypsum and MDF panels. To minimise this issue water proof coating can be applied to the bamboo fibre reinforced mycelium bonded sawdust panel.

5.4. *WEIGHT COMPARISON OF MYCELIUM PANEL WITH OTHER MATERIALS*

The weights of 1ft^2 size specimens of bamboo fibre reinforced mycelium bonded sawdust panel contain different amounts of bamboo fibre. The average weight of Mycelium panel is compared with Gypsum and MDF panels shown in Figure 10.

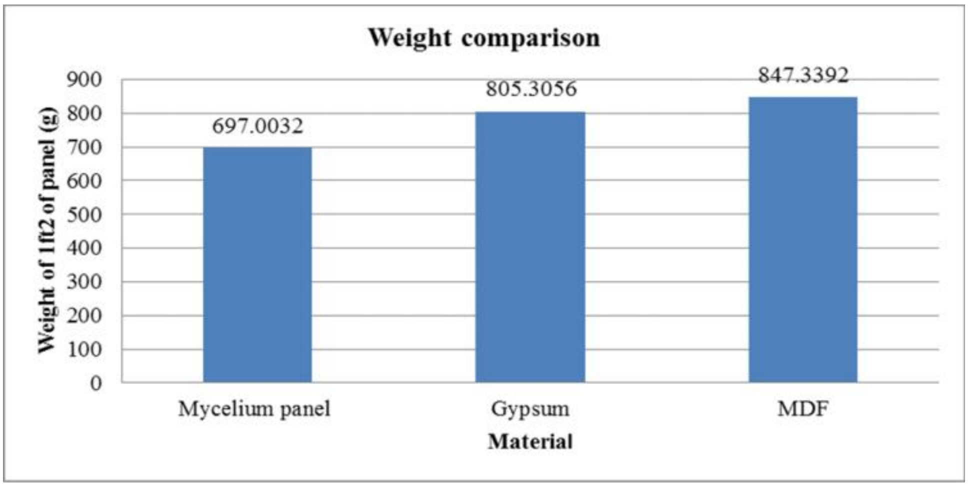


Figure 10: Weight of Mycelium, Gypsum and MDF Panels (1ft^2)

According to Figure 10 it can be identified that bamboo fibre reinforced mycelium bonded sawdust panel has the lowest weight when compared to Gypsum and MDF panels.

5.5. *COST COMPARISON OF MYCELIUM PANEL WITH OTHER MATERIALS*

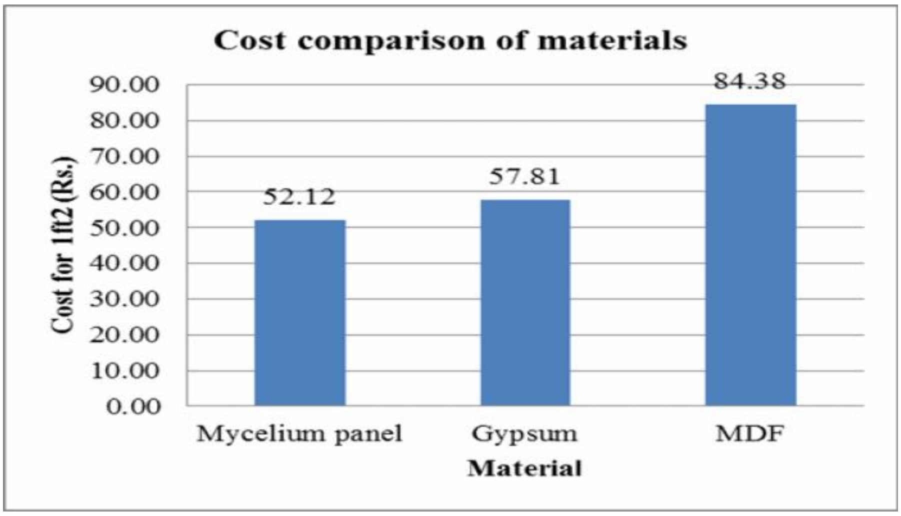


Figure 11: Cost Comparison of Mycelium, Gypsum and MDF Panels (1ft2)

According to Figure 11 it is clear that the cost of $1ft^2$ of bamboo fibre reinforced mycelium bonded sawdust panel is less than the cost of Gypsum and MDF panels. Through the experimental study it is found that, the bamboo fibre reinforced mycelium bonded sawdust material is suitable for partition wall panels when compare to other materials available in the market. Tests specimens were prepared according to the ASTM D 1037 (1978) standard. To find the standard of the properties of the material, compression strength parallel to surface and water absorption tests were done by using the test specimens of the bamboo fibre reinforced mycelium bonded sawdust material.

Compression strength test was done by varying the bamboo fibre content in the specimens. The optimum amount of bamboo fibre proportion, in order to get the maximum compressive strength was shown by the compressive strength test. Other than that ultimate compressive strength, yield strength, density, specific strength and Young's modulus were calculated too. The properties of bamboo fibre reinforced mycelium bonded sawdust material were compared with Gypsum and MDF panels to find the position in the market. The test data analysis showed the strength of the bamboo fibre reinforced mycelium bonded sawdust material was more than the strength of the Gypsum board and lower than the strength of MDF board. As the water absorption of bamboo fibre reinforced mycelium bonded sawdust material is higher than Gypsum board and MDF board, a water proofing is applied on the surface of the panel to overcome this weakness. When compared to Gypsum panels and MDF panels unit weight of bamboo fibre reinforced mycelium bonded sawdust panel is low, which is a significant property of partition wall.

The cost comparison shows the cost of bamboo fibre reinforced mycelium bonded sawdust panel is cheaper than the Gypsum panel and the MDF panel. The cost of bamboo fibre reinforced mycelium bonded sawdust panel can be reduced by using the new techniques.

Finally it can be concluded that the bamboo fibre reinforced mycelium bonded sawdust material is at a competitive level when it is compared with other partition wall panel materials in the market.

6. CONCLUSIONS

In building construction some materials that used in the past cannot be used today because of the resource limitations and economical impact. To overcome this problem researchers have done experiments to find new sources of material. Usually many people require good quality, low cost, energy efficient and environmental friendly materials which help to increase the adoptability and efficiency of the construction. Therefore bamboo fibre reinforced mycelium bonded sawdust composite material is found as an alternative building material which can be used for partition wall panel material. Mycelium is a part of part of the life cycle of the mushrooms. Mycelium has a vast usage in many industries, highly use in food industry. In this innovative material, mycelium is used as a glue to bind sawdust particles. As the mycelium is a living agent it grows on sawdust media. This panel making process was done by four major steps as preparing mixture, preparing mould to grow mycelium, getting mushroom cultivation and compressing and drying the panel. In the preparing process of this panel board, mushrooms are taken out as a by product which is widely use in food industry. The validity of this production is creating a link between construction industry and food industry. This material can be successfully used to build partition walls which fulfil the performance attributes that partition wall panels should have as one of the objectives of this research.

During this research of study bamboo fibre reinforced mycelium bonded sawdust material was tested for compression strength parallel to surface and water absorption to indicate the properties of material. As the results of the compression strength test it showed this material can bare $3.64x10^6$N load per square meter. When the average ultimate compressive strengths of Gypsum and MDF test specimens were compared with the ultimate strength of bamboo fibre reinforced mycelium bonded sawdust panel the result showed the compression strength of mycelium panel is slightly higher than Gypsum boards. It also indicated that the amount of bamboo fibre proportion that gives the higher strength is 28g of bamboo fibre per 1kg of prepared sawdust mixture. Other than that it has calculated yield strength 3.35 $x10^6N/m^2$, density 732.59kg/m^3, specific strength 4566.31Nm/Kg and Young's modulus 2.800 GPa. All these properties of new material were compared with Gypsum and MDF panels to find the position in the market. The result showed the stiffness of bamboo fibre reinforced mycelium bonded sawdust panel is in between Gypsum and MDF panels. When compare the specific strength of above mentioned materials it can be identified that bamboo fibre reinforced mycelium bonded sawdust panel has a value between Gypsum panel and MDF panel. In the water absorption test, the amount of water absorbed by this mycelium material was higher than when compared to other materials such as Gypsum and MDF. To minimize the amount of water absorption, water resistant coat can be applied. When compared to the other materials such as Gypsum and MDF the unit weight of bamboo fibre reinforced mycelium bonded sawdust material was the lowest. Light weight is an important property of partition walls. The estimated cost for 1ft^2 in size bamboo fibre reinforced mycelium bonded sawdust material is Rs.52.12. It is lower than the cost of Gypsum and MDF boards. As the low cost is a primary attribute that partition wall should have, the new material has fulfilled that requirement. From these values finally it can be concluded that bamboo fibre reinforced mycelium bonded sawdust panel remains competitive level with other materials that available in the current market.

7. REFERENCES

American Heritage Science Dictionary Online, 2005. *Fungus* [online]. Available from: http://www.thefreedictionary.com/fungus [Accessed 4 May 2014].

Arulnandy, V., Pathmashni, L. and Wijerathnam, R.S.W., 2008. Cultivation of Oster Mushroom on Sawdust. *Ceylon Journal of Science*, 37(2), 177-182.

ASTM International, 1978. *Annual Book of ASTM Standards.* West Conshohocken: ASTM International, ASTM D 1037.

Campbell, N.A., Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minotsky, P.V. and Jackson, R.B., 2008. *Biology.* 8th ed. California: Pearson Benjamin Cummings.

Civil Engineering Terms, 2011. *Purpose and Advantages of Partition Walls* [online]. Available from: http://www.civilengineeringterms.com/articles/what-are-partition-walls-purpose-advantages-of-partition-walls [Accessed 10 February 2014].

Corrosionpedia, 2014. *Yield Strength* [online]. Available from: http://www.corrosionpedia.com/definition/1193/yield-strength [Accessed 02 June 2014].

Ecovative's Mushroom Materials, 2013. Video [online]. Ecovative, 4 September. Available from: http://www.youtube.com/watch?v=P4YEvHUxIEE [Viewed 5 June 2014].

Ghavami, K., 2004. Bamboo as Reinforcement in Structural Concrete Elements. *Cement and Concrete Composites,* 27(1), 637-649. Marotta, T.W., 2005. *Basic Construction Materials.* 2nd ed. New Jersey: Pearson Education Inc.

Mcnaught, A.D. and Wilkson, A., 1997. *Compendium of Chemical Terminology*. 2nd ed. New York: Blackwell Scientific Publications.

Munir, M.R., 2012. *Non Structural Elements of a Building*. Power Point presentation, India.

Oyster Mushrooms Growing on Bamboo Raft, 2011. Video [online]. Jsunlau, 5 February. Available from: http://www.youtube.com/watch?v=bWPBjkVBUw4 [Accessd 5 April 2014].

Peirson, B., 2005. *Comparison of Specific Properties of Engineering Materials*. United States: Grand Valley State University.

Stamets, P., 2005. *Mycelium Running*. New York: Ten Speed Press.

The Power of Fungi, Mushrooms and Mycelium, 2012, Video [online]. Emerging Awareness, 24 May. Available from: http://www.youtube.com/watch? v=Ed71Wqb98vo [Viewed 3 May 2014].

A STUDY ON LIMITATIONS IN MATERIAL PROCUREMENT PRACTICE FOR CONSTRUCTION IN PUBLIC SECTOR

Vajira Edirisinghe* and Kavitha Kajendran
International College of Business & Technology, Sri Lanka

ABSTRACT

Due to the high accountability of public construction projects, several rules and regulations are being adopted in material procurement practice in public sector. These rules and regulations are practiced as per the framework provided by Procurement Guideline 2006 - Goods and Works and the Manual. Procurement Guideline 2006 is published by National Procurement Agency, Democratic Socialist Republic of Sri Lanka. This procurement guideline is applicable for any Procurement Action financed in whole or in part by Government of Sri Lanka or a Foreign Funding Agency. While these guidelines are being implemented, there are several limitations found by the practitioners.

Hence this research was aimed to study the practical issues in implementing procedures stated in the Procurement Guideline 2006 - Goods and Works and the Manual.

This study was done by collecting data from semi structured interviews with the industrial professionals who involve in public sector construction material procurement such as Architects, Contract Administrators, Procurement Officers, Project Managers, Quantity Surveyors, Contractors and Site Engineers.

Findings of this study revealed that there are limitations existing in public sector construction procurement practice and that create cost and time overrun and quality issues.

Keywords: *Material Procurement; Procurement Guideline 2006; Public Sector Construction.*

1. INTRODUCTION

Since construction projects and/or their outcomes heavily affect our modern society, the importance of a well-functioning construction industry is beyond doubt Cheung *et al.* (2001 cited Eriksson and Westerberg, 2011). In many countries the construction industry has, however, attracted criticism for inefficiencies in outcomes such as time and cost overruns, low productivity, poor quality, and inadequate customer satisfaction (Egan, 1998; SOU, 2000; Yasamis *et al.*, 2002; Chan *et al.*, 2003 cited Eriksson and Westerberg, 2011). Practitioners, researchers, and society at large have, therefore, called for a change in attitudes, behaviour, and procedures in order to increase the chances for project success and improved end products. The client is proposed to act as a change agent in such a change.

Colombo Page (2013) stated that Sri Lankan government has spent 5.9 percent of country's GDP as public investment in 2012 to provide major services despite a shortfall in the revenues, the Finance and Planning Ministry stated in its 2012 report. The government spent Rs. 444 billion in 2012 in comparison to Rs. 422 billion in 2011 in keeping with the commitment of maintaining annual public investment at 6 percent of GDP. According to the annual report of the Ministry of Finance for the year 2012, the government has been able to maintain public investment at an average of 6.2 percent of GDP during the period from 2005 to 2012 in comparison to 4.7 percent during 2002-2004 period.

The Sri Lankan government's interest in construction can be seen when referring to the national output and expenditure during year 2009-2013 as per the Central Bank of Sri Lanka Annual Report 2012.

* Corresponding Author: E-mail - vajira@icbtcampus.edu.lk

NATIONAL OUTPUT AND EXPENDITURE TABLE 1

Gross National Product by Industrial Origin at Current Prices of Major Economic Activities

Rs. million

Sector	2009	2010	2011	2012 (a)	2013 (b)
AGRICULTURE	**613,694**	**717,910**	**791,761**	**833,477**	**933,276**
1. Agriculture, Livestock and Forestry	**534,140**	**624,134**	**682,558**	**698,510**	**776,917**
1.1 Tea	64,476	72,314	67,896	75,201	88,540
1.2 Rubber	19,278	44,096	62,616	46,577	28,819
1.3 Coconut	52,585	60,439	72,439	65,551	77,639
1.4 Minor Export Crops	13,086	17,888	18,088	19,849	23,683
1.5 Paddy	102,776	113,883	95,807	95,029	124,524
1.6 Livestock	52,412	54,526	57,484	62,341	60,049
1.7 Other Food Crops	163,276	191,408	233,292	250,949	278,533
1.8 Plantation Development	11,169	11,878	13,009	15,117	15,580
1.9 Firewood and Forestry	35,861	33,720	36,010	40,089	47,839
1.10 Other Agricultural Crops	19,222	23,982	25,916	27,808	31,710
2. Fishing	**79,554**	**93,777**	**109,204**	**134,967**	**156,358**
INDUSTRY	**1,434,701**	**1,649,268**	**1,956,658**	**2,388,241**	**2,815,428**
3. Mining and Quarrying	**79,204**	**89,226**	**112,386**	**152,113**	**183,934**
4. Manufacturing	**875,562**	**1,009,003**	**1,191,579**	**1,354,897**	**1,536,090**
4.1 Processing (Tea, Rubber and Coconut)	38,354	45,707	53,384	62,619	69,624
4.2 Factory Industry	795,032	916,407	1,084,256	1,233,234	1,402,353
4.3 Cottage Industry	42,176	46,888	53,939	59,044	64,113
5. Electricity, Gas and Water	**113,687**	**127,625**	**141,474**	**168,959**	**200,722**
5.1 Electricity	96,321	106,029	115,854	137,558	165,140
5.2 Gas	12,224	15,616	19,003	22,874	24,865
5.3 Water	5,142	5,980	6,616	8,527	10,717
6. Construction	**366,248**	**423,414**	**511,220**	**712,272**	**894,683**
SERVICES	**2,786,897**	**3,236,926**	**3,794,893**	**4,356,837**	**4,925,166**
7. Wholesale and Retail Trade	**948,425**	**1,096,961**	**1,357,662**	**1,519,995**	**1,662,498**
7.1 Import Trade	282,929	341,798	468,713	509,664	512,987
7.2 Export Trade	138,950	157,590	186,904	203,739	224,238
7.3 Domestic Trade	526,546	597,573	702,046	806,592	925,273
8. Hotels and Restaurants	**24,988**	**33,213**	**44,254**	**57,943**	**69,105**
9. Transport and Communication	**599,934**	**709,400**	**818,386**	**988,688**	**1,162,669**
9.1 Transport	558,206	656,469	753,942	925,764	1,098,388
9.2 Cargo Handling-Ports and Civil Aviation	21,488	25,667	28,149	32,727	32,132
9.3 Post and Telecommunication	20,240	27,263	36,295	30,197	32,149
10. Banking, Insurance and Real Estate etc.	**499,304**	**597,540**	**709,316**	**841,369**	**946,044**
11. Ownership of Dwellings	**161,485**	**171,871**	**189,269**	**212,129**	**248,633**
12. Government Services	**445,543**	**500,547**	**532,455**	**570,976**	**651,395**
13. Private Services	**107,219**	**127,393**	**143,551**	**165,736**	**184,822**
GROSS DOMESTIC PRODUCT	**4,835,293**	**5,604,104**	**6,543,313**	**7,578,554**	**8,673,870**
Net Factor Income from Abroad	-55,795	-69,776	-72,041	-154,925	-234,910
GROSS NATIONAL PRODUCT	**4,779,498**	**5,534,327**	**6,471,272**	**7,423,629**	**8,438,960**

Source: Department of Census and Statistics

(a) Revised
(b) Provisional

Figure 1: Gross National Product by Industrial Origin at Current Prices of Major Economic Activities
Sourse: Department of Census and Statistics (2012)

According to Amarapathy (2013), tendering is probably the most critical and important 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.

The purpose of a procurement guideline is to inform the policies that govern in procurement of goods, works and services (other than consultant services) which is financed in whole or in part by the government or foreign agency for a project (Procurement Guidelines Goods and Works, 2006). The financial agreement governs the legal relationship between the parties involved in procurement and the guidelines are made applicable to procurement of goods and works for the project are governed by the biding documents and by the contracts signed.

It is very important that the public procurement function is discharged honestly, fairly and in a manner that secures best value for public money. Procurement Entity must be cost effective and efficient in the use of resources while upholding the highest standards of decency and reliability. Management in government departments and officers should ensure that there is an appropriate focus on good practice in purchasing and where there is a significant procurement division that procedures are in place to ensure compliance with all relevant guidelines.

Essential principles to be observed in conducting the procurement function include non-discrimination, equal treatment, transparency, mutual recognition, proportionality, freedom to provide service and freedom of establishment.

Sri Lanka for its public sector procurements has formulated a set of procedures in year 2006, named as Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006), published by the National Procurement Agency (NPA). Time to time there have been several supplements published to update the Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) to compete with the changing economy, technology and project types.

This study is based on the current procurement practices in the government sector when using the procedures laid down in the Procurement Guidelines - Goods and Works (2006) and by following above procedures what are the difficulties which the practitioners' face and suggestions based on the practical experiences.

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

- To study the Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) the supplements published by amending clauses in the Procurement Guidelines - Goods and Works (2006).
- To analyse the use of Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) and its issues in practical use.
- To provide suggestion based on practical scenarios of the procurement practitioners.

This paper has been structured under following topics respectively; Research gap, Limitations of the study, Detailed study on Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006), Research findings and analysis, Conclusion and Recommendations.

2. RESEARCH GAP EXPLORATION

Continuously changing world construction industry change with economy, technology, procedures, rules and responsibility is very important to have set of rules and regulations in order to maintain sustainable procurement action especially in Government sector.

For Sri Lankan government sector procurement, and Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) have been published in year 2006 to implement a good and honest procurement practice. This guideline is the main ruler in the government sector when it comes to procurement. Though there are supplements to the guideline and the manual is already published it is very important to do more studies on this. Only government sector is practicing these procedures especially when it comes to Government of Sri Lanka (GOSL) financed projects and some foreign funding agency projects which they agree to follow above guideline. Studies on the issues of practicing procurement using Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) are limited. Therefore this paper aims to identify the issues in using Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) to do government sector procurement.

3. LIMITATIONS OF THE STUDY

This study was narrowed down to the procedures in Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006). The research findings are unique to Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006). Also, the interview survey was done with the Contract Administrators, Chief Quantity Surveyors, Project Managers and Site Engineers has experience on the engineering projects material and service procurement.

4. PROCUREMENT GUIDELINES (GOODS & WORKS) 2006 AND MANUAL

4.1. BACKGROUND

According to the Guidelines on Government Tender Procedure-Revised Edition-1997, the "Guidelines on Government Tender Procedure -1996 was prepared based on the Public Finance Circular No.350 dated 22.11.1996, based on various comments and suggestions General Treasury has revised the guidelines and published as "Guidelines on Government Tender Procedure-Revised Edition-1997". Improvements to the revised guidelines were;

1. Inclusion of separate detailed chapters on matters such as evaluation of tenders, selection of consultants, donor funded projects, various methods for selection of tenderers etc,
2. Re-formatting the book combining all connected matters together for easy reference,
3. More details and explanations on procedures such as pre-qualification, bid opening, bid documents etc,
4. Improved formats, check list and flow charts.

According to the World Bank Country Procurement Assessment Report in June 2003 referred by Gunarathne (2008), issues were found in government procurement practiced during that time which was based on "Guidelines on the Government Tender Procedure-Revised Edition-1997". The issues were such as time consuming, permitted corrupt practices and also resulted in exceptionally delayed implementations.

The investigation and analysis of the data for World Bank Report was carried out with the full cooperation and participation of GOSL, the Asian Development Bank and the Japan Bank for International Cooperation and the National Construction Contractors Association of Sri Lanka. The senior government officials who participated with the World Bank in this report include officials from the Procurement Support Bureau under the Ministry of Finance and Planning, the Ceylon Electricity Board, State Pharmaceuticals Corporation, Ministry of Port Development and Shipping, National Water Supply and Drainage Board as well as the Deputy Auditor General and the Director General of the Bribery Commission amongst others.

In the short term, recommendations were made to strengthen the Procurement Support Bureau, simplifying the Review and Approval Process, revision of guidelines, development of standard tender and contract documents and the standardization of goods specifications. In the medium term, some of the recommendations were to create a Procurement Regulatory Agency, establish a Procurement Accreditation System and strengthen the Bribery Commission and the Auditor General's Department and to introduce a Code of Conduct. Recommendations on long term actions included enacting a Public Procurement Law if necessary and reviewing, revising and implementing a Procurement Training Master Plan.

Based on the above the NPA was formulated by a Cabinet Memorandum dated May 6th, 2004 by the former President Chandrika Kumaratunga, to eliminate these problems through proper monitoring of the tender process.

According to the Memorandum, the tasks and main objectives of the NPA are the following:

- To unify the government procurement system and bring standard application to all government institutions,
- To confirm better transparency and good governance in relation to government procurement awards,
- To confirm that the equal opportunity is given for all the eligible as well as interested parties in participating in public bidding,
- To confirm that best value for money in terms of price, quality and timely delivery will be achieved during government procurement,
- To confirm that the government procurement system is made efficient and simplified in order to promote development needs of the country,
- To put in place a monitoring system relating to selection of successful bidders and award of government tenders.

A Presidential Directive dated July 8, 2004 based on the May 2004 Cabinet Memorandum, specified that the government is interested in implementing the above changes in the government procurement.

Additionally, as per the Directive, the Board of Management of the NPA comprised of Chief Executive Officer/Chairman Daya Liyanage, Chandra Wickremasinge, Ananda Gunasekera, Dayanath Jayasuriya and Dayani De Silva.

The functions of the Board are to develop, apply and appraise policies and practices on procurement of goods and services and the disposal of goods and services, to develop a set of practical and more efficient guidelines for the procurement of goods and services and the disposal of goods and services, complying with the government policy, to identify and prioritize procurements and directly be in charge of such procurements and to develop a procedure pertaining to procurements and disposals and ensure that such procedure is obtained.

The NPA in 2006 published the Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) as solution and a governing procedure for the public procurement in Sri Lanka. The scope of the Guideline was to enhance the transparency of Government procurement process to minimize delays and to obtain financially the most advantageous and qualitatively the best services and supplies for the nation Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006). The intension of the Manual issuance is to provide assistance, advice, directions and procedures to be followed in carrying out procurement activities by the public sector Procurement Entities. The manual explains in more detail how specific aspects of procurement should be handled in consistent with the Guidelines-2006 (Procurement Manual, 2006).

4.2. PERIODICAL REVIEW

Periodical review has been done in regular intervals and revised supplements are issued (Refer Table 1) in order to achieve the present economical, contractual, designs and construction procedures.

Changes to the Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) come due to major changes may be required in response to changes in State laws, changers in economic policies, changers and developments in the industries and changes in organisation and management. Finally, those individuals who regularly use the guideline and the manual can provide valuable assistance in identifying needed updates and improvements (State of Delaware, 2002).

Table 1: Periodical Review Supplements Published by Finance Ministry

Supplement No	Date of Issue	Section Superseded
01	2006-09-08	2.7.4, 2.7.5, 2.7.6
02	2006-09-12	2.14.1
03	2006-09-13	Supplement - 02
04	2006-09-29	2.9.1
05	2006-09-29	Supplement - 03
06	2006-10-05	Supplement - 05
07	2006-10-11	Supplement - 01
08	2006-10-11	2.7.1
09	2007-05-04	5.3.5
10	2007-06-28	Supplement - 04
11	2007-06-28	Supplement - 06
12	2007-08-09	3.9.1
13	2007-10-03	1.5
14	2007-10-03	8.13.4
15	2007-11-01	5.4.14
16	2008-04-11	Supplement - 11
17	2010-04-30	7.9.5
18	2010-09-06	5.4.4, 5.4.6, 5.4.8
19	2010-09-06	9.3
20	2011-01-01	Supplement - 16
21	2012-02-23	2.14.1
22	2011-03-09	Supplement - 12
23	2011-05-12	2.3.7
Public Finance Circular 01/2012	2012-01-05	Supplement - 22
24	2012-03-21	8.3 & 8.4
25	2012-06-01	Supplement - 10
26	2012-08-08	3.4.5
27	2012-08-08	2.8.1
28	2014-07-04	Supplement – 20& 21

4.3. ADVANTAGES OF PROCUREMENT GUIDELINES (GOODS & WORKS) 2006 AND MANUAL

4.3.1 ACCEPTED BY ALL USERS

Since Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) is a standard document for public procurement, all users accept the rules and regulations of the guide and manual and follow it. When disputes come, both the parties, buyers and suppliers refer to the guide and manual and adhere it.

4.3.2. PREPARED REFERRING TO INDUSTRIAL PROFESSIONALS' RECOMMENDATIONS

The documents were prepared with the involvement of several professionals who are dealing with public procurement, therefore, their experiences have been included in the preparation of Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006).

4.3.3. PERIODICAL REVIEW IS DONE AND DOCUMENTS ARE UPDATED

The documents are reviewed in regular intervals addressing the practical issues faced in industry, changes in law and economic policies while using the documents. This reduces the disputes in the process and increases the accuracy of the document.

4.3.4. USERS BECOME CONVERSANT WITH THE DOCUMENTS

The users, who are following the documents regularly, become conversant with the rules and regulations. This reduces the misunderstandings within the parties, increases the efficiency and avoids unnecessary dispute arrivals.

4.4. DISADVANTAGES OF PROCUREMENT GUIDELINES (GOODS & WORKS) 2006 AND MANUAL

4.4.1. MAY NOT SUITABLE FOR ALL CIRCUMSTANCES

Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) might not be suitable for all circumstances. In some circumstances, it might create unnecessary delays and expenses while trying to practice the guidelines and manual strictly.

4.4.2. PROCEDURES HAVE TO BE REGULARLY UPDATED WITH THE PERIODICAL REVIEW

The users have to be regularly updating themselves with the new supplementary as they are published. Also, while applying new supplements, there might be confusions until it comes to use and in some situations, the total system might have to be revised with the new review.

5. METHODOLOGY

This section explains how the research data has been collected and analysis is done in order to achieve the research aim and objectives.

5.1. DATA COLLECTION

The data is collected through qualitative thematic analysis process using the facts collected in the literature review. The limitations in public procurement are collected through semi-structured interview with the industrial professionals who involve in public sector construction material procurement. Sample group was consisting of 11 Senior and Junior Architects who are working in several government institutes in design office and project offices, 9 Contract Administrators, 20 Procurement Officers, 11 Project Managers, 8 Quantity Surveyors, 10 Contractors and 15 Site Engineers from government institutes and Sri Lanka Army.

6. RESEARCH FINDINGS AND ANALYSIS

Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) is the base in public sector procurement. When there is a laid down rules and regulations it is very useful for the practitioners to do the procurement process efficiently and effectively.

The government of Sri Lanka in December 2007 officially informed to close down the NPA operations and its functions have reverted back to the Public Finance Division of the Treasury Department

(Gunarathne, 2008). Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) is still in practice for the procurement in government sector.

In the Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) the monitoring and controlling unit of all government procurement is stated as the NPA. Even in the supplements still the power is vested to NPA which is no more in practice.

6.1. Clause 2.1. National Procurement Agency (NPA), Clause 5.3.4. Eligibility of Bidders 5.3.12. and Option I – Bid Declaration

According to sub clause 2.1.1. the principal authority for formulating and effecting amendments to these Guidelines; issuance of manuals, SBDs, evaluation methodologies, standard contracts, and specifications and power to clarify any other issues was given to NPA.

According to sub clause 5.3.4. no contract shall be awarded to any contractor or supplier who is blacklisted by NPA and details are published in NPA website. According to sub clause 5.3.12. any complain must be reported immediately to the NPA.

Since NPA is no more functioning these clauses have to be amended, because the practitioners need a clear path to get information and guidance when they required in doing government sector procurement. Not only in the above clauses but also throughout the guideline it refers to NPA which is really important to amend.

6.2. Clause 5.3.13.(A) Option 2 - Bid Guarantee/Cash Deposit

According to the clause, procurement entity should take a 1% - 2% bid security for the contracts according to the bid value and in practice we can identify few contractors or suppliers will submit it with the quotation or the bidding document.

Mostly payment process is slow in the public sector and on the other hand according to the guideline it is being instructed to ask a bid bond.

6.3. Clause 9.8 E-Procurement

According to the clause electronic submission of bids were not allowed. Electronic procurement does not only automate and facilitate internal process, but it can also be extended across the entire supply chain, covering internal as well as enabling information sharing and integration (Schoenherr and Tummala, 2007).

7. Conclusions

Government tender procedure is the guideline which we used for government procurement before forming the NPA; which formed by a cabinet memorandum dated May 6, 2004 by the former President Chandrika Kumarathunga. The main reason to form the NPA was the WB report in June 2003 which shows the corrupted government procurement system and procedures which become a Major road block to implement development programmes since it involves a time consuming process which permits corrupt practices and also result in exceptionally delayed implementations (Natasha, 2008).

The NPA with the involvement of expertise published Procurement Guidelines - Goods and Works (2006) and Procurement Manual (2006) which is in use for the government procurement with 28 supplements. Still the practitioners have identified several issues in following the guideline.

8. Recommendations

To minimise above issues the study suggests to formulate a unit which will monitor access and provide assistance to do proper government procurement without corruptions, efficiency and effectively. In selecting contractors or suppliers to call tenders PE can make them in to groups to avoid bidders’ joint hand and bid for the tenders. Also the guideline must give provision to the PE to select and categorize the contractors and suppliers according to PE.

As e-Procurement includes new technologies and changes in traditional procurement approaches, the need to train staff in procurement practices and the use of e-Procurement tools are critical to the success of an e-Procurement initiative (WB, 2003). End-users can realize the immediate benefits of the e-Procurement system once they understand the operational functionalities (Consortium for Global Electronic Commerce [CGEC], 2002). This means that training should be given a high priority, alongside the need for public sector agencies to identify the skills required by all those engaged in procurement (ECOM, 2002).Finally it will save time and cost in the procurement process.

Public procurement is an important function of government (Thai, 2001). It has to satisfy requirements for goods, works, systems, and services in a timely manner. Furthermore, it has to meet the basic principles of good governance: transparency, accountability, and integrity (Wittig, 2003; Callender and Schapper, 2003). Another main principle of governments is to achieve value for money in procurement (Department of Finance [DOF], 2001).

9. REFERENCES

Amarapathy, A.M.P., 2013. *E-Tendering Framework for Public Construction Procurement in Sri Lanka.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Central Bank of Sri Lanka, 2013. *Annual Report 2012*. Colombo: Central Bank of Sri Lanka.

ColomboPage, 2013. *Sri Lanka Invests 5.9 Percent of GDP in Public Projects Last Year* [online]. Available from: http://www.colombo page.com/archive_13A/Jun18_1371 571382CH.php [Accessed 10 May 2014].

Department of Census and Statistics, 2012. *Survey of Construction Industries 2011*. Colombo, Sri Lanka.

Eriksson, P.E. and Westerberg, M., 2011. Effects of Cooperative Procurement Procedures on Construction Project Performance: A Conceptual Framework [online]. *International Journal of Project Management*, 29(1), 197-208. Available from: http://www.sciencedirect.com/science/article/pii/S02678631000 0050 [Accessed 10 May 2014].

Consortium for Global Electronic Commerce (CGEC) (2002, October). *Measuring and Improving Value of E-Procurement Initiatives*. Madison, WI: University of Wisconsin-Madison, Consortium for Global Electronic Commerce.

Department of Finance (DOF), (2001). *Strategy for the Implementation of e-Procurement in the Irish Public Sector*. Dublin, Ireland.

Gunarathne, N., 2008. National Procurement Agency Shut Down. *Sunday Times*, 04 May.

National Procurement Agency, 2006. *Procurement Manual* [online]. Colombo. Available from: http://www.treasury.gov.lk/depts/pfd/publications/ProcurementManual200620060817withSup8.pdf [Accessed 10 February 2014].

National Procurement Agency, 2006. *Procurement Guidelines: Goods and Works* [online]. Colombo. Available from: http://www.treasury.gov.lk/depts/publications/ProcurementGuidelines2006_amded12June.pdf [Accessed 10 February 2014].

State of Delaware, 2002. *Professional Services Procurement Manual*. State of Delaware.

Thai, K. and Grimm, R., 2000. Government Procurement: Past and Current Developments. *Journal of Public Budgeting, Accounting and Financial Management*, 12(2), 231–247.

Thai, K.V., 2001. Public Procurement Re-Examined [online]. *Journal of Public Procurement,* 1(1), 9-50. Available from: http://ippa.org/jopp/download/vol1/Thai.pdf [Accessed 10 May 2014].

Schoenherr, T. and Tummala, V.M.R., 2007. *Electronic Procurement: A Structured Literature Review and Directions for Future Research* [online], 1(1/2), 8-37. Available from: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2321482 [Accessed 11 May 2014].

University of Bath School of Management Working Paper Series. *School of Management Claverton Down , Bath, BA2 7AY. United Kingdom.*

A STUDY ON THE IMPACTS OF SCHEDULE COMPRESSION TECHNIQUES ON CONSTRUCTION PROJECTS IN SRI LANKA

Jallini Theivendran* and Sachie Gunatilake

Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction delay is considered to be one of the recurring problems in the construction industry and it has an adverse effect on project success in terms of time, cost and quality. Previous researchers have stressed the importance of early identification of construction delays and have suggested major delay-reducing remedies. Among this, 'Compressing Schedule' is a commonly used method to expedite the construction process. The consequences of schedule compression can be troublesome if productivity and quality of the project are sacrificed for the sake of remaining ahead of schedule. Therefore, this research was carried out to identify the impacts of schedule compression techniques on projects and suggest the strategies to be followed to overcome those negative impacts. A questionnaire survey and ten semi-structured interviews were conducted with Sri Lankan construction contractors. Altogether, 11 number of schedule compression techniques were found to be commonly used in the Sri Lankan context. Additional cost, quality issues, productivity problems, conflicts, coordination problems and abortive works were highlighted as the recurring negative impacts. In order to mitigate the impacts, the research has stressed and recommended strategies for each technique.

Keywords: *Construction Delay; Impacts; Mitigation Strategies; Schedule Compression.*

1. INTRODUCTION

Timely completion is important for all construction projects due to the monetary effects associated with a project's completion date. However, in practice it is challenging to achieve both time and cost aspects together (Bandara, 2012). According to Ssemwogerere (2011), construction delays can result in serious financial loses to contractors such as additional overhead costs incurred beyond the originally planned project costs. Furthermore, it affects clients with significant financial difficulties and economic risks such as loss of market opportunities and high interest rates. Subsequently reducing both construction projects' cost and time is a prime problem in today's market-driven economy. Achieving these two objectives simultaneously is desirable, but often it must rank according to the importance: one before the other (Mubarak, 2010).

If any construction delays are encountered where the contractor is culpable, then the contractor needs to take all necessary steps to accelerate the project (Firth, 2011). In order to meet these requirements, the normal construction work schedule needs to be compressed with the help of schedule compression. Schedule compression is an effort to reduce project durations for early delivery, or to recover the occurred delays (Mubarak, 2010). Schedule compression is usually performed in the construction industry by means of schedule compression techniques. Even though, past researchers in other countries have identified a variety of schedule compression techniques, very few studies can be found that compare impacts of each technique. In fact, the effects of each technique such as; imposing extra cost, risk of changes and rework are inherently different (Hazini *et al.*, 2013). Currently, there is inadequate knowledge for selecting schedule compression techniques to be employed and mitigating the potential negative outcomes of schedule compression techniques.

* Corresponding Author: E-mail - jallini@gmail.com

As stated by Hazini *et al.* (2013) determining the best technique in compressing project schedules has always been a challenge. In particular, some techniques will impact more on the project while others will impact little. Therefore, when it is needed to compress a construction schedule, the management team should select a method that minimises the impacts on the project. Therefore, the aim of this research is to identify the impacts of schedule compression techniques used in construction projects in Sri Lanka. The following sections in the paper discuss the concept of schedule compression and its necessity for construction projects, the techniques used to compress schedules in construction projects, the identified impacts associated with most commonly used compression techniques on construction projects as well as strategies to overcome these impacts.

2. LITERATURE REVIEW

2.1. WHAT IS SCHEDULE COMPRESSION?

When a construction project falls behind schedule, in order to reduce the damages and bring the project back on schedule, the contractor's rate of performing the remaining activities must be increased: i.e. in other words, stated that the contractor's individual schedule need to be compressed (Mansur, 2004). This compression process is referred to as "Schedule Compression" or "Accelerating a Project" (Mansur, 2004; Moselhi and Esfahan, 2013; Mubarak, 2010). According to Mansur *et al.*, (2003) schedule compression can be said of as the shortening, squeezing or compaction of the project schedule. Similarly, Thomas (2000) also define schedule compression as having more work to perform in the same period of time or having a shorter period of time to perform the same amount of work. According to Baker (1991), schedule compression may be carried out to serve one of three purposes: reducing total design-construct time from that considered normal; accelerating a schedule for owner convenience; and recovering lost time after falling behind schedule.

Contractor and client usually aim to establish the delicate balance between the overall cost of a project and its duration. As such, contractor may want to compress or accelerate the schedule of a construction project because of below reasons (Mubarak, 2010);

1. The contractor's normal finish date in the planned schedule does not meet the imposed finish date of the contract
2. After starting construction and completing a percentage of work, the contractor realizes that the project is behind schedule. Contractor needs to compress the remainder schedule to avoid finishing late get out of liquidated damages
3. In some cases, the contractor may have a benefit from early completion
4. When economy is well, starting another job earlier making more profit to the contractor. This time frame may require the contractor to compress the current project to free certain resources for the new project

Client, on the other hand, may order accelerated delivery of their under-construction projects because of (Esfahan, 2011);

1. Monetary considerations such as project financing e.g. to meet prescribed fiscal requirements,
2. To minimise the effects of change orders on project schedules,
3. To recover from delays for which they were the main source such as late delivery of material and/or equipment,
4. To minimise project total cost, because of stockholder pressure and
5. Simply because of their desire to complete the project earlier to address market demands in case of the development of a new product or service by the owners‟ organisation that needs to get to market as soon as possible due to rising loss-of-opportunity costs

In compressing a project, the critical work must be performed more quickly, and/or the sequences must be changed to allow more of the critical work to occur at the same time (Trauner *et al.*, 2009). Previous studies have identified several techniques of compressing a schedule, which provides a practical and usable catalogue of techniques used effectively for compressing a schedule in the construction industry. Figure 1 depicts the schedule compression techniques identified through the literature review categorised into five main groups.

Schedule compression can be fulfilling the urgent need. However, the consequences of schedule compression can be troublesome if productivity and quality of the project are sacrificed for the sake of remaining ahead of schedule (Nepal *et al.*, 2006). It is, therefore, important to counteract and/or minimise the effects of schedule compression on construction performance by adopting sound and proper strategies.

3. RESEARCH METHOD

The aim of this study was to carry out an in depth investigation on the impacts of the schedule compression techniques on construction projects. A questionnaire survey was carried out among the building construction contractors to identify the commonly used schedule compression techniques. The questionnaires were distributed to a random sample of 45 contractors, who are handling schedule compression in Sri Lankan construction industry. The respondents were required to indicate the usage of each technique based on a six point Likert scale. 38 responses were obtained resulting in a 84% response rate. One sample t-test was used for the questionnaire survey analysis and to find out the significant schedule compression techniques that are most commonly practiced in the industry.

In order to identify the impacts and mitigating strategies of the most commonly used compression techniques 10 semi structured interviews were conducted among Sri Lankan contractors. The interviews were digitally recorded (with permission), transcribed and was coded under the principles of qualitative content analysis.

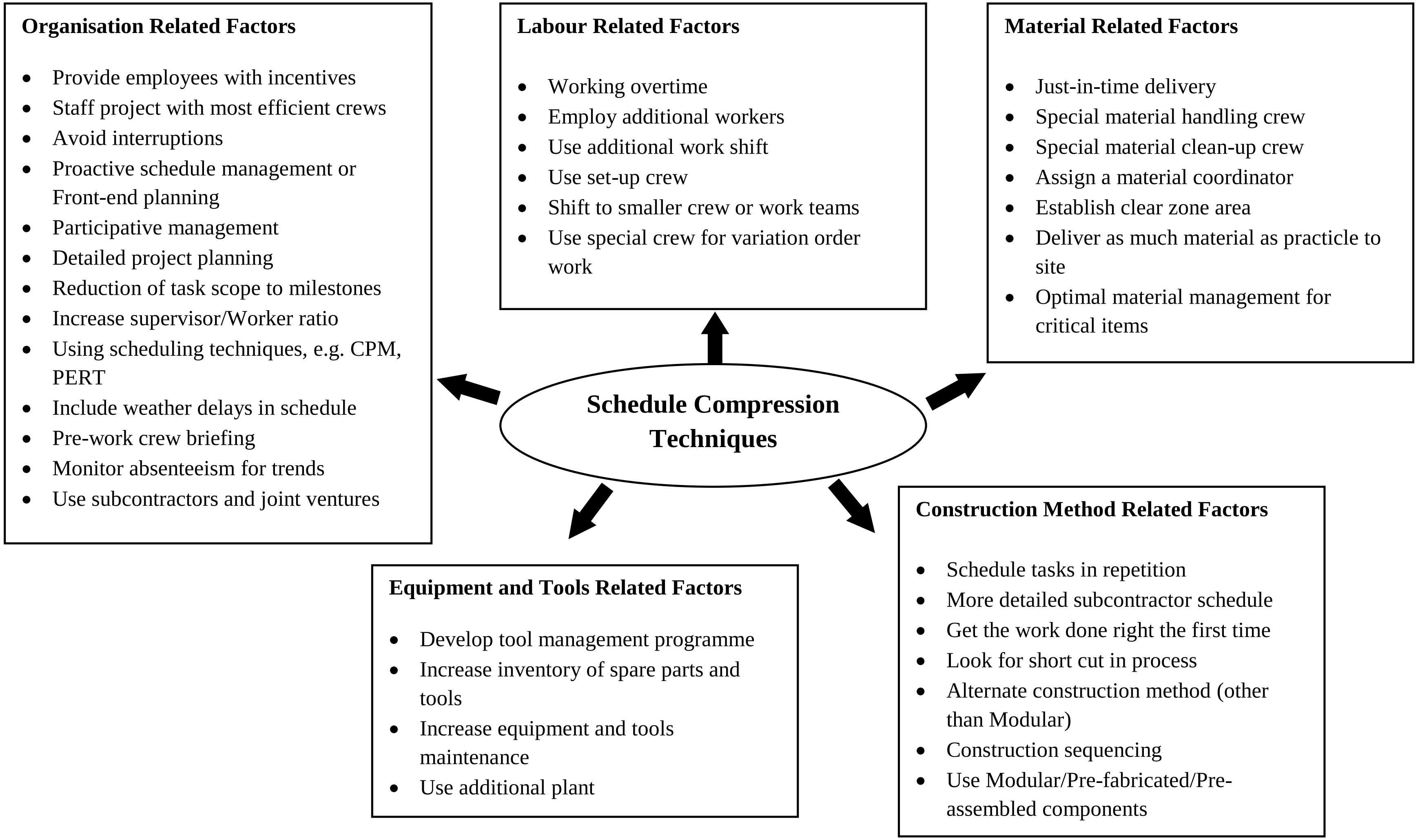


Figure 1: Schedule Compression Techniques

4. RESEARCH FINDINGS

Following sections discuss research findings of the study under the broad headings of commonly used schedule compression techniques in the Sri Lankan construction industry, the impacts of the commonly used schedule compression techniques and the strategies to mitigate the negative impacts of schedule compression techniques.

4.1. MOST COMMONLY USED SCHEDULE COMPRESSION TECHNIQUES IN SRI LANKAN CONTEXT

According to the t-test, the population mean µo was considered as "3" which is used as the test value for the analysis. The critical t value is 1.6871 when the degrees of freedom (tn-1) is 37 and the probability level (α) equals to 0.05. Based on the critical t-value, the null hypothesis is rejected when the tested t-value exceeds 1.6871. In order to find the significant items, the techniques which has got the greater t-value than critical t-value was selected. That means, the null hypothesis is rejected and the alternative hypothesis is accepted. Based on the rejection, the significant schedule compression techniques were identified and ranked as given in Table 1.

Table 1: Identification of Significant Schedule Compression Techniques

Item No.	Schedule Compression Technique	t value	Sig. (2-tailed)/ P-value	Mean	Rank	Std. Deviation
	Labour Related Factors					
L1	Working overtime	4.603	0.000	3.842	2	1.128
L2	Employ additional workers	2.758	0.009	3.474	7	1.059
	Material Related Factors					
M1	Optimal material management for critical items	2.546	0.015	3.447	8	1.083
	Construction Method Related Factors					
CM1	More detailed subcontractor schedule	3.656	0.001	3.579	4	0.976
CM2	Construction sequencing	3.221	0.003	3.553	5	1.058
	Equipment and Tools Related Factors					
	-					
	Organisation Related Factors					
O1	Provide employees with incentives	1.720	0.094	3.290	11	1.037
O2	Staff project with most efficient crews	3.239	0.003	3.500	6	0.952
O3	Participative management	2.309	0.027	3.395	9	1.054
O4	Detailed project planning	7.544	0.000	4.079	1	0.882
O5	Increase supervisor/Worker ratio	2.086	0.044	3.316	10	0.933
O6	Use subcontractors and joint ventures	3.774	0.001	3.684	3	1.118

As indicated in Table 1, out of the techniques identified through the literature review (see Figure 1), 11 were found to be commonly used in the Sri Lankan context. These include two labour related, one material related, two construction method related and six organisation related factors. No techniques emerged as significant from the equipment and tools related category shown in Figure 1. These techniques are explained in detail in the following section along with their impacts on projects.

4.2. THE IMPACTS OF THE MOST COMMONLY USED SCHEDULE COMPRESSION TECHNIQUES

Through the qualitative content analysis and cognitive mapping, the problems and impacts associated with these 11 most commonly used schedule compression techniques were identified. These are discussed in detail under each technique below.

Detailed Project Planning

When contractor follows the initial detailed plan, the disruptions will lead to delays in construction projects. According to the respondents, delay in material delivery, restrictions in obtaining utility connections, major variation, unforeseen situation, non-availability of resources subcontractors issues create disruptions to the project. Hence this situation may require the contractor to redo the scheduling process for the rest of the project. The idea behind this planning is looking into the remaining portion of the project as a new project and planning for this portion to meet the original schedule. Due to these issues detailed project planning is subjected to generate negative impacts to the project. If the new schedule is prepared based on the previous data, it will not match the future events. Preparation of a new schedule creates practical issues and quality problems. For instance, in order to cope up with the schedule the contractor may assign less skilled workers to the project without any evaluation. As a result of poor performance of unskilled workers, quality issues may be created in the project. Further it incurs additional cost to the contractor.

Working Overtime

Workers are instructed to work on overtime during the construction period to increase the rate of progress and minimise the delays. However the worker’s additional overtime period impacts the project negatively when the overtime is extended to long term. Based on the responses, the negative effects are misuse the overtime, increase in cost, loss of productivity, health and safety problems and lower quality.

Use Subcontractors and Joint Ventures

Usage of subcontractors and joint ventures is one of the schedule compression techniques which is used for the purpose of fair sharing of responsibilities and risks among the project contributors while reducing the workload of main contractor. Even though it is beneficial for the main contractor due to increased resources, there are several negative effects as well. Employing subcontractors and joint ventures is a different issue. Though the work has been subcontracted it should be supervised properly as the workers may not have the adequate skill and also it will help to avoid conflicts between subcontractors. Further, the respondent suggested that contractor need to arrange advance payment for the subcontractors. Therefore the contractor should be capable in financial wise. In addition to the advance payment, the contractor has to bear some administrative cost to monitor or supervise the subcontracting work. Moreover the contractor is in a position to arrange additional facilities for the subcontractor such as accommodation to workers.

At the same time, as one respondent stated “the performance of the subcontractor is questionable all the time”. Sometimes the subcontractors who have given the performance bond may not work properly. In such occasions, the subcontract may need to be terminated or replaced by another subcontractor. Managing subcontractors is also a difficult task. As pointed out by a respondent, every subcontractor has their own working style. Most of the time it deviates from the main contractor’s sequence of work leading to coordination problems between main contractor and subcontractor.

More Detailed Subcontractor Schedule

Subcontractors’ works are detailed and scheduled in all construction project to achieve the better coordination among subcontractors. Scheduling subcontractors' works help to maintain a baseline for all the subcontractor activities and avoid delays in main contractor’s works. Preparation of a subcontractor schedule is a difficult task for the main contractor. As the greater amount of subcontractors, the coordination of all individual subcontractor schedules to the main contractor schedule is a challenging task. Moreover, the subcontractors generally directly coordinate with the main contractor rather than among them. Accordingly, if the main contractor needs to complete a unit of work, he needs to face a situation of lesser coordination among subcontractors.

Moreover, the existing subcontractor schedule will get affected when additional subcontractors are coming into project. Due to the urgency the main contractor put additional subcontractors to the project without any evaluation. Hence it will create different skill levels between existing workers and new workers. Due to the detailing of subcontractor schedule, the one work will be divided among subcontractors in order to expedite the work. For an example; if two subcontractors are asked to work on one concrete slab, it will create conflicts between subcontractors so as to cover up higher amount of work than the other person in order to receive a higher payment.

Construction Sequencing

Due to the disruptions to the project, the existing sequence cannot be followed in construction projects. Therefore, the contractor in a position to shifts and shuffle certain activities to cover up the schedule compression period. Due to this re-sequencing, the contractor faces the negative impacts which are risk of further delays, abortive works, resource idling and increase in cost. For instance, respondents noted that re-sequencing will delay the pre-planned activities and increase the project overheads for the additional facilities like storage.

Staff Project with Most Efficient Crews

Employees with higher efficiency level are always required for the project. Though it is beneficial to speed up the work but finding out an efficient crew is a challenging thing. Under the schedule compression period, it is impractical to evaluate the efficiency level of each worker. At the same time, there is no gauge to measure the efficiency. Some negative impacts of this technique were identified such as; retention of efficient workers, lack of performance capacity and cost. In addition, assigning a large amount of work for the efficient crew will create a situation of losing the efficient crew owing to physical and mental stress.

Employ Additional Workers

Employing additional workers is another schedule compression technique which is used to increase the number of workers on the job to finish the work in a shorter time period. Contractor can use this technique freely when market situations and budget permits. Based on the responses, the impacts are; quality issues, additional facilities, labour idling, conflicts between workers, not giving expected outcome, difficulties in supervision and increases in cost.

Optimal Material Management for Critical Items

Certain items of construction material should be designated as critical to assure their optimal management during delays in order to avoid wastages. For that, there should be a certain management control in the stores. Then the contractor needs to follow a certain procedure when ordering materials to the site. The optimal material management plan needs to be flexible so as to be adjusted based on site requirements. Otherwise, it can result in delays in ordering and material delivery to the site. If there is any delay in material delivery it will create an idling situation at the site. If the time is short, then the contractor may need to arrange more suppliers to procure materials resulting in increased costs.

Participative Management

Participative management has identified that no manager can be a fountain of all knowledge. It insists to tap the ideas of those closest to the work; i.e. the individual worker as they may have the best idea of all for performing the work in the shortest and most cost-effective time. According to the respondents, training programmes for junior staff, weekly or monthly management level meetings and senior management site visits are some of the techniques used to practice participative management. Some of the negative impacts that are resulted due to this are conflicts between parties, multi-point responsibility and indirect increase time.

Increase Supervisor to Worker Ratio

Supervisor to worker ratios should be increased with changes in the work force or with changes in the criticality or complexity of the work so as to maintain quality and sufficient control of the work force. The increase in ratio creates negative impacts as increase in cost and division in responsibility.

Provide Employees with Incentives

Incentives have proven to motivate stronger performance when fairly administered. However it impacts the project performance negatively when incentive scheme was not properly implemented resulting in demotivation of employees in other projects and increase in cost.

4.3. STRATEGIES TO MITIGATE THE IMPACTS OF SCHEDULE COMPRESSION TECHNIQUES

The analysis of interview data, further revealed strategies that could be used to mitigate the impacts of the aforementioned negative impacts of the schedule compression techniques (refer Table 2).

In order to avoid the impacts of detailed project planning, an advanced planning should be adhered by the contractor. Such as monthly meetings at the head office and weekly progress review meetings at the site. Due to this top management, project managers, procurement people and other site estimators can be involved to the meeting. From this everyone can discuss about the review of the project, resource availability and availability of subcontractors for the future work. Moreover the impacts can be reduced by proper change in sequence of activities or change in the specification with the approval.

When considering the impacts of working overtime, the target scheme will be a good solution to overcome the negative effects. By giving specific targets based on the programme, workers will get motivated and worked toward the targets. Furthermore the impacts can be reduced by limiting the overtime period maximum up to 5 hours. Additionally shift work can be used put another gang for night works. Therefore always a fresh team will work for the night time. All of these can be possible when there is a proper super supervision

The subcontractors and joint ventures issues can be avoided by the selection of known familiar subcontractor. Further the selection of two subcontractors at a time will create a virtual competition between them. From this arrangement the works can be completed quickly and the absence of one subcontractor will not affect the work. For the more detailed subcontractor schedule, proper coordination and clear demarcation is required. it will be helped to avoid the conflict situation in between subcontractors. Likewise a proper management plan can overcome the impacts of construction sequencing.

The impacts of staff project with most efficient crews can be overcome by introduction of new technologies. Involvement of new technology decreases the requirement of efficient workers. In addition to that recruitment of an additional project manager to the site for a particular period will overcome negative effects. Most important thing is he should be an in house project manager. Otherwise it will increase the cost. With a proper management plan and division of scope will reduce the impacts from employ additional workers to the site.

Table 2: Strategies to Mitigate the Impacts of Schedule Compression Techniques

	Most Commonly Used Schedule Compression Techniques	Effective Strategies
1	Detailed project planning	• Advance planning • Change the sequence of activities • Change the specification with the approval of consultant
2	Working overtime	• Target incentives • Proper plan and supervision • Shift work • Policy on maximum overtime hours
3	Use subcontractors and joint ventures	• Find out the history of subcontractor • Proper negotiation • Familiarity with subcontractor • Assign individual targets and incentives • Select two Subcontractors at a time to create virtual competition

	Most Commonly Used Schedule Compression Techniques	Effective Strategies
4	More detailed subcontractor schedule	• Adhere to main contractors schedule • Proper coordination and supervision • Clear demarcation
5	Construction sequencing	• Maintain a proper plan
6	Staff project with most efficient crews	• Mix the best crews with non performing crews • Assign another project manager • Use of new technologies
7	Employ additional workers	• Employ experienced and skilled people • Proper planning • Divide the scope of work
8	Optimal material management for critical items	• Earlier storage • Increase staff in material management • Adhere to certain supplier
9	Participative management	• Participative management with single point responsibility • Control the micro groups
10	Increase supervisor/Worker ratio	• Bring best supervisors to the project • Provide incentives and scope enhancement to existing supervisors
11	Provide employees with incentives	• Provide food • Provide incentives with targets

Impacts of optimal material management for critical items will be decreased by proactive storage. Further the involvement of knowledgeable, enthusiastic, capable and committed material staff will overcome the impacts. Proper knowledge and control on participative management reduces the impacts eventually. The effects of increase in supervisor to worker ratio will be overcome by target and incentives scheme. Moreover, the involvement of masters in supervisor for a certain period will reduce the cost impacts. Instead of providing monetary incentives to employees, the arrangement of giving foods to the site people will motivated them.

5. CONCLUSIONS

Schedule compression is one of the delay minimising methods practiced by the Sri Lankan construction industry. The aim of this research was to identify the impacts of schedule compression techniques used in construction projects. Altogether, 11 techniques were identified as most commonly used in the Sri Lankan context. Even though the construction industry practitioners use the schedule compression techniques to mimimise the delays in construction projects, the techniques on the other hand deliver some negative impacts to the projects. Hence, the commonly practicing techniques have failed to provide an effective delay minimising approach to the Sri Lankan contractors.

The outcomes of the research revealed negative impacts of the schedule compression techniques in the Sri Lankan construction industry. In particular, additional cost, quality issues, productivity problems, conflicts, coordination problems and abortive works were highlighted as the recurring negative impacts. In order to mitigate the impacts, the research has stressed and recommended the strategies for each technique.

6. REFERENCES

Baker, R.D., 1991. *Time-cost relationship in construction.* Thesis (MSc), University of Florida.

Bandara, W.R., 2012. *Crashing applicaton for time cost trade-off in building projects: A case study.* Thesis (BSc). University of Moratuwa.

Esfahan, N., 2011. *Project schedule compression considering multi-objective decision environment.* Thesis (MSc), Concordia University.

Firth, D.S., 2011. *Acceleration* [online]. Available from: http://www.derekfirth.com/uploads/7/7/9/1/7791851/2011_scc_paper_on_acceleration_october_2011.pdf [Accessed 18 April 2014].

Hazini, K., Dehghan, R. and Ruwanpura, J., 2013. A heuristic method to determine optimum degree of activity accelerating and overlapping in schedule compression. *Canadian Journal of Civil Engineering,* 40(4), 382-391.

Mansur, S.A., 2004. *Productivity assessment and schedule compression index for construction project planning.* Thesis (PhD), Universiti Teknologi Malaysia.

Mansur, S.A., Putra, C.W. and Mohamed, A.H., 2003. Productivity assessment and schedule compression index (PASCI) for project planning. In: *5th Asia Pacific Structural Engineering and Construction Conference,* Johor Bahru, Malaysia, 133-147.

Moselhi, O., and Esfahan, N.R., 2013. Project schedule compression: a multi-objective methodology. *Construction Innovation: Information, Process, Management,* 13(4), 374-393.

Mubarak, S., 2010. *Construction project scheduling and control* [online]. Avaailanle from http://www.unimasr.net/ums/upload/files/2011/Mar/UniMasr.com_b22f24e9f6a269f417444453d5ff82d57. pdf [Accessed 10 March 2014].

Nepal, M.P., Park, M., and Son, B., 2006. Effects of schedule pressure on construction performance. *Journal of Construction Engineering and Management,* 132(2), 182-188.

Ssemwogerere, K., 2011. A case for acceleration rather than extension of time on construction projects in Uganda. In: *2nd International Conference on Construction and Project Management*, 192-195.

Thomas, H.R., 2000. Schedule acceleration, work flow, and labour productivity. *Journal of Construction Engineering and Management, 126* (4), 261-267.

Trauner, T.J., Manginelli, W.A., Lowe, J.S., Nagata, M.F. and Furniss, B.J., 2009. *Construction delays-understanding them clearly, analyzing them correctly.* 2nd ed. California: Elsevier Inc.

A SYSTEM FOR IMPLEMENTING RESETTLEMENT HOUSING PROJECTS IN THE NORTHERN PROVINCE OF SRI LANKA

Ahalya Luxman*
Ministry of Housing and Samurdhi, Sethsiripaya, Battaramulla, Sri Lanka

B.A.K.S. Perera
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

With the end of the armed conflict in May 2009, the resettlement activities of the Government of Sri Lanka (GOSL) commenced in November 2009 in the Northern Province (NP). Non-Governmental Organisations (NGOs) and International Non-Governmental Organisations (INGOs) and foreign governments were involved in providing transitional shelters, repairing damaged houses and constructing new houses. The number of houses initially planned to be constructed could not be completed on schedule. According to media reports, there have been issues during Before Construction Period (BCP) and During Construction Period (DCP). Thus it has become necessary to propose a framework to identify a suitable system for implementing housing projects in these areas.

This study develops an approach to solve identified problems using a mixed research approach. The Relative Important Index and Spearman Rank Correlation were used for the data analysis.

A suitable system consisting of two frameworks was then developed to make the beneficiaries aware of the importance of keeping land documents safely to prove their ownership of the land and also on the proper utilization of funds they receive through grants. The Implementing Partners also need to conduct awareness programmes on these aspects. Authorities need to issue land documents and resolve common issues related to land ownership and the Banks need to serve the resettled people well and open new branches and mobile banking services in the areas.

Keywords: *Before Construction Period; During Construction Period; Framework; Housing Projects; Resettlement.*

1. INTRODUCTION

1.1. BACKGROUND

In Sri Lanka there is a long history of people getting voluntarily or involuntarily displaced (Centre for Poverty Analysis (CEPA), 2009).These Internally Displaced Persons (IDPs) who live in camps faced many difficulties (International Medical Health Organisation, 2010). In November 2009, the GOSL initiated an accelerated resettlement programme in the Northern Province to enable people to return to their homes or to their districts of origin at least. (United Nations Human settlement programme (UN Habitat, 2010).

According to the 2012 report of the Ministry of Resettlement Performance and Progress, as at 2012.08.31 there were 93,631 houses in the Northern Province that had got fully damaged due to the conflict (Ministry of Resettlement, 2013). The GOSL had to seek assistance from Semi Government Organisations, INGOs, local NGOs, UN Agencies and countries like India, Australia, Pakistan and Saudi Arabia etc. to help families to reconstruct their damaged houses. Some housing programmes such as the World Bank funded North East Housing Reconstruction Programme (NEHRP) were initiated even before the war ended.

* Corresponding Author: E-mail - ahalya.lk@gmail.com

1.2. AIM AND OBJECTIVES

The aim of this study is to identify a suitable system for implementing housing projects when resettling displaced persons in the Northern Province and had the following as its main objectives:

- Identification of significant problems
- Identification of the causes of those significant problems
- Identification of the role of each party involved in the abovementioned projects in solving these problems

Proposing frameworks to identify a suitable system for implementing these housing projects in BCP and DCP.

2. LITERATURE REVIEW

2.1. PROBLEMS RELATED TO DISPLACEMENTS IN SRI LANKA

In Sri Lanka, most of the displacements occurred internally and Thiyagaraja (2012) stated that they are a major obstacle for development. There were overcrowding, spread of communicable diseases, insufficient medical care, shortage of clean drinking water, lack of freedom of movement, separation from family members and psycho social problems etc. in the Menik Farm Relief Villages in Vavuniya (International Medical Health Organisation, 2010).

2.2. RESETTLEMENT AND GOVERNMENT INSTITUTIONS

Thiyagaraja (2012) stated that Sri Lanka is the first South Asian country to incorporate fully into its state policy the guiding principles of displacement. The displaced people have to be resettled either in their original places of living or in alternative places provided they are agreeable. Thiyagaraja (2012) stated that the Ministry of Relief, Rehabilitation and Reconciliation was set up in July 1999 to ensure that basic needs of people affected by conflict are met and to rebuild their productive livelihoods.

The Ministry of Resettlement was established during the latter part of 2005 mainly to resettle the displaced people of the Northern and the Eastern Provinces in coordination with the World Bank, UNHCR, United Nations International Children's Emergency Fund, NGOs and INGOs. There are several other Ministries also that deal with IDPs and their resettlement (South Asian for Human Rights, 2012).

2.3. IMPORTANCE OF HOUSING FACILITIES IN RESETTLEMENT

The war victims of the Northern and Eastern Provinces lost their dignity with the loss of their homes. They lived in temporary shelters, welfare camps or with friends and relatives (NEHRP, 2012).The NEHRP report also indicated that a limited number of housing programmes were undertaken by UN agencies, donor agencies and the NHDA in these areas. Barakat (2003) argued that housing reconstruction should receive more prominence in post - conflict and post - disaster work.

Shaw and Ahmed (2010) classified the provision of post disaster housing assistance mainly under two modes, i.e rebuilding them in their origin allocations and in alternative locations. More than 230,000 houses are estimated to have got damaged or destroyed during the conflict (United Nations Office Coordination of Humanitarian Affairs (UNOCHA), 2010).

Indian Housing Projects, NEHRP and United Nations Human settlements Programme (UN Habitat) are some of the major Projects implemented in the North.

2.4. DETAILS OF RESETTLEMENT HOUSING PROJECTS AS AT 31.12.2013

Table 1 shows that in the Northern Province there is a difference of 19,533 between the required number of houses and the number of houses that were planned.

Table 1: District Wise Details of Housing Projects 2013 (Owner Driven Model) in Northern Province as at 31.12.2013

S.No	District	No. of Houses Required	No. of Houses Planned	No. of Houses Completed
1	Jaffna	33,386	20,808	13,891
2	Kilinochchi	26,730	16,309	10,415
3	Vavuniya	14,189	9,057	3,657
4	Mannar	6,150	13,124	6,860
5	Mullaitivu	15,065	9,743	6,808
	Total	**88,574**	**69,041**	**43,311**

Source: Jaffna District Secretariat, 2014; Vavuniya District Secretariat, 2014; Mannar District Secretariat, 2014; Mullaitivu District Secretariat, 2014; Kilinochchi, 2014

2.5. OVERVIEW OF THE APPROACHES AND MODALITIES OF HOUSING PROJECTS

Karunasena and Rameezdeen (2010) stated that a good housing reconstructing strategy meets social needs while ensuring long term disaster mitigation and sustainability. Barenstein (2006) has identified five approaches, namely Owner Driven, Subsidiary Housing, Participatory Housing, Contractor Driven for houses built in their original locations and the Contractor Driven Approach for houses built in alternative locations. Barakat (2003) indicated two types of models, i.e Contractor Model (Donor Driven Model) and Self-build Model (Owner Driven Model).Donor Driven Approach and the Owner Driven Approach are used in the Northern Province.

2.6. OWNER DRIVEN APPROACH - PROBLEMS AND THEIR CAUSES

2.6.1. VILLAGE RELATED PROBLEMS

The wrong selection of war affected villages (The World Bank, 2011) and the duplication of selected villages (Shaw and Ahmed, 2010) are the two problems that come under this category.

2.6.2. BENEFICIARY RELATED PROBLEMS

Barakat (2003) stated that the selection of the beneficiary is difficult. Unnati (2006) indicated some deserving families had not been selected for warrant of legal documentation. Further Shaw and Ahmed (2010) observed that there had been delays in selecting beneficiaries after the 2004 Tsunami in India and Sri Lanka.

2.6.3. LAND RELATED PROBLEMS

- ***Land Ownership*** **-** Barakat (2003) indicated that in Kosova and Ruwanda there were difficulties in verifying the legal status and ownership of land subsequent to a disaster. In post – disaster situations, especially after a conflict, the legal framework collapses totally and it is difficult to verify the legal status of land and ownership especially with new owners.
- ***Shortage of Suitable Land and Loss of Agricultural Land*** **-** In Sri Lanka and Kenya, there is a shortage of land for residential purposes (Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011; Njathi, 2011). Further in India, Barenstein and Iyengar (2012) indicated that in India the use of agricultural land for housing projects is a critical issue for farmers.

2.6.4. FUND RELATED PROBLEMS

- ***Delay in Receiving Second and Third Installments*** **-** Karunasena and Rameezdeen (2010) observed that victims were unable to collect their instalments on schedule as they failed to show their progress making them depend on their own resources.

- ***Corruption*** **-** In the Gujarat Earth Quake (2001) Reconstruction Programme implemented in India, technical staff in anticipation of bribes, allowed beneficiaries to construct their houses by themselves (Unnati, 2006). Dauvergne (1997) indicated that there was corruption in the Indonesian Housing Reconstruction Programme.
- ***Beneficiaries' Behaviour*** **-** The guideline published by the International Federation of Red Cross and Red Crescent Societies (2010) states that under the owner driven model, beneficiaries utilize the money they receive to meet their daily expenses and that the most vulnerable families will not take part in the Programme fully unless there is a financial benefit.
- ***Insufficient Grants and Under Estimation*** **-** Krishnar (2011) observed that beneficiaries in the Vadamaradchchi South West Division in the Jaffna District faced difficulties when the grants they received under NEHRP were insufficient. Beneficiaries also failed to meet the budgetary requirements (Zabihullah *et al.*, 2011). Barakat (2003) stated that in China, authorities underestimate the work and according to Chang (2012) this compels beneficiaries not to take part in the programmes. They do not seek support from banks because of high lending rates and lack of information on credit facilities (Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011).

2.6.5. PHYSICAL RESOURCE RELATED PROBLEMS

After the December 2004 Tsunami, the cost of building material started to increase because of the shortage of resources (Jayasuriya and McCawley, 2008; Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011). In Indonesia there had been a shortage of building material and the need for alternatives had created a major bottleneck in the programme (Nazara and Resosudarmo, 2007; Zuo and Wilkinson, 2008). Barenstein and Iyengar (2012) stated that in India, targets could not be met because of the low quality of material used which resulted in poorly built structures. Barakat (2003) indicated that there was a disruption in the chain of supply and according to Chang (2012) in China there was inflation in the earthquake affected areas.

2.6.6. HUMAN RESOURCE RELATED PROBLEMS

Shaw and Ahmed (2010) indicated that in the Tsunami reconstruction programmes in Sri Lanka and India, local government offices did not have sufficient resources to cope up with their drastically increasing workloads. High wages had to be paid for labourers (Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011). Indonesian reconstruction programmes there was a shortage of human resources (Verby *et al.*, 2007). Prior to the Christchurch earthquakes of 2010 and 2011, the shortage of human resources was identified as one of the potential constraints that follow a major disaster in local production facilities (Nazara and Resosudarmo, 2007).

2 .6.7. CONSTRUCTION QUALITY RELATED PROBLEMS

The World Bank (2010) observed that the fact that owner driven houses are not designed by professionally qualified architects and the fact that owners often occupy their houses before completion of work are two main reasons for the poor construction quality. Low quality houses are prone to damage (Guideline of the International Federation of Red Cross and Red Crescent Societies, 2010). In Indonesia due to poor coordination and communication between the housing providers and beneficiaries there were issues on the quality of work. (ACARP, 2007 and Steinberg, 2007).

2.6.8. BUILDING PERMIT RELATED PROBLEMS

The procedure for obtaining building permits was complicated. In Ruwanda, there was no set procedure for obtaining a building permit (Barakat, 2003). Unatti (2006) stated that often a beneficiary had to spend at least Rs.10,000.00 from the Rs. 550,000.00 he received, for designing the house and for obtaining the permit. Bureaucracy and intuitional problems caused the delays in obtaining building permits (Verby *et al.*, 2007).

2.6.9. INFRASTRUCTURE FACILITIES AND AMENITIES RELATED PROBLEMS

Shaw and Ahmed (2010) pointed out that in Sri Lanka; there were delays in developing infrastructure under the Tsunami reconstruction programme. There had also been a shortage of services and amenities in the housing sector in Sri Lanka and Indonesia (Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011 and Oxfam, 2006).

2.6.10. OTHER PROBLEMS

Work related problems due to delays in commencing the work (Guideline of International Federation of Red Cross and Red Crescent Societies, 2010), Communication and coordination related problems (Verby *et al.*; 2007, Shaw and Ahmed, 2010; ACARP, 2007; Zabihullah *et al.*, 2011), Environmental problems (UN Habitat, 2010 and Salazar, 2011), Construction related problems due to delays and incomplete work (Salazar, 2011; Ophiyandri *et al.*, 2010; Oxfam, 2006). Culture related problems (The World Bank, 2010; Chang, 2012 and Dauvergne, 1997) and Weather related problems (UNHabitat, 2012; Susilawati and Al – Surf, 2011) are some of the other problems.

2.7. CONTRIBUTION FROM THE SYSTEM

System is an organized purposeful structure created to solve problem. System can concentrate on end results rather than the means, provides an orderly and efficient plan of action, develops coordination of the specialized activities, provides a good basis of control and frees management from many daily details of operations management (Banerjee, 2012).

3. METHODOLOGY

3.1. PRELIMINARY SURVEY

Preliminary Survey is one of the guidance to develop the detailed Survey. Since it helped to validate the factors which developed using literature review and develop the questionnaire for the detailed survey. Semi structured interviews were adopted in this study as preliminary survey since in this research, researchers had to get respondents' opinion about the suitability of identified problems, causes and roles relevant to the implementation of housing projects for resettlement in Northern Province of Sri Lanka. Further interviewees were asked to express their ideas, views, share the knowledge and experiences on the above mentioned matters. Considering semi structured interview, all questions are well structured and no space for respondents' opinion. Further face -to -face interviews were used in this study due to highest response rates, less time consuming , less expensive and Small Number of (only six) interviews were held. Two interviewees were randomly selected for each (three) type of resettlement housing projects.

3.2. QUESTIONNAIRE

Section A of the questionnaire obtained information on the respondents and the rest of the sections focused on problems encountered in implementing housing projects, their ranking and causes and role of each stakeholder in resolving the problems and their ranking. A five point Likert Scale, commonly used in the literature and ranging from 1 (Very Low Significance and Importance) to 5 (Very High Significance and Importance) was used in the study. The Quantitative Research Approach and the Qualitative Research Approach were both used for the study. Therefore the research approach used in the study is a mixed approach.

3.3. DATA ANALYSIS

The Relative Important Index (RII) was used to determine the relative significance of the problems, their causes and the importance of the role of each party in implementing housing projects. To examine the agreement of the ranking of the significant or important variables between beneficiaries and implementing partners, the Spearman Rank Correlation Test was conducted. The Statistical Software package Minitab and Microsoft Excel were used for data analysis.

4. FINDINGS

The questionnaire survey was conducted for the first three objectives of the study.

4.1. *SIGNIFICANCE OF MAIN PROBLEMS BASED ON THE IMPLEMENTING PARTNERS'(C) AND BENEFICIARIES' (D) VIEWS*

As indicated in Table 2, both Implementing Partners and Beneficiaries ranked BCP related problems (**A)** above DCP related problems **(B)**. This is justified as in a post conflict situation all systems collapse and people find it difficult to submit required documents either them being lost or misplaced. The selection of the most deserving village and the beneficiary is also not easy. In the BCP stage, there are common Problems such as those due to land mines and High security Zones. There are also individual problems such as loss of land documentation, delays in getting approval for using one's own resources in the BCP stage making them more significant than those of DCP.

Table 2: Main Problems and their Ranks

Notation	Main Problems	Implementing Partners (C)		Beneficiaries (D)		Overall (C+D)	
		RII	Rank	RII	Rank	RII	Rank
A	Before Construction Period (BCP)	0.779	1	0.768	1	**0.774**	**1**
B	During Construction Period (DCP)	0.738	2	0.756	2	**0.747**	**2**

4.2. *SIGNIFICANCE OF GROUP PROBLEMS BASED ON THE IMPLEMENTING PARTNERS' (C) AND BENEFICIARIES' (D) VIEWS*

The significance of group problems in the BCP is shown in Table 3.

Table 3: Significance of Group Problems in Main Problem A

Main Problem	Notation	Group Problems	Implementing Partners (C)		Beneficiaries (D)		Overall (C+D)	
			RII	Rank	RII	Rank	RII	Rank
A	A_1	Ownership of Land	0.845	1	0.856	1	0.850	**1**
	A_2	Selection of Beneficiary	0.793	3	0.792	2	0.793	**2**
	A_3	Selection of Village	0.807	2	0.72	3	0.763	**3**
	A_4	Commencement of construction	0.741	4	0.692	5	0.717	**4**
	A_5	Approval of housing plans	0.717	5	0.66	4	0.689	**5**

4.3. *SIGNIFICANCE OF GROUP PROBLEMS BASED ON THE IMPLEMENTING PARTNERS' (C) AND BENEFICIARIES' (D) VIEWS*

Table 4 indicates the significance of group problems in the DCP stage.

Table 4: Significance of Group Problems in Main Problem B

Main Problem	Notation	Group Problems	Implementing Partners (C)		Beneficiaries (D)		Overall (C+D)	
B			**RII**	**Rank**	**RII**	**Rank**	**RII**	**Rank**
	B_1	Fund	0.834	1	0.836	1	0.835	**1**
	B_2	Infrastructure facilities	0.717	2	0.676	2	0.697	**2**
	B_3	Physical Resources	0.700	4	0.656	3	0.678	**3**
	B_4	Other	0.666	5	0.608	4	0.637	**4**
	B_5	Human Resources	0.710	3	0.548	5	0.629	**5**

5. FRAMEWORKS

5.1. FRAMEWORK FOR IMPLEMENTATION OF HOUSING PROJECTS

The two frameworks developed based on the findings are shown in Figures1 and 2.

5.2. OBJECTIVES OF THE FRAMEWORKS

The objectives of the two frameworks are as follows:

- To indicate in one single diagram for easy reference, the most significant problems, their most significant causes and the most important role of the implementing partners and beneficiaries.
- To indicate the relationships among the above mentioned factors

5.3. FRAMEWORK FOR BCP

Based on the findings, **ten** most significant sub problems (**overall RII** > **0.65**) **thirteen** most significant causes of them (**overall RII** > **0.65** or causes of identified sub problem with an **Overall Rank 1)** and important roles of implementing partners and beneficiaries related to these sub problems (overall **RII** > **0.75**) were identified. Table 5 shows the relevant details.

5.4. FRAMEWORK FOR DCP

Based on the findings, **twelve** most significant sub problems (**overall RII** > **0.65**), **fifteen** most significant causes of these sub problems (**overall RII** > **0.65** or with an Overall **Rank of 1**) and important roles of implementing partners and beneficiaries related to these sub problems (**overall RII** >**0.75**) were identified. Table 6 shows the relevant details.

5.5. USE OF THE SYSTEM

Developed system provides following uses;

- Reduce bottlenecks to implement resettlement housing projects as well as community based owner driven approaches especially BCP and DCP stages.
- Educate the beneficiaries who are involving resettlement housing projects.
- Conduct advocacy programmes to officials, politicians and etc. who are stakeholders of the resettlement housing projects.

Table 5: Notation of Identification Factors in the Framework for BCP

Sub Problems	**Causes**	**Roles of Implementing Partners**	**Roles of Beneficiaries**
A_{11} - Loss of Land Development Ordinance (LDO) Permits/ Grants/ Deeds	C_1 - Conflict situation	RI_1 - Taking action to issue land documents	RB_1 - People to obtain land documents
A_{12} - Families who previously occupied the land not transferring / subdividing it to the new owners	C_2 - Low income families	RI_2 - Instructing Beneficiaries to take responsibility to keep documents with them	RB_2 - Taking responsibility to keep land documents safely
A_{13} - Non regularization of encroachments which took place prior to 15.06.1995	C_3 - No awareness about importance of transfer	RI_3 - Conducting awareness programme about the importance of Land documents/ starting on time /building plan/permit	RB_3- To participate actively
A_{21} - Non selection of eligible families as beneficiaries	C_4 - Lack of Human Resources in Offices	RI_4 - Conducting Land Mobile Services periodically	RB_4 - Owners to submit on time
A_{22} - Influence exerted by pressure groups and political parties during beneficiary selection	C_5 - Un educated families	RI_5 - Regularizing land ownership	RB_5 - To get interested in getting other housing projects
A_{23} - Delay in receipt of House Damage Assessment Survey form / conducting the above Survey	C_6 - Affected families' villages being not selected	RI_7 - Making beneficiaries understand the criteria of selection and avoiding complaints to politicians	RB_6 - Not to complain unnecessarily
A_{31} - Non Selection of affected villages	C_7 - Beneficiary not fulfilling the requirements	RI_8 - Making arrangements to resettle the people in their own land	RB_7 - To be interested in resettling in their own land
A_{32} - Delay in selection of affected Villages	C_8 - Political parties interested in their election campaigns	RI_9 - Implementing income generation projects	RB_8 - To be interested in resettling in their own land
A_{41} - Delay in the commencement of construction	C_9 - Lack of infrastructure facilities	RI_{10} - Arranging the supply of material on time	RB_9 - To get involved in income generation projects
A_{51} - Delay in getting approval of building plan	C_{10} - Delay in getting approval for the building plan	RI_{11} - Advising technical staff to provide technical advice	
	C_{11} - No proper utilization of funds	RI_{12} - Conducting awareness programme about procedure to get building permit	
	C_{12} - Delay in getting approval to use one's own resources		
	C_{13} - No awareness on the procedure to get approval for the building plan		

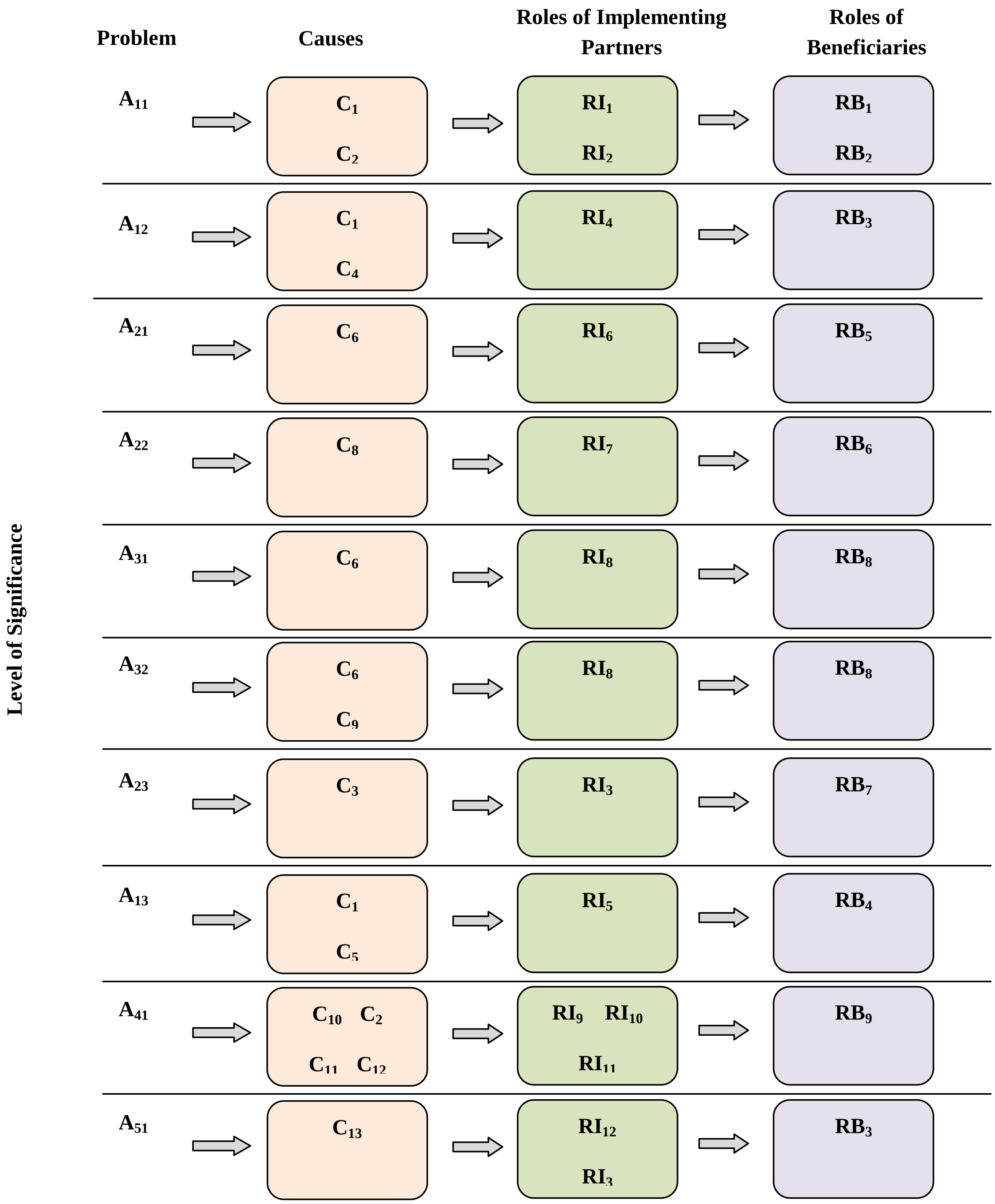


Figure 1: Framework for BCP

Table 6: Notation of Identification Factors in the Framework for DCP

Sub Problems	Causes	Roles of Implementing Partners	Roles of Beneficiaries
B_{11} - Failure to properly utilize funds	C_1 - Lack of income generation facilities for resettled people	RI_1 - Creating income generation opportunities/	RB_1 - To be self-employed
B_{12} - Delay in releasing second and third instalments of payments	C_2 - Low income of the Beneficiaries	RI_2 - Conducting awareness programme about the importance of completing the construction on time	RB_2 - To participate in awareness programmes
B_{13} - Lack of Bank facilities	C_3 - Beneficiary not fulfilling the requirements	RI_3 - Instructing the beneficiaries of any changes immediately	RB_3 - To be keen to get involved in income generation activities
B_{14} - Change in names/Account Numbers of beneficiaries	C_4 - Lack of infrastructure facilities and security	RI_4 - Instructing the officers to perform duties on time	RB_4 - To be kept informed immediately of any changes
B_{21} - Lack of services and amenities (water supply, electricity and etc.)	C_5 - Non availability of the original beneficiary (Death / being out of the country)	RI_5 - Instructing Beneficiaries to fulfil the requirements on time	RB_5 -To fulfil the requirements on time
B_{31} - Shortage of physical resources	C_6 - Difficulty in providing all services and amenities in a short period	RI_6 - Priority to be given to development work in resettled places	RB_6 - To inform their needs
B_{32} - Slow Delivery	C_7 - Increasing price of material	RI_7 - Educating the people (interest) on banking services	RB_7 - To be aware of banking services
B_{51} - Unavailability of skilled labourers	C_8 - Lack of transportation facilities	RI_8 - Improving road development especially in resettlement areas on time	RB_8 -To coordinate with suppliers and requesting them to deliver material at low prices
B_{33} - Lack of storage	C_9 - Non availability of proper storage facilities	RI_{10} - Advise to/ select a common place for proper storage	RB_9 -To participate in training programmes
B_{41} - Lack of community influence and participation in construction planning and designing facilities	C_{11} - Implementing partners following donors' guidelines	RI_{11} - Conducting/ participating in awareness programmes about planning and designing of constructions	RB_{10} - Finding labourers from adjoining areas
B_{52} - Unskilled labourers	C_{15} - Lack of skilled labourers	RI_{12} - Conducting training programmes	
	C_{13} - Unequal distribution of the labour force	RI_{13} - Finding labourers from adjoining areas	
	C_{14} - Skilled Labours being involved with other on-going Mega development projects		
	C_{12} - Implementing partners being keen to perform their agencies' duty perfectly		

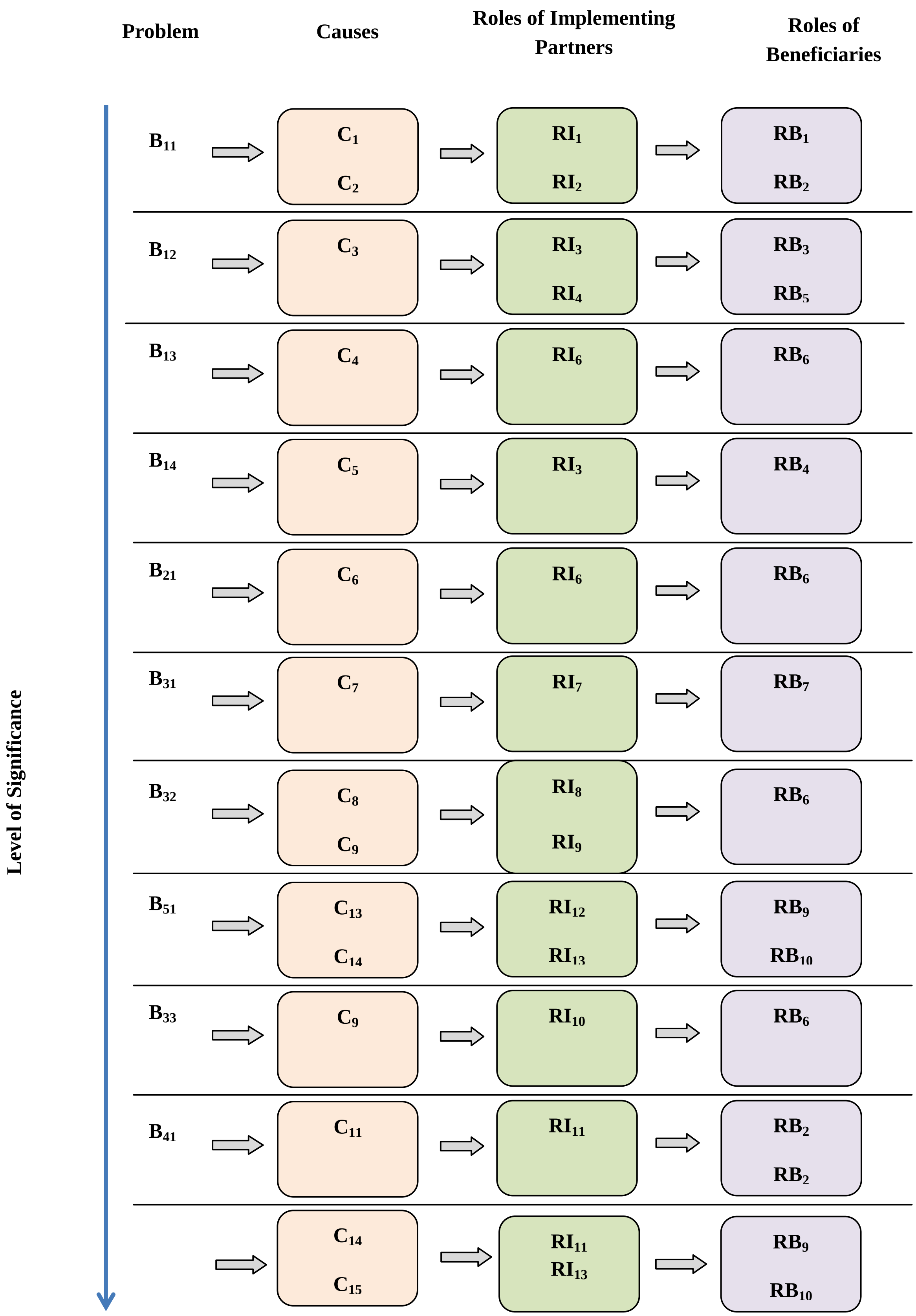


Figure 2: Framework for DCP

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

Main Problems, Group Problems and Sub Problems were the three types of problems considered in this study. According to RII values obtained for the Main Problems, problems 'Before Construction Period (BCP)' are more significant than those encountered 'During Construction Period (DCP)'. Under BCP 'Ownership of Land' is the most significant group problem and under DCP 'Fund Related' problems is the most significant group problem. Considering the sub problems under land related problems, 'Loss of LDO Permits/Grants/Deeds' is the most significant sub problem. Likewise under Fund Related Problems, 'Failure to properly utilize funds' is the most significant sub problem. The most significant cause of the sub problem 'Loss of LDO Permits/ Grants/ Deeds' under BCP is 'Displacement'. The most significant cause of the sub problem 'Failure to properly utilize Funds' under DCP is 'Lack of income generation facilities for resettled people'.

The roles of the implementing partners and beneficiaries in relation to the most significant sub problem 'Loss of L.D.O permits/ Grants/ Deeds' under BCP in the order of their importance are 'Taking action to issue copies of deeds for private land', 'Regularizing land ownership' and 'Taking responsibility to keep land documents safely'. Likewise the roles of the implementing partners' and beneficiaries' in relation to the most significant sub problem 'Failure to properly utilize funds' under DCP in the order of their importance are 'Implementing income generation activities' and 'To be keen to get involved in income generation activities'.

The final objective was to propose frameworks to identify a suitable system for the implementation of BCP and DCP. The two frame works identified could be used in any future housing projects mitigating associated impediments.

6.2. RECOMMENDATIONS

This study reveals that Implementing Partners should conduct awareness programme on the importance of having land documents and the relevant authorities should take necessary action to issue copies of the missing deeds to land owners formally. Land related issues on ownership should be resolved by conducting land mobile services, strengthening human resources and utilizing aid received from donors and NGOs. All land documents must be computerized. Beneficiaries should be aware of the importance and usefulness of land documents and should take care of them. Beneficiaries must actively participate in the awareness programmes and land mobile services.

Implementing partners should get the beneficiaries involved in income generation activities. Resettled people should strive to have their own income sources rather than waiting for outside aid. Banks should provide an optimum service to resettled people and there should be new branches and mobile banking services. Beneficiaries should be interested in these new services. To ensure that the most deserving Villages and Beneficiaries are selected, housing plans should be approved with transparency without yielding to pressure groups and the beneficiaries too need to cooperate with officers to help them perform their duties properly. Authorities should give priority to infrastructure development projects in resettlement areas. Implementing partners, relevant agencies, community and other service providers should have good communication and coordination among them working as a team. It is also recommended that authorities consider using the frameworks developed use them in future housing projects.

7. REFERENCES

Aceh Community Assistance Research Project (ACARP), 2007. *The Acehnese Gampong Three years on Assessing Local Capacity and Reconstruction Assistance in Post- tsunami Aceh* [online]. Banda, Aceh: ACARP. Available from: http://www.worldcat.org/title/acehnese-gampong-three-years-on-assessing-local-capacity-and-reconstruction-assistance-in-post-tsunami-aceh-report-of-the-aceh-community-assistance-research-project-waacarp/oclc/489265374 [Accessed 21 March 2013].

Banerjee, A., 2012. Five Main Advantages System Approach in Management [online]. Sri Lanka. Available from: http://www.preservearticles.com/2012051832330/5-main-advantages-of-systems-approach-in-management.html [Accessed 16 May 2015].

Barakat, S., 2003. Housing Reconstruction after Conflict and Disaster. *Humanitarian Practice Network (HPN) Paper* [online], (43), 1- 40.

Barenstein, J.D., 2006. Housing Reconstruction in Post-Earthquake Gujarat: A Comparative Analysis. *Humanitarian Policy Network Paper* [online], 54.

Barenstein, J.D. and Iyengar, S., 2010. From Housing to Reconstruction in India. In: Lyons, M., Schilderman, T. and Boano, C., Ed. *Building Back Better*, Warwickshire, UK: Practical Action Publishing Ltd, 164-188.

CEPA (Centre for Poverty Analysis), 2009. Force to Move: Involuntary Displacement – Policy and Practice. In: *9th Annual Symposium on Poverty Research in Sri Lanka.*

Chang, Y.A., 2012. *Resourcing for Post- Disaster Housing Reconstruction* [online]. Dissertation (Doctoral). Available from: http://www.researchspace.auckland .ac.nz/does/uoa-docs/rights.htm [Accessed 18 June 2013].

Dauvergne, P., 1997. *Globalization and Deforestation in the Asia- pacific.* Australian National University, Canberra.

International Federation of Red Cross and Red Crescent Societies (IFRC), 2010. *Owner - Driven Housing Reconstruction Guideline of IFRC* [online]. Available from: http://www.sandradurzo.org/Conferences/ODHR_Guidelines.pdf [Accessed 21 March 2015].

International Medical Health Organisation, 2010. *The Internally Displaced Persons (IDPs) of Sri Lanka* [online]. PowerPoint Slide No: 5. Available from: www.ThelMHO.org [Accessed 16 May 2013].

Jaffna District Secretariat, 2014. *District Statistical Hand Book – 2014*. Jaffna, Sri Lanka: Jaffna District Planning Secretariat.

Jayasuriya, S. and McCawley, P., 2008. Reconstruction after a Major Disaster: Lessons from the Post – Tsunami Recovery: Issues and Challenges in Indonesia, Sri Lanka and Thailand. *Working Paper,* (25). Tokyo: Asian Development Bank Institute.

Karunasena, G. and Rameezdeen, R., 2010. Post - Disaster Housing Reconstruction: Comparative Study of Donor Driven vs Owner Driven Approach. *International Journal of Disaster Resilience in the Built Environment* [online], 1(2), 173- 191.

Kilinochchi District Secretariat, 2014. *District Statistical Hand Book – 2014*. Kilinochchi, Sri Lanka: Kilinochchi, District Planning Secretariat.

Krishnar, S., 2007. *Planning Socio Economic Development in Economically Disadvantages Groups in Vadamaradchy South West Division through Reconstruction Housing Reconstruction Programmes.* Unpublished Dissertaion (M.Sc.). University of Jaffna.

Mannar District Secretariat, 2014. *District Statistical Hand Book – 2014*. Mannar, Sri Lanka: Mannar District Planning Secretariat.

Ministry of Construction, Engineering Services, Housing and Common Amenities, 2011. *National Housing Symposium, Sri Lanka Foundation Institute*, Colombo 22-23 March 2011.

Ministry of Resettlement, 2013. *Progress and Performance Report – 2012.* Sri Lanka: Ministry of Resettlement.

Mullaitivu District Secretariat, 2014. *.District Statistical Hand Book – 2014*. Mullaitivu, Sri Lanka: Mullaitivu District Planning Secretariat.

Nazara, S., and Resoundarmo, B.P., 2007. Aceh-Nias Reconstruction and Rehabilitation: Progress and Challenges at the End of 2006. *Discussion Paper.* Tokyo: Asian Development Bank Institute.

Njathi, M.E., 2011. *The Challenges of Housing Development for Low Income Market.* Thesis (MBA). Strathmore University.

North East Housing Reconstruction Programme (NEHRP), 2012. *Preparation of the Implementation, Completion Results Report.* Paranthan, Kilinochchi, Sri Lanka: NEHRP.

Ophiyandri, T., Amaratunga, D. and Pathirage, C., 2010. *Community Based Post Disaster Housing Reconstruction: Indonesian Perspective* [online]. Available from: http://www.cib2010.org/post/files/papers/536.pdf [Accessed 16 March 2013].

Oxfam, 2006. *Oxfam International Tsunami Fund International* [online]. Second Year Report December 2006. Available from: http: //www.oxfam.ca/sites/default/files/Oxfam-international-tsunami-fund-second-year-report.pdf [Accessed 16 May 2015].

Shaw, J. and Ahmed, I., 2010. .*Design and Delivery of Post – Disaster Housing Resettlement Programme*: *Case Studies from Sri Lanka and India* [online]. Melbourne, Australia: The Royal Melbourne Institute of Technology. Available from: http://mams.rmit.edu.au/2uisye01kgb5z.pdf [Accessed 30 March 2013]

South Asian for Human Rights, 2012. *Internally Displaced Persons in Sri Lanka: Legal Framework and Key Issues.*

Steinberg, F., 2007. Housing Reconstruction and Rehabilitation in Aceh and Nias, Indonesia- Rebuilding lives [online]. *Habitat International,* 31(1), 150-166. Available from: http://www.sciencedirect.com/science/article/B6V9H-4N0XN7T-1/2/a28e92ad63f31cda9ada4e54ef8b9299 [Accessed 18 March 2013].

Susilawati, C. and Al surf, M., 2011. Challenges Facing Sustainable Housing in Saudi Arabia: A Current Study Showing the Level of Public Awareness. In: *17th Pacific Rim Real Estate Society Conference.*

The World Bank, 2010. *Involuntary Displacement* [online]. Available from: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTINVRES/0,,menuPK:410241~pagePK:149018~piPK:149093~theSitePK:410235,00.html [Accessed 16 March 2013].

The World Bank, 2011. *Involuntary Resettlement* [online]. Available from: http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTINVRES/0,,contentMDK:20486618~menuPK:1242235~pagePK:210058~piPK:210062~theSitePK:410235,00.html [Accessed 30 March 2013].

Thiyagarajah, J., 2012. *A Road Map to the End of Displacement in Sri Lanka? FMR/BRRKINGS-BERNSPECIAL/ISSUE* [online]. Available from: http:// www.brookings.edu/fp/projects/idp/resources/Henglish.pdf [Accessed 16 May 2015].

UN-HABITAT, 2010. *Support to Conflict Affected People through Housing* [online]. Available from http://www.unhabitat.lk/project7a.html [Accessed 15 May 2013].

UNNATI, 2006. *Owner Driven Housing Process Post Earthquake Reconstruction Programme.* Bhachau: Ahmedabad, Gujarat, India: UNNATI.

UN Office for the Coordination of Humanitarian Affairs (UN OCHA), March 2010. *Sri Lanka: North East Joint Humanitarian Update #21* [online]. Available from: http://www.humanitarianinfo.org/srilanka_hpsl/Files/Situation%20Reports/Joint%20Humanitarian%20Update/LKRN040_100227-100312%20-%20SL%20-%20IA%20-%20Sitreps%20-%20Update%20-%2021.pdf.

Vavuniya District Secretariat, 2014. *District Statistical Hand Book – 2014*. Vavuniya, Sri Lanka: Vavuniya, District Planning Secretariat.

Verby, M., Manu, C. and Berman, L., 2007. *Community Development Approach in Aceh Reconstruction, Reflecting on Lessons Learned for Yogyakarta – Lesson Learned from the Field, A Practical Guideline in Modern Project Management Style in Post-Disaster Areas.* In: *International Seminar on Post – Disaster Reconstruction: Assistance to Local Governments and Communities*, Yogykarta. Urban and Regional Development Institute.

Zabihullah, S., Vaughan. C. and Trigunarsyah, B., 2011. Post – Disaster Housing Reconstruction: Challenges for Community Participation. In: *The International Conference on Building Resilience: Interdisciplinary Approaches to Disaster Risk Reduction, and the Development of Sustainable Communities* [online], Heritance Kandalama, Sri Lanka. Available from: http://www.eprints.qut.edu.au/4217 [Accessed 16 May 2015].

Zuo, K. And Wilkinson, S., 2007. Supply Chain and Material Procurement for Post Disaster Construction: The Boxing Day Tsunami Reconstruction Experience in Aceh, Indonesia. In: *The CIBW89 International Conference on Building Education and Research BEAR 2008,* Heritance Kandalama, Sri Lanka.

AN INVESTIGATION INTO SKILLED LABOUR REQUIREMENT IN SRI LANKAN BUILDING CONSTRUCTION INDUSTRY

Nishadi Anuruddika* and Y.G. Sandanayake
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The construction industry, being predominantly labour intensive, heavily relies on the adequate supply of workforce and their skills. With the speedy growth of Sri Lankan construction industry after the ethnic war, demand for skilled workforce has been increased. The overall aim of this research is to analyse the present situation of skilled labourers in Sri Lankan building construction industry with respect to skill trades, in order to address the timely need of the present and future context of the industry.

The research was conducted using a questionnaire surveys among project managers in the building construction industry. The questionnaire survey was carried out to identify the significant skill trades and to investigate the current status of the skills and future required skills. Further, the questionnaire used to identify the skill shortage in building construction industry.

Skills related to service installation was identified as significant as the skills related to structural construction. However, the current status of the most of the skill trades is that these are not sufficient to fulfil the demand of the industry, except for bricklaying and plastering. The future supply of the skills also indicated an unbalanced level in likely demand and likely supply of skills. Hence, the government, industry and construction companies are having a responsibility of addressing the shortfall. It is also important to consider more training schemes and attractive remunerations with benefits to create a positive attitude towards the building construction industry among migrants and young generation in Sri Lanka.

Keywords: *Construction Industry; Skilled Labour; Skilled Labour Demand and Supply; Skill Shortage; Strategies.*

1. INTRODUCTION

In the contemporary world, construction industry holds immense potential for stimulating growth of national economy by providing necessary infrastructure background to other industries and generating substantial employment (Osei, 2013). Being a significant pillar of country's economy, construction industry requires effective and efficient strategies for resource utilization, while minimizing the unstable level of activities which ultimately leads to achieve a successful project completion. Being a major attributer, labour resource impinges on construction activities in terms of quantity and quality. According to Ozorhon *et al.* (2007), special skills and technical knowledge are requisites of the construction industry due to the complexity and solidity of its nature. Similarly, Dainty *et al.* (2005) identified skilled workforce as predominant in the industry, since the paucity and insufficiency of skilled workforce can create poor quality work and delays to the construction works.

Skilled labour demand is associated with construction output, labour productivity, real wage in the construction industry, material price and interest rate (Wong *et al.*, 2011) while the supply of construction skills depends on the recruitment of young people, together with some upgrading of semi-skilled operatives to skilled operatives (Agapiou, 1996). However, demand (requirement) and supply (available) of skilled workforce of each sector are set in accordance with the market conditions. Work load fluctuation of the construction industry directly allied with the skilled workforce and creates either a

* Corresponding Author: E-mail - nishadianuruddika@yahoo.com

shortage or a surplus of workforce due to inevitable complex nature of projects, sophisticated involvement of construction technology and exposure of dynamic business culture by the industry (Ramasaran and Hosein, 2005). Similarly, absence of planning for skilled manpower generates fluctuations of labour pool triggering surpluses and shortages resulting low quality and wastages in long run.

The fluctuation of the skilled workforce has been identified throughout the world even in developed countries. The Construction Labour Research Council in USA has forecasted the required workforce to be trained and retained up to 2016 as 185,000 to achieve the expected growth of the industry (Olsen *et al.*, 2012 as cited in Oseghale and Abiola-Falemu, 2015) and according to Chan and Dainity (2007) the unrealistic approach of defining the skill levels affected on the skill shortage of UK. Similarly, 17% unemployment rate and 13% underemployment rate have been discovered within the Hong- Kong construction labour market reflecting a mismatch of labour equilibrium (C&SD, 2004). A decade ago, in the local construction industry, only five percent are skilled labourers among 500,000 directly employed workers and it is one third out of the forecasted skilled labour requirement (Weddikkara, 2006).

The upward trend of Sri Lankan construction industry after the end of ethnic war in 2009 has created an immense demand for the workforce in different skills with the construction of landmark buildings and infrastructure development in Sri Lanka. Consequently, skilled labour demand has upturn with the leapfrog in technology for new development projects. Therefore, the aim of the study is to investigate the skilled labour requirement in Sri Lankan building construction industry which has not been thoroughly explored in relation to the Sri Lankan context in recent years under present context.

2. LITERATURE REVIEW

2.1. SKILLED LABOUR DEMAND AND SUPPLY

Demand of skilled workforce in the industry is influenced by the changing workload in the industry. Similarly, demand for manpower in construction industry of Asian region is unstable due to the rapid changes in the economy. Forecasting labour demand is a crucial factor for manpower planning and development of a country in terms of quantitative and qualitative aspects (Jayalath, 2011). Manpower demand is associated with several factors and these can affect the labour demand in long run and short run (Wong *et al.*, 2006). According to Wong *et al.* (2005), labour demand is highly influenced by type, size, complexity and method of construction of the project. Literature findings emphasise that the demand for skills depends on construction output, technology, wage level, labour productivity, economic growth and labour regulations.

Investigation of the current market conditions and utilization of skills, which relates to the market demand through the institution products and alternative strategies, is the process of manpower planning (Jorssen, 1989). The future supply of construction skills depends on the recruitment of young people, together with some upgrading of semi-skilled operatives to skilled operatives (Agapiou, 1996). According to Briscoe and Wilson (1993), the complexity and problematic nature cause fluctuations in the skill shortage. Adequacy of these skills in the industry depends on the supply which fluctuates with wage rate, population and composition, migration and immigration and geographical mobility.

2.2. STRATEGIES TO ADDRESS SKILLED LABOUR SHORTAGE

According to Rwelamila (2002), the construction industry is not investing in training as the industry heavily depends on informal trained workforce. A major part of this workforce cannot cope up with the pace of technological changes in terms of construction materials and methods. This has led to some of the works in progress and finished works exhibiting poor quality. There is a remarkable diversity in educational background in the construction industry (Kikwasi, 2011) and to tackle different aspects of the skills shortage strategies should be implement. Mackenzie *et al.* (2000) categorised strategies to cater skilled labour demand in to government response strategies and construction organisation response strategies as shown in the Table 1.

Table 1: Strategies to Address Skilled Labour Shortage

Industry and Government Response Strategies	Contractor Response Strategies
▪ Long term training schemes	▪ Wage increments
▪ Establishment of training institutions	▪ Positive working environment
▪ Make aware and attract unemployed persons	▪ Sufficient and accredited training programs
▪ Introduction of new technologies	▪ Benefits and incentives
	▪ Greater use of machineries
	▪ Motivation and encourage the team work

Source: Adapted from MacKenzie *et al.* (2000)

2.3. SKILLED WORKFORCE IN SRI LANKAN CONSTRUCTION INDUSTRY

In the research of Jayawardhne and Gunawardhne (1998), workers of the local construction industry are identified as "all-rounders" in their field and most of them have trained and educated through informal unsystematic ways. Further, they emphasised that, over 60% of skilled labour gang is not employed efficiently within the local industry. However, the critical situation of the labourers in the industry is highlighted, as the redundancy of construction workers at the project completion who hired on a project basis (Jayawardhne and Gunawardhne, 1998).

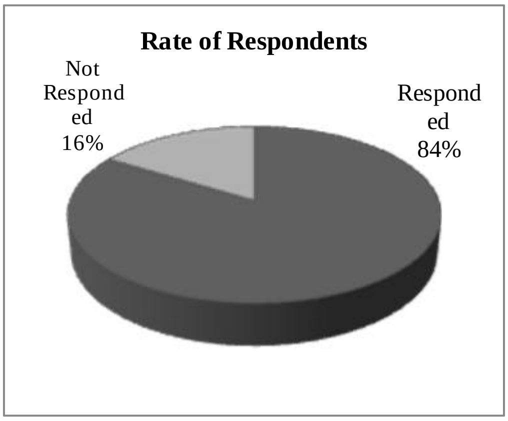
Trainings for construction labourers are mainly carried out by public and private training institutions in Sri Lanka (Jayawardane *et al.*, 2008). National Apprentice and Industrial Training Authority (NAITA), Vocational Training Authority (VTA), Department of Technical Education and Training (DTET), Institute of Construction Training and Development (ICTAD) and Chamber of Construction Industry Sri Lanka (CCI) are some training institutions established in Sri Lanka.

Two schemes are established in order to define skill levels of construction labourers in Sri Lankan training institutes. National Trade Test (NTT) and National Vocational Qualifications System (NVQ) are two tests used to measure the skills of local crafts (Jayawardane *et al.*, 2008).

3. RESEARCH METHODOLOGY

A comprehensive literature review was carried out through journals, books, articles, reports, government publications, dissertations, previous research investigations and electronic publications to identify the basic facts and the theories already subjected to discussion on skilled workforce in construction industry. Preliminary investigation was carried out to investigate the applicability of identified facts of literature synthesis to Sri Lankan construction context. Preliminary investigation was conducted among five (5) project managers involved in building construction industry. Subsequently, a detailed questionnaire was distributed to thirty seven (37) project managers to identify further information on skill trades, present and future demand and supply of skill trades and strategies to address the skilled labour shortage. Thirty one (31) project managers were respondents to the questionnaire. Further, the detailed questionnaire was used to investigate the opinions of the respondents regarding the current and future level of skilled labour demand and supply in identified skills trades. Figure 1 shows the rate of responses and experience of the respondents of detailed questionnaire survey.

The gathered data through the questionnaire were analysed using the mean weighted rating and the T test. The analyses focused on ranking the responses of the participants based on their mean values and these mean values were identified as the level of significant. The responses for likely demand and supply of each trade of skill were analysed under the middle value (median) of the responses which indicate the middle response of the practitioners to compare the expected likely demand and supply of skilled labourers.Meanwhile, based on the T test, significant strategies and determinants of supply and demand were identified. Additionally, the identified significant strategies and determinants were ranked based on acquired mean values.



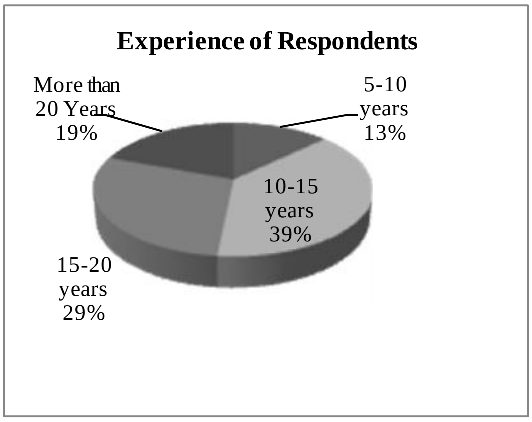


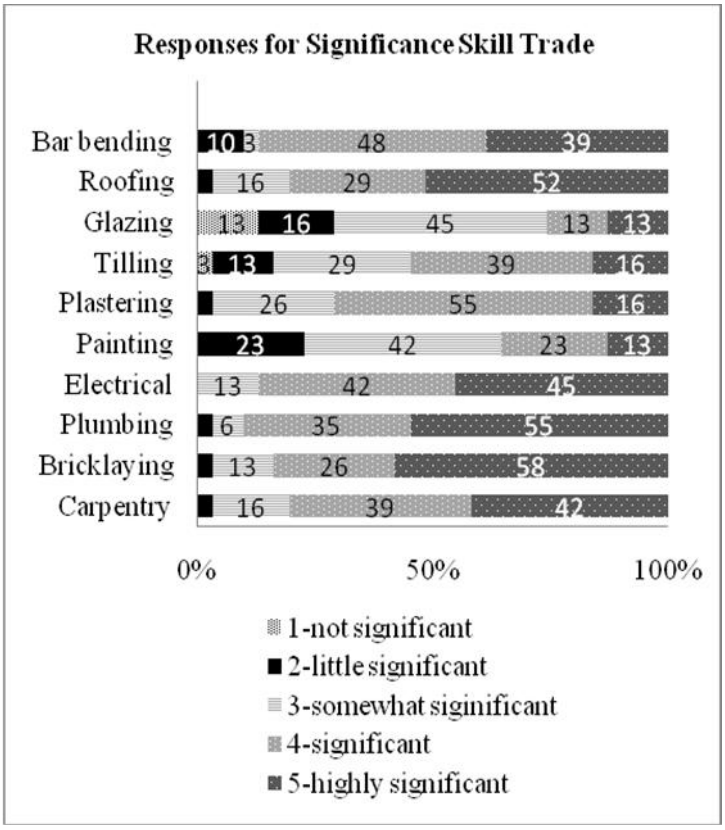
Figure 1 : Rate of Responses and Experience of Respondents

Data obtained through detailed questionnaire survey was analysed using mean weighted rating and statistical one sample t-test.

4. DATA ANALYSIS AND RESEARCH FINDINGS

4.1. SIGNIFICANCE OF SKILL TRADES

The study identified 10 most common skill trades from the literature review and preliminary investigation. Detailed questionnaire survey was used to identify the significance of the traditional skill trades most commonly use in Sri Lankan building construction industry using the mean weighted rating and frequency of responses analysis. The findings are shown in Figure 2.



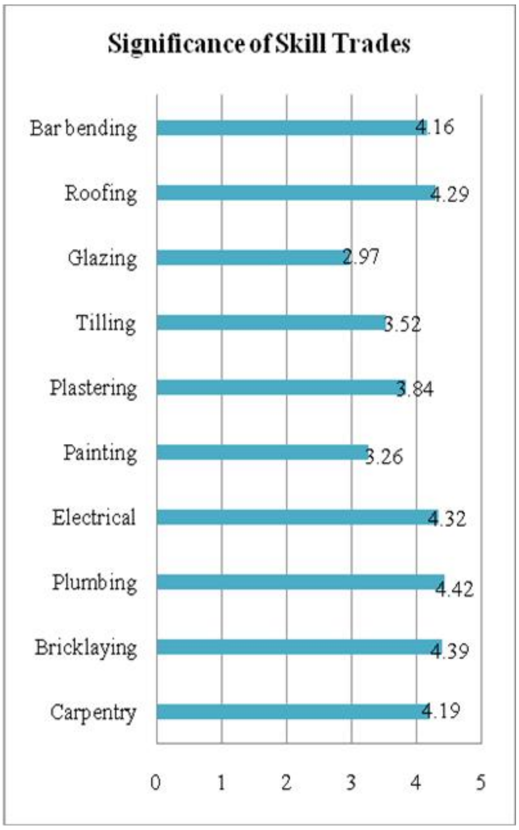


Figure 2: Mean Values and Responses of the Significance of Skill Trades

According to the findings, skills related to structural construction and services have been ranked between "highly significant" and "significant" and skills related with finishes in building construction has received "somewhat significant". As shown in Figure 2, more than 70% of respondents ranked all the trades as highly significant or significant except for glazing, tiling and painting. Plumbing was ranked as the most significant skill trade with a mean value of 4.42, where 90% of respondents ranked it as a highly significant or significant skill trade for building construction. Further, more than 50% of the respondents have given high significance to plumbing, bricklaying and roofing. The analysis further revealed that the skills related to service installation and structural constructions are significant and essential skills in building construction disregarding the type of the project. However, glazing has been ranked as the least significant skill of trade with mean value of 2.97, where 61% of respondents have experienced it as little significant or somewhat significant trade.

4.2. *CURRENT DEMAND AND SUPPLY OF SKILLED LABOUR IN SRI LANKAN CONSTRUCTION INDUSTRY*

The current level of skilled labour demand and supply was investigated under the identified skill trades and the opinions of the respondents are presented in Figure 3. The opinions of the respondents regarding the current demand and supply of skills were analysed through mean weighted rating and frequency of responses.

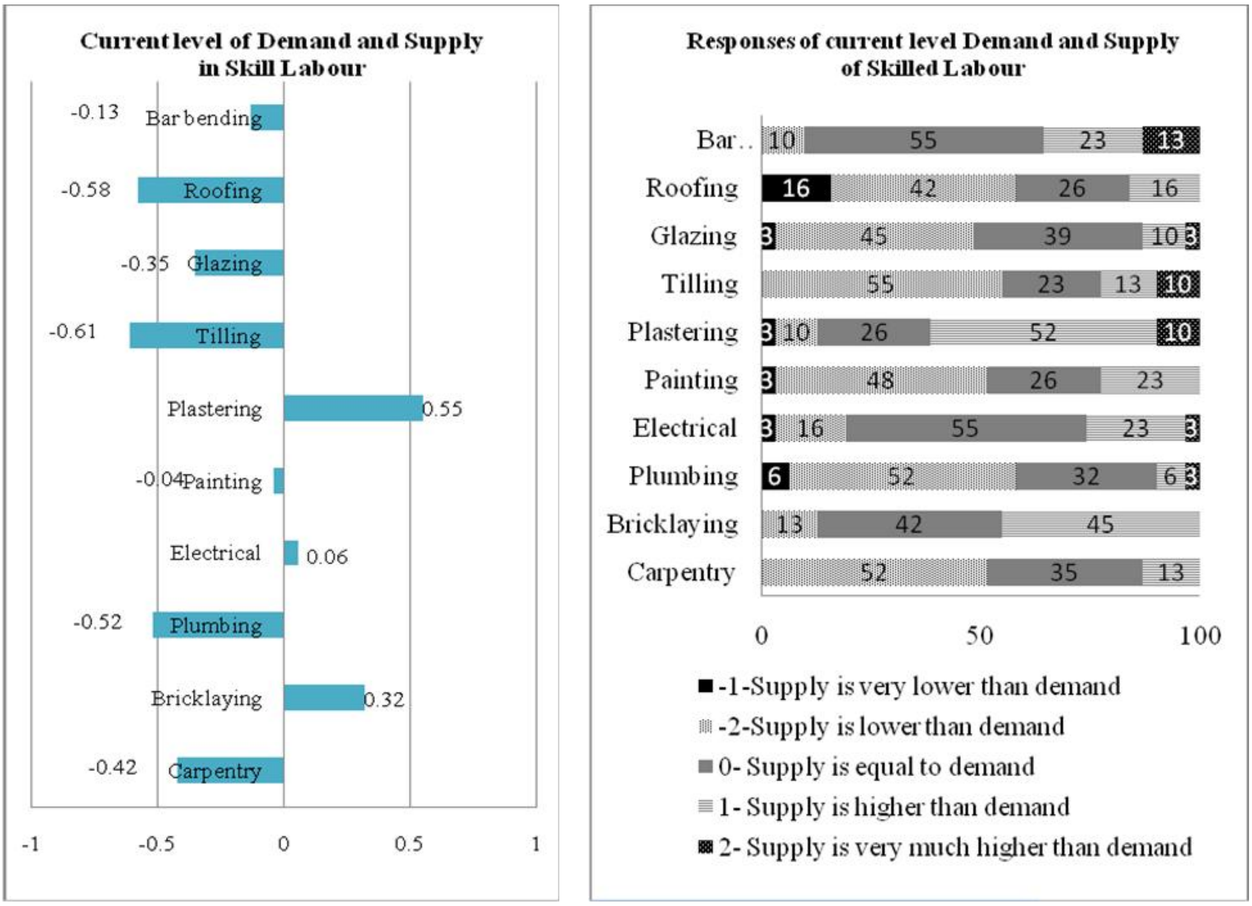


Figure 3: Mean Values and Responses of the Current Level of Demand and Supply in Skilled Labour

Respondents have ranked plastering with the highest mean value of 0.55, revealing the current supply of the skilled labourers for plastering is higher than the current demand level in the industry. According to the respondents' opinions, more than 50% of respondents have ranked plastering as highly supplied skilltrade than the current demand. Bricklaying (mean value 0.32) was ranked as another significant skill trade where, 87% of responses obtained between high supply of skilled labourers than demand and very much high supply of skilled labourers than demand. Electrical was ranked marginally in between high supply than demand and equal demand and supply. However, more than 50% of respondents indicated electrical as nonaligned skill trade where the supply of skilled labourers equal to the demand. Painting was raked in the similar way, inclined to the negative of electrical. Roofing, tiling and plumbing were identified as the skill trades where the supplies of particular trades do not match with the current demand level.

4.3. *FUTURE LIKELY DEMAND AND SUPPLY OF SKILLED LABOUR IN SRI LANKAN CONSTRUCTION INDUSTRY*

The analysis of likely demand and supply of each skill trade in future is given in Table 2. The responses for likely demand and supply of each trade of skill were analysed under the middle value (median) of the responses which indicate the middle response of the practitioners to compare the expected likely demand and supply of skilled labourers.

Table 2: Comparison of Likely Supply and Demand of Skilled Labour

Trades of Skills	Median Values for Likely Demand	Responses for Likely Demand	Median Values for Likely Supply	Responses for Likely Supply	Comparison
Carpentry	3	Average demand	2	Low supply	D>S
Bricklaying	3	Average demand	3	Average supply	D=S
Plumbing	4	High demand	3	Average supply	D>S
Electrical	4	High demand	3	Average supply	D>S
Painting	4	High demand	3	Average supply	D>S
Plastering	4	High demand	4	High supply	D=S
Tilling	4	High demand	3	Average supply	D>S
Glazing	3	Average demand	3	Average supply	D=S
Roofing	4	High demand	3	Average supply	D>S
Bar Bending	4	High demand	3	Average supply	D>S
Truss Working	4	High demand	3	Average supply	D>S
Cladding	4	High demand	3	Average supply	D>S
Ironworking	3	Average demand	3	Average supply	D=S
Welding	4	High demand	3	Average supply	D>S
Landscaping	4	High demand	2	Low supply	D>S
Pile Working	5	Very high demand	3	Average supply	D>S

The analysis revealed the gap between likely demand and likely supply trades in future according to the opinions of the respondents. However, likely demand and likely supply of bricklaying and plastering shows the equal level of demand and supply of skilled labour with considered to the median values of the opinions of the respondents. Pile working and landscaping reveals a sizeable divergence between likely supply and likely demand. The significant difference of demand and supply has been caused due to an unavailability of training in the Sri Lankan construction industry.

4.4. *STRATEGIES TO ADDRESS SKILL SHORTAGE*

The identified strategies through literature, preliminary questionnaire survey and detailed questionnaire survey, were analysed using statistical one sample t-test to investigate the significance and mean weighted rating to rank the strategies. The findings are presented in Table 3. Level of effectiveness of the strategies were collected by the using a likert scale of 1-5, where 5 represents very high effectiveness, 4 represents high effectiveness, 3 represents average effectiveness, 2 represents low effectiveness and 1 represents very low effectiveness.

Table 3: Effectiveness of the Strategies to Cater the Demand of Skilled Labour

Determinants of Supply	t Value	Significance/ P Value (1-tailed)	Mean Difference	Mean
Industry and Government Response Strategies				
Greater economic stability within the industry	2.716	0.005	0.613	3.613
Long term training schemes	2.540	0.008	0.484	3.484
Establishment of training institutions	2.327	0.013	0.516	3.516
Considerate short term training schemes	2.528	0.008	0.452	3.452
Make aware and attract unemployed persons	2.208	0.018	0.419	3.419
Introduction of new technologies	2.752	0.005	0.645	3.645
Contractor Response Strategies				
Manpower planning	3.057	0.002	0.581	3.581
Wage increments	2.867	0.004	0.645	3.645
Positive working environment	2.706	0.006	0.484	3.484
Sufficient and accredited training programs	1.871	0.036	0.290	3.290
Benefits and incentives	3.580	0.001	0.742	3.742
Greater use of machineries	0.338	0.369	0.065	3.065
Motivation and encourage the team work	0.895	0.189	0.161	3.161
Subcontracting	0.329	0.372	0.065	3.065
Hiring multi-skilled labourers	-2.284	0.015	-0.484	2.516
Rescheduling the work	3.684	0.000	0.839	3.839
Instruct labourers to work overtime	3.437	0.001	0.548	3.548
Greater use of prefabricated items	1.545	0.067	-0.258	2.742

From the respondents' perceptions, it is clear that introduction of new technologies within the industry is one of the best approaches to tackle the construction industry skills shortage. Greater economic stability within the industry and establishment of training institutions were identified as most important strategies to cater the demand of the skilled labour with mean values of 3.613 and 3.516 respectively. All most all the other strategies identified under industry and government response strategies were ranked as effective strategies around the value of 3. Hence, the strategies proposed can be considered as important in contributing to the resolution of the skills shortage.

The majority of the strategies under contractor responsive strategies were identified as high effective strategies to the construction industry. Rescheduling the work has gained more responses as a high effective strategy for contractors' in a skilled workforce shortage. This is followed by wage increments, positive working environment, benefits and incentives, instruct labourers to work overtime and manpower planning as primary solutions to the skills shortage. Subcontracting (mean value = 3.065) and hiring multi skilled laboures (mean value = 2.516) was ranked as less effective strategies. Hence, the respondents did not favour the strategies of recruiting alternative sources of construction labour. The mean value for greater use of prefabricated items and greater use of machineries indicated the poor response towards the substitution of new technologies and design changes attributable to the skill shortage. This is strongly supported by the mean value obtained for the greater use of machineries.

However, the positive working environment, benefits and incentives, motivation and encourage the team work and wage increment have a considerable impact to the workforce to reside in the industry. Hence, these strategies are significant in retaining the exiting the workforce in the industry.

5. CONCLUSIONS AND RECOMMENDATIONS

It is an accepted fact that the construction sector plays an important role as being crucial and strategic to the development of the economy. Construction sector remains as an important part of an economy and it contributes to economic stabilization both in boom and bust. Therefore, construction materializes to have a fair relationship with national output. Construction is not only an integral part of the modernization process, but its labour-intensive nature makes it particularly attractive as a means of creating employment in developing countries. Labour intensive nature of the construction industry has created an immense role for the skilled labourers within the industry. However, the instability nature of the industry has been affected on the stabilization of the skilled labour demand and supply. Therefore, this research provides a useful starting point for determining the probable future skill shortages in skills trades relate to building construction.

Questionnaire survey was used to fulfil the aim of the study on investigating the future requirement of skilled labour in Sri Lankan building construction industry. Survey was carried out among 31 Project Managers in construction industry.

Findings highlighted that the most of the identified skills are significant to the building construction sector. In fact, out of the thirty one survey respondents who employ skilled labour in their projects, majority reported that skills related to service installation is significant as much as the skills related to structural construction.

The current demand and supply of the skill trades shows an unbalanced level in considerable skills due to lack of training programmes. Lower wage level, poor attitude of younger generation and working conditions have created scarcity in skill supply which adversely influenced on skilled labour demand with the increment of construction output in the present days of Sri Lankan construction industry. Hence, most of the skills have a shortfall except in plastering and bricklaying.

Similarly, most of the skill trades identified within the study, reveals a mismatch in likely skill supply and demand attributable to scantiness of skill workforce planning in the industry. There is a likely demand for some of the traditional skills in the building market in Sri Lanka. However, the likely supply does not show an adequacy level in both traditional skills and upcoming skills. An action plan considering should be developed by employers and trade associations to cater the demand of skilled labour in the industry.

The industry response for the skilled shortage in the industry is in a low level and stabilisation of the construction industry becomes a major determinant of the skilled labour shortage. If the construction industry hopes to sustain or increase the number of people entering the industry in future years, construction employers must be actively encouraged to reconsider their current approach to develop through accredited training programmes. Consequently, firms should adjust their operations to adapt to available supplies of labour and other inputs. In the meantime, government and industry level perception towards this global phenomenon is a necessity.

6. REFERENCES

Agapiou, A., 1996. *Forecasting the Supply of Construction Labour*. Thesis (PhD). Loughborough University: Loughborough.

Briscoe, G. and Wilson, R.A., 1993. *Employment Forecasting in the Construction Industry*. Ashgate Publishing.

Chan, P.W. and Dainty, A.R., 2007. Resolving the UK Construction Skills Crisis: ACritical Perspective on the Research and Policy Agenda. *Construction Management and Economics*, 25(4), 375-386.

C & SD, 2004. *Unemployment Rate by Previous Industry, Census and Statistics Department, Hong Kong Government, Hong Kong* [online]. Available from: http://www.info.gov.hk/censtatd/eng/hkstat/fas/labour/ghs/unemp_by_p_ind_index.html [Accessed 28 May 2015].

Dainty, A.R., Ison, S.G. and Briscoe, G.H., 2005. The construction Labour Market Skills Crisis: The Perspective of Small–Mediumsized Firms. *Construction Management and Economics*, 23(4), 387-398.

Jayalath, J., 2011. *Human Resource Demand Forecasting–Sri Lankan Experience* [online]. Available from: http://youthskills.lk/HRDAsiaConf/document/presentation_day_01/FullPaper_Jayalath.pdf [Accessed 28 May 2015].

Jayawardane, A.K.W. and Gunaradena, N.D., 1998. Construction Workers in Developing Countries: A Case Study of Sri Lanka. *Construction Management and Economics,* 16(5), 521-530.

Jayawardena, H.S., Senevirathne, K. and Jayasena, H.S., 2008. Skilled Workforce in Sri Lankan Construction Industry: Production Vs. Acceptance. 460-470.

Jorssen, V.G., 1989. Planning for Manpower Requirements: StaffPlan–an Analytical Model. *International Journal of Manpower*, 10(4), 3-14.

Kikwasi, G., 2013. Causes and Effects of Delays and Disruptions in Construction Projects in Tanzania. *In Australasian Journal of Construction Economics and Building-Conference Series*, 1(2), 52-59.

Mackenzie, S., Kilpatrick, A.R. and Akintoye, A., 2000. UK Construction Skills Shortage Response Strategies and an Analysis of Industry Perceptions. *Construction Management and Economics*, 18(7), 853-862.

Osei, V., 2013. The Construction Industry and Its Linkages to the Ghanaian Economy-Polices to Improve the Sector's Performance. *International Journal of Development and Economic Sustainability*, 1(1), 56-72.

Oseghale, B.O., Abiola-Falemu, J.O. And Oseghale, G.E., 2015. An Evaluation of Skilled Labour Shortage in Selected Construction Firms in Edo state. *Nigeria,* 4(1), 156-167.

Ozorhon, B., Arditi, D., Dikmen, I. and Birgonul, M.T., 2007. Effect of Host Country and Project Conditions in International Construction Joint Ventures. *International Journal of Project Management,* 25(8), 799-806.

Ramsaran, R. and Hosein, R., 2006. Growth, Employment and the Construction Industry in Trinidad and Tobago. *Construction Management and Economics*, 24(5), 465-474.

Rwelamila, P.D., 2002. Creating an Effective Industry Strategy Construction in South Africa. *Building Research and Information*, 30(6), 435-445.

Wedikkara, C., 2006, *Real Estate and Construction: Lanka Business* [online]. Available from: http://www.lankabusinessonline.com/news/sri-lanka-faces-skilled-worker-shortage-to-meet-construction-boom/1322729967 [Accessed 28 May 2015].

Wong, J.M., Chan, A.P., and Chiang, Y.H., 2005. Time Series Forecasts of the Construction Labour Market in Hong Kong: the Box-Jenkins Approach. *Construction Management and Economics*, 23(9), 979-991.

Wong, J.M., Chan, A.P., and Chiangn, Y.H., 2006. The Changing Construction Labour Market: A Case ofHong Kong. *Journal of Engineering, Design and Technology*, 4(1), 1-17.

Wong, J.M., Chan, A.P. and Chiang, Y.H., 2011. Construction Manpower Demand Forecasting: A Comparative Study of Univariate Time Series, Multiple Regression and Econometric Modelling Techniques. *Engineering, Construction and Architectural Management*, 18(1), 7-29.

APPLICABILITY OF ICTAD PRICE FLUCTUATION FORMULA FOR GOVERNMENT FUNDED INTELLIGENT BUILDING PROJECTS

S.C. Jayaweera, B.A.K.S. Perera and S.J.A.R.S. Jayasinghe*
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In high inflationary situations, government fiscal policies etc., have an effect on price fluctuations in Intelligent Building (IB) projects which are funded by the Government. It can increase the cost of material, plant and labour, while increasing the risks that both the contractors and the clients have to face. The use of the ICTAD price fluctuation formula in construction projects of more than three months duration, especially those of the Government, will help to recover these unforeseen costs at least to a certain extent. The formula however has its own inherent constraints. The objective of this research is to identify these constraints and suggest solutions to overcome them.

An expert survey and a case study were done towards achieving the main objective. The case studies comprised a document review and semi structured interviews. Code-based content analysis was used to identify the significant conclusions that could be made from the semi-structured interviews. The QSR. NVivo computer software was used to simplify the content analysis.

The results emphasised that in the case of IB projects of the Government, there is a difference between the actual price fluctuations and the corresponding figures obtained using Institute of Training and Development (ICTAD) price fluctuation formula as the formula had its own limitations. Therefore there is a need to modify the way the 'cost adjustment' factor is determined in IB projects of the Government. By using reliable price indices while taking steps to improve the currently available norms, it will be possible to make available to future IB projects a better operating framework.

Keywords: *ICTAD Price Fluctuation Formula; Intelligent Building (IB); Price Fluctuation.*

1. INTRODUCTION

The price fluctuations of a project being unavoidable and difficult to forecast, they are important to the project and also make the undertaking of the project risky (Subasinghe, 2009). According to Ashworth (1999), fluctuation which depends on the provisions in a contract, is the allowance made for the cost increases caused by inflation irrespective as to whether the contractor has to be compensated or not Several formulae such as those developed by the Federation International Des Ingenieurs Conseils (FIDIC), NEDO, Osborne, Baxter and the Institute for Construction Training and Development (ICTAD) are being used in the construction industry to reimburse price fluctuations (Harshana, 2013). In Sri Lanka, two methods are being used for computing these price fluctuations, i.e traditional method and the formula method (Liyanage, 2005). Ranathunge (2010) pointed out that the calculation of fluctuations through the formula method is simpler and less time consuming when compared to calculating same using the traditional method.

The formula method has been approved by the Government for compensating price fluctuations and its use ihas been made mandatory for public sector projects (Jayalath, 2013). Sub Clause 5.4.2 of the Procurement Guidelines related to Goods and Works published by the National Procurement Agency (2006) states that in any contract for works the duration of which exceeds three months, the price variation formulae for the Sri Lankan Rupee component shall be included in the bidding document and the contract agreement.

* Corresponding Author: E-mail - jruchini@yahoo.com

Subsequent to the end of the war, the Government has been increasingly investing in the building construction sector and it can be seen that a significant proportion of this investment is on Intelligent Buildings (IB) (Central Bank Sri Lanka, 2012). Intelligent Building Construction is a collection of several new construction techniques which have advantages over traditional methods (Santos, 2011). So and Chan (1999) stated that in these intelligent buildings, computerized systems perform specific and isolated tasks while being integrated with other systems. According to the current rules and regulations specified for IB projects of the Government, the ICTAD price fluctuation formula although it has its own short comings, has to be used to calculate price changes. This formula however has not been adjusted or revised to suit the construction techniques that have been developed of late. In this context it is essential to analyse the impact and the risk of using the current ICTAD price fluctuation formula in Intelligent Building projects of the Government so as to identify the ways of minimising these negative effects. Therefore, this research has adhered to clear and concise literature review on price fluctuation recovery methods and the significant of government IB projects. Thereafter, data collection methods such as interviews and case study were carried out in identifying the issues when applying ICTAD formula in IB projects. Ultimately the aim of this research has been accomplished by identifying the constraints of using the formula in IB projects of the Government and at proposing solutions to overcome them in order to use them in an efficient and effective manner in government IB projects.

2. LITERATURE SYNTHESIS

Fluctuations are granted to contractors as compensation in accordance with conditions laid out in the relevant contracts when there is an increase in building costs (Harshana, 2013). These cost increases will differ depending on the extent of inflation (Ashworth and Hogg, 2002). Liyanage (2005) stated that the so increased costs have a significant effect especially on large scale projects of very long duration. Subasinghe (2009) also stated that price fluctuations, being unavoidable and difficult to forecast, will have a significant impact on a project and that the parties to the contract could not be made liable to these price fluctuations. Therefore it can be stated that price fluctuations contribute significantly to the risks that have to be faced by the construction industry.

2.1. CAUSES OF PRICE FLUCTUATIONS

Sendooran (2005) defined that prices can increase for several reasons such as the increase of oil prices in the world market and changes in technology and inflation. However depending on the conditions and the methods of construction used in the projects concerned, the reasons for fluctuation could vary. According to Hanna and Blair (1993), market conditions, inflation, actions on the part of the Government, taxes and political influence are the fundamental reasons for these fluctuations.

2.2. PRICE FLUCTUATION FOR DIFFERENT TYPES OF CONTRACTS

There are two types of contracts related to construction projects as indicated in Figure 1. i.e. contracts with fixed prices and those in which price fluctuations are allowed (Subasinghe, 2009).

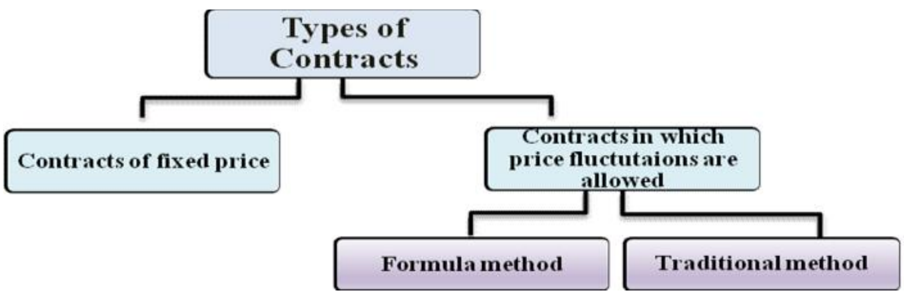


Figure 1: Different Types of Contracts

Suraweera (2001) emphasised that depending on the contractual clauses provided in the relevant agreements, price fluctuations could either be recoverable or non-recoverable. According to Cook (1991), in fixed price type contracts the costs of material and labour are not considered as those that could get affected by fluctuations. Hence, price fluctuation clauses are not provided for in this type of contracts with both parties having to agree on a fixed contract sum and in case of price fluctuations there will be no contract sum adjustments (Ramus, 1981). Subasinghe (2009), identified that these types of contracts can make it very risky for the contractor to undertake the project since he will have to take full responsibility for all costs. On the other hand, according to Ramus and Birchall (1996), contracts in which price fluctuations are allowed are identified as contracts containing provisions for reimbursement of increases of labour costs and material prices as well as statutory costs. A price fluctuation formula is made available in these projects to calculate costs due to price fluctuations and provide guidance on cost changes (Anon, 2009). Price fluctuation clauses in the standard forms of contract are described below.

2.3. Price Fluctuation Clauses in Standard Forms of Contract

Price fluctuation clauses are included in Standard Forms of Contracts such as the FIDIC Standard Form of Contract, ICTAD Standard Bidding Document and Procurement Guidelines (Subasinghe, 2009). Sub Clause 70.1 of the Fourth Edition of the 1987 Red Book - FIDIC Conditions of Contracts, deals with the fluctuations in the labour and material costs or in any other factors that affect the cost of construction. It is difficult to ascertain the fluctuations purely based on information provided in these standard forms unless there is official control of the rates of wages in the country where labour is employed. Clauses 38, 39 and 40 of the 1980 Edition of the Joint Contracts Tribunal (JCT) Standard revised in 1989 provide provision for price fluctuations. These provisions focus on limited fluctuations (firm price), full fluctuations and on the price adjustment formula and Brook (2004) stated that no increase has been allowed therein for overheads and profits, site supervision, site establishment costs, plant and temporary work. Clause 13.7 of the ICTAD (2007), deals with price fluctuations as adjustments for changes in cost. ICTAD (2007) states that the amounts computed from the formula given in this Clause for changes in the cost of labour, material, plant and other inputs to the works, shall be added to or deducted from the payment to the contractor. In the Procurement Guidelines published by the National Procurement Agency it is stated that in the price adjustment of any contract for works the duration of which exceeds three months, the price variation formula for the Sri Lankan rupee component shall be included in the bidding document and in the contract agreement. The price variation formula developed by the ICTAD has to be used in such cases even though there can also be other recovery methods.

2.4. Price Fluctuation Recovery Methods Practiced by the Construction Industry

Liyanage (2005) concludes that to compensate the parties to a contract for fluctuations, there are two main methods of calculating the price fluctuations, i.e traditional method through which the contractor will be paid for the actual costs incurred and the formula method through which the contractor will be compensated for the price fluctuations depending on the value of work done. Turner (cited Subasinghe 2009) stated that the traditional method is to make an adjustment for the contractor's expenditure relating to fluctuations taking the prime cost as the basis. According to Suraweera (2001), the formula method will calculate a sum or sums which will compensate the parties to the contract for losses incurred by them due to an increase or decrease in costs (Suraweera, 2001). There could be a slight difference between what is recoverable using the formula method and what is recoverable using the traditional method. The formula method does not calculate the actual amount of losses incurred (Ramus, 1981). Most contractors who use the formula method to compute fluctuations agree that the amount recovered is a reasonable recovery of the increased costs (The Chartered Institute of Building [CIB], 1997).

2.5. ICTAD Price Fluctuation Formula

This formula has been developed for the contracts whose contract value exceeds Rs. 10 Million and is applicable for adjustments for changes in local costs. De Mel (2008) stated that the ICTAD formula has been developed using several assumptions which minimise the complexity of the formula and make the formula easy to use.

$$F = \frac{0.966\,(V - V_{na})}{100} \sum_{\text{All Inputs}} \frac{P_x (I_{xc} - I_{xb})}{I_{xb}} \qquad \text{(Eq. 01)}$$

V = Valuation of work done for period
V_{na} = Non-adjustable elements
P_x = Input percentage
I_{xb} = Base index for input X, publish by ICTAD
I_{xc} = Current index for input X, publish by ICTAD

Subasinghe (2009) demonstrated that even though there are several price fluctuation methods, the ICTAD formula is the most prominent and beneficial method practiced in most of the traditional projects and IB projects in Sri Lanka. Among them IB projects are important due to their unique and special features.

2.6. INTELLIGENT BUILDINGS

The IB aims at rearranging and enriching the capabilities of independent building management and communication systems through well planned and coherent building concepts (Croome, 2004). It has become a viable and a justifiable alternative for the evaluation of a cost of a building against its life cycle benefits. According to Chapman (2004), special features of IB projects are;

- Maximum transparency and communication among subsystems
- Electrical design features that are tailored to suit the Intelligent Building concept
- Flexible and modular High Voltage Air Conditioning (HVAC) systems
- Availability of high-speed fibre optic communication networks for carrying data and video
- Individually controlled HVAC terminal units which could be controlled by the occupants themselves

2.7. ASSESSMENT OF RESEARCH GAP THROUGH THE LITERATURE SYNTHESIS

Considerable research has been conducted worldwide on price fluctuation in construction projects. However only very little research has been done for the use of the ICTAD price fluctuation formula used only in Sri Lanka, that too in relation only to traditional construction projects. Therefore this research is aimed at identifying issues that arise when the ICTAD price adjustment formula is used in the Intelligent Building projects of the Government and makes suggestions to overcome the identified issues.

3. RESEARCH METHODOLOGY

Creswell (2003) concluded that a suitable research approach has to be selected to deal with any research problem. The Qualitative research approach was used in the research to arrive at the conclusions. The background study in this particular research revealed a research gap as there were no available studies on the accurate application of the fluctuation formula to the IB projects. A comprehensive literature survey was initially conducted to determine the concept of price fluctuation and price fluctuation recovery methods related to intelligent buildings.

The selection of an appropriate data collection method is the main element of a research. Due to their significance, an expert survey and a case study were identified to find solutions for the issues that were identified. Kumar (2011) indicated that, the basic purpose of an expert survey is to support interview outcomes by identifying key factors and case studies in the relevant areas. Data collection was done through an expert survey. Yin (2003) stated that, an empirical inquiry would investigate a contemporary phenomenon in the context of a real-life situation where the boundaries between each other are not clear and that it would obtain evidence from multiple sources.

A preliminary interview survey was carried out among industry experts who were very familiar with the ICTAD price fluctuation formula and IB projects so that a comprehensive guideline could be developed to conduct case study interviews. The empirical study was conducted using a case study research approach. The unit of analysis for the case studies was IB projects, and the research was carried out both at individual and organisational levels. The number of case studies was limited to two and they were examined mainly through semi structured and face-to-face interviews. Eight interviews were conducted and the NVIvo 2010 software was used for analysing the data collected. The data collected by reviewing documents on monthly fluctuations pertaining to each case was analysed using statistical data analysis methods with a view to producing a more realistic outcome. Table 1 is provided with a details of respondents of the interview.

Table 1: Details of Interviewees

Interviews Code	Designation	Years of Experiences	Organisation Category
Respondent A	Chief Quantity Surveyor	23	Consultancy
Respondent B	Chief Quantity Surveyor	14	Consultancy
Respondent C	Assistant Director	21	Regulator
Respondent D	Senior Quantity Surveyor	18	Contractor
Respondent E	Construction Managers	13	Consultancy
Respondent F	Chief Quantity Surveyor	11	Contractor
Respondent G	Senior Quantity Surveyor	16	Consultancy
Respondent H	Project Manager	13	Contractor
Respondent I	Senior Quantity Surveyor	14	Consultancy
Respondent J	Project Manager	16	Contractor

4. ANALYSIS AND RESEARCH FINDINGS

There is a precise and a clear outcome from the analysis of the research findings. Intelligent building projects have special features exclusive to them. They have maximum interaction among their different systems and during their construction phase material is purchased in bulk. Moreover most of the IB projects in the state sector, a s emphasised by Respondent B, are carried out in accordance with Board of Investment (BOI) regulations of the Government. A special feature of the IB projects of the Government is the fact that it is mandatory to apply the ICTAD formula in their implementation. These projects take a long time for completion as the buildings concerned are designed to have automated systems. IB projects as explained by Respondent A, use new technologies to provide building services. According to this respondent, Intelligent Buildings can think and do functions by themselves implying that hey contain fully automated functions programmed according to a special schedule which enables them to function independent of others. All these features were revealed during the expert survey and some of the buildings selected for case studies had these special features. Figure 2 illustrates the special features of IB projects.

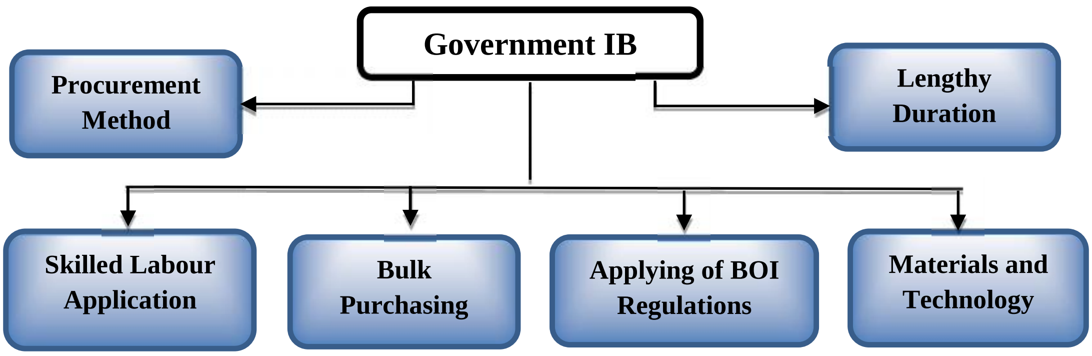


Figure 2: Special Features of IB Projects

The survey also revealed the following assumptions which had been used in developing the ICTAD formula:

- Inputs are uniformly distributed through the projects
- Indices used are same irrespective of the location of the building in the country
- Foreign exchange conversion rates do not fluctuate
- Interim statements will be submitted by contractors every month

Since this research mainly focused on the applicability of ICTAD formula to Intelligent Buildings of the Government, the practicability of applying this formula can be determined through the research. In IB projects, there can be several mechanical, electrical and plumbing (MEP) items such as BMS, lifts, electrical distribution systems, systems, the cost of which would amount to a considerable percentage of the total contract sum. i.e. 30%-40%. The ICTAD formula will not be able to recover the price fluctuations related to these systems as most of these costly items are not considered in calculations because of the non-availability of the relevant indices. Thus this formula will not help either the client or the contractor to make accurate calculations when there are special features. It may at times even be beneficial only to one party. Further, the calculation of input percentage has become a complex and a tedious process due to the unavailability of appropriate and updated Building Schedule of Rates (BSR) norms and sometimes this leads to conflicts between the contractor and the client. The Interviewee D specifically emphasised that in the case of certain types of material, there is no source from which the particular categories to which these material belong could be identified making it difficult to submit claims. He further said that input percentages have to be prepared for a group of Bills of Quantities (BOQ) items and that input quantities are determined by using norms. The other limitations are the non-consideration of parity rate fluctuations and market trends of indices, high taxes on imported material, inaccurate assumptions, etc.

In order to study the relevance of the findings of the expert survey to a practical situation, an in-depth analysis of two selected cases was done. The two case studies revealed that there is a difference between the actual fluctuation and the fluctuation computed using the formula. The following formula was used to compare the two fluctuations:

$$Amount\ of\ actual\ price\ fluctuation = \frac{100}{90}\sum_{i=1}^{n} Q_i\, \mathrm{a}_i \qquad \text{(Eq. 02)}$$

Q = Quantity of Input

λ_i = Price difference of Input *i*

Using this formula, thirteen Interim Payment Certificates (IPCs) of Case A and Case B were analysed to verify whether there had been any difference between the amount of actual price fluctuation and the amount compensated using the ICTAD formula. Table 2 provides the details of the two cases selected for the study.

Table 2: Details of Two Cases

Project	Case A	Case B
Project Cost (Rs.)	2.6 billion	4.2 billion
Project Duration	40 months	36 months
Type	Administrative complex	Administrative complex
Stories	12 stories	13 stories
Net Floor Area	46000 m^2	40000m^2
Location	Baththaramulla	Colombo 01

Table 3 provides a summary of the analysis of these differences relating to case A.

Table 3: Difference Between Actual Fluctuation and Fluctuation Computed Using the Formula

IPC (Case A)	Work Done According to IPC	Amount of Actual Fluctuation	Amount Paid as Fluctuation	Amount Payable to the Contactor as Fluctuation	Amount Over Paid as Fluctuation	Fluctuation Difference
1	19,016,569.04	747,734.29	890,159.87	890,159.87	142,425.58	0
2	37,107,568.52	1,250,848.60	2,156,635.52	2,156,635.52	905,786.92	0
3	34,614,720.11	1,272,891.90	1,871,899.85	1,871,899.85	599,007.95	0
4	17,100,543.52	994,930.36	1,715,397.17	1,715,397.17	720,466.81	0
5	28,112,589.01	1,481,047.16	1,791,033.78	1,722,147.86	309,986.62	68,885.91
6	27,671,812.57	1,273,011.70	1,818,588.14	1,653,261.95	545,576.44	165,326.19
7	30,721,629.98	1,291,955.33	2,417,206.74	2,083,798.91	1,125,251.41	333,407.83
8	45,418,610.40	1,642,867.06	2,859,805.63	3,042,346.41	1,216,938.57	(182,540.78)
9	27,171,224.88	1,107,024.20	2,178,337.94	1,785,522.90	1,071,313.74	392,815.04
10	11,732,672.18	777,643.66	1,346,989.92	1,388,649.40	569,346.25	(41,659.48)
11	5,370,096.04	364,253.42	540,861.14	551,899.12	176,607.72	(11,037.98)
12	79,465,390.65	2,891,446.03	5,782,892.06	5,354,529.69	2,891,446.03	428,362.37
13	41,492,255.75	1,715,883.38	2,917,001.74	2,859,805.63	1,201,118.36	57,196.11
Total	**404,995,682.6**	**16,811,537.09**	**28,286,809.50**	**27,076,054.29**	**11,475,272.4**	**1,210,755.2**

The fluctuation calculated using the ICTAD formula is taken as the amount that is payable to the contractor. The difference between the actual fluctuation and the calculated fluctuation is considered as fluctuation over paid. Fluctuation difference which is indicated in the last column indicates the difference between the payable amount and the actual amount paid.

By referring to Table 2, it can be clearly seen that there is a difference between the actual fluctuation and the fluctuation paid to the contractor. To illustrate this situation in detail, the percentage of this fluctuation as against the work done is calculated and shown in Table 4.

Table 4: Percentages of Fluctuation in Case A

IPC	Actual Fluctuation %	Fluctuation Paid to the Contactor%	Fluctuation Over Paid %
1	0.04	0.05	0.01
2	0.03	0.06	0.02
3	0.17	0.01	-0.05
….	….	….	….
….	….	….	….
12	0.04	0.15	0.12
13	0.04	0.07	0.03
Project	**0.09**	**0.15**	**0.06**

According to Table 3, the actual fluctuation in Case A is 9% of the total work done. However, the client has paid to the contractor 15% as fluctuation cost against the total work done. It is therefore clear that the client has overpaid 6% of the total work done because of the limitations of the ICTAD formula when applied to IB projects of the Government. The findings of a similar analysis done for Case B are graphically shown in Figure 3.

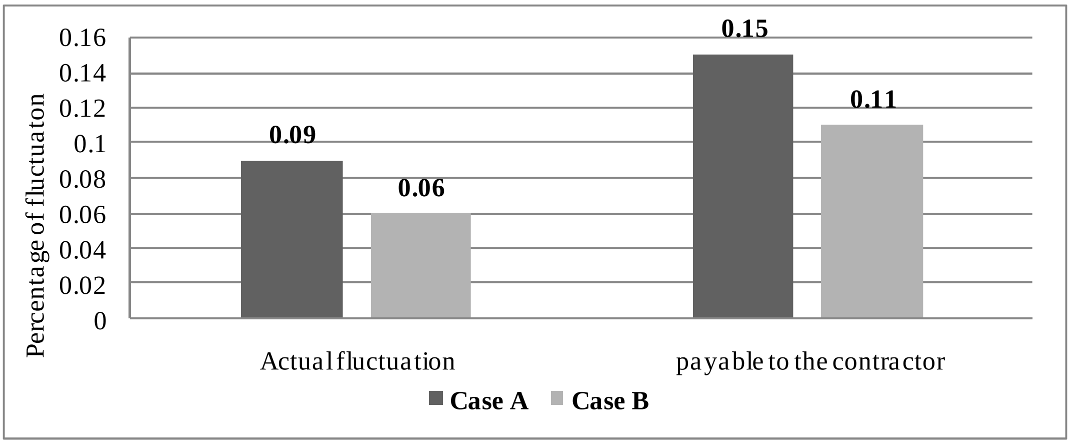


Figure 3: Difference between Actual Fluctuation and Formula Fluctuation in Case A and Case B

Table 3 and Figure 3 clearly indicate that here have been overpaid amounts in both cases which was 6% in Case A and 5% in Case B. This over paid amounts called Fluctuation Differences in Table 3 and Figure 3 are due to following factors:

- Base and current indices being not properly applied in accordance with instructions provided in the ICTAD publication - ICTAD formula method for adjustment to contract price due to fluctuation in prices.
- Most of the actual prices of material and relevant price variations being not included in the cost of work actually done.
- Cost of items related to provisional sums being not deducted from the cost of work done which benefits the contractor when compensated through the ICTAD formula.

The findings enabled to identify the suggestions that can be made to mitigate the effects of the limitations of ICATD price fluctuation formula while emphasising the importance of identifying factors that can be used to revise the formula to suit IB projects. According to interviewees, new indices related to special material and MEP items used in IB projects have to be determined as these components contribute considerably to the cost of these projects. Since, in the literature review Chapman (2004) has emphasised that IB projects are very much concern on advanced services installations and that indicates that advanced and new types of materials are being used at sites. Whereas, in ICTAD formula fluctuation restricted to several inputs like material, plant and equipment and labour published from the bulletin (Suraweera, 2001). Hence it is important to have these indices as otherwise the results obtained using the formula may not be accurate and in developing these indices due consideration has to be given to demographical factors. In the past , these indices would have been developed based on prices that were available in and around Colombo and presuming that they are same in other areas of the country as well, which is not reasonable as the type of resources obtainable and available in those areas could be different.

Furthermore, the cost adjustable factor needs to be changed from 15% to 30% and the coefficient factor from 0.966 to 0.855 respectively since in IB projects the cost adjustable factor is around 30%. Since according to Samareweera (2008), inaccurate assumption like equal distribution of inputs though out the contract duration is used to calculate the fluctuation easily. Therefore, the necessity of the appropriate adjustment to the formula comes to the stage. Furthermore, enhancement of current available norms and develop missing norms to calculate the input percentages correctly is also an important suggestion. At present outdated BSR norms are used and some of the required norms are not available at all. Apart from that, in IB projects Chapman (2004) has highlighted that, number of various new materials, specialised skilled labours and well equipped plants are used. Therefore, there should be more focus on the enhancement of currently available norms and updating the BSR according to the requirement in IB projects. Thereby an efficient evaluation and calculation of price fluctuation can be done for the IB projects in Sri Lanka, in order to carry out the pre-construction process in a reliable manner and to provide a better output for the government as well.

5. CONCLUSIONS AND RECOMMENDATIONS

IB projects are special when compared to traditional building projects as they have distinctive features. They use modern technologies, innovative material, and different procurement systems and at times continue for months and years. Therefore, there is a strong probability in price escalations of labour, material and equipment during the implementation of the project. The ICATD formula has several significant drawbacks when it is used to calculate price escalation in IB projects of the Government, as it does not suit the modern construction methodologies. Therefore, this study was aimed at identifying the limitations of the ICTAD formula when it is applied to IB projects of the Government and to presenting suggestions to overcome those limitations.

In order to accomplish the aim of the research, a mixed approach was adopted by collecting primary data from semi structured interviews and from a close ended case study survey. A documentary survey was conducted to obtain secondary data from documents that have already been published. The analysis of this data revealed that both the traditional method and the formula method deal with price fluctuations and that at times the contractors are overpaid for price fluctuations as there are deviations from the ICTAD formula when price fluctuations are computed. The limitations of the formula method were also identified and improvements to it were suggested by highlighting some of the areas which are not clear. Therefore it is necessary to change the ICTAD formula to 0.855 and a proper method of calculation has to be proposed to calculate the quantity of work done during the respective valuation period. Price indices are one of the most important factors to be considered in calculating fluctuations according to the ICTAD formula method. These indices have to be therefore prepared as accurately as possible. The main drawback of the indices is that they have been prepared on a national basis without giving due consideration to the possibility that there could be regional variations thus resulting in inaccuracies in the calculated fluctuations. Therefore, in order to ensure a fairly accurate calculation of the fluctuations, the ICTAD will have to focus on preparing indices district wise as location indices. As it is very essential for the industry to have a better understanding of the ICTAD formula, it is also necessary to conduct training programs for the members of the industry who are involved in calculating price fluctuations. These steps will enable the proper use of price fluctuation formula leading eventually to better practices in the construction industry.

6. REFERENCES

Anon, D., 2009. Price Adjustment Formula for Construction [online]. *Key Changes*, 1(1), 1-3. Available from: http://doi:10.1162/qjec.2010.125.2.675 [Accessed 11April 2014].

Ashworth, A., 1999. *Cost Studies of Buildings*. 3rd ed. New York: Addision Wesley Longman Publishing.

Ashworth, A. and Hogg, K., 2002. *Willis's Practice and Procedure for the Quantity Surveyor*. 11th ed. Malden: Blackwell Science Ltd.

Brook, M., 1978. *Estimating and Tendering for Construction Work*. 2nd ed. Great Britain: Reed Educational Publishing Ltd.

Central Bank of Sri Lanka, 2012. *Annual Report 2012*. Colombo: Department of Government Printing.

Chapman, A., 2004. *Intelligent Buildings Design and Building Management Systems, code and design 2004-07* [online]. Gary Mills Technical Content 2004. Available from: http://www.businessballs.com/ intelligentbuildingsdesign.htm [Accessed 15April 2014].

The Charted Institute of Building [CIB], 1997. *Code of Estimating Practice*. 2nd ed. Berkshire: Englemere Services Ltd.

Cook, A.E., 1991. *Construction Tendering*. London: Batsfor Ltd.

Creswell, J.W. and Clark, V.L.P., 1998. *Qualitative Inquiry and Research Design*. California: SAGE publications.

Croome, D.C., 2004. *Intelligent building: Design, management and operation.* 2nd ed. London, Austrailia: Thomas Telfore Publishing.

De Mel, J., 2009. *Basic Concepts and Derivation of ICTAD Formula and Introduction of ICTAD Formula.* ICTAD price fluctuation formula. Colombo: Institute for Construction Training and Development.

Hanna, A.S. and Blair, A.N., 1993. A Rational Method for the Treatment of Escalation in Construction Costs [online]. *Organisation and Management of Construction the Way Forward,* 1(3), 1415-1425. Available from: research.library.mun.ca/1361 [Accessed 15 April 2014].

Harshana, A.S., 2013. *Calculating Input Percentage of ICTAD Price Fluctuation Formula: Method and Issues.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

Institute for Construction Training and Development (ICTAD), 2007. *Bulletin of Construction Statistics.* Colombo: ICTAD.

Institute for Construction Training and Development (ICTAD), 2007. *Standard Bidding Document Procurement of Works-Major Contracts.* Colombo: Institute for Construction Training and Development, (ICTAD/SBD/02).

Jayalath, C., 2013. *Arguing Construction Claims.* 1st ed. Colombo: S Godage and Brothers Pvt Ltd.

Kumar, R., 2011. *Research Methodology: A Step-By-Step Guide for Beginners.* 3rd ed. New Delhi: Sage Publications Inc.

Liyanage, B., 2005. *Examination of Price Fluctuation Reimbursement by Simplified ICTAD Formula.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

National Procurement Agency, 2006, January. *Procurement Guideline 2006 : Good and Works* [online]. Colombo: Department of Government Printing. Available from: www.treasury.gov.lk//Procurement Guidelines2006_amded12June.pdf [Accessed 20 April 2014].

Ramus, J.W., 1981. *Contract Practice for Quantity Surveyors*. 3rd ed. Guildford and Kings Lynn: Great Britain Bidders Ltd.

Ramus, J. and Birchall, S., 1996. *Contract Practice for Surveyors*. 3rd ed. Great Britain: A Division of Read Educational and Professional Publishing Ltd.

Ranathunga, H.K., 2010. *The Impact of ICTAD Formula Price Fluctuation on Road Project.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

Santos, M., 2011. *The Intelligence of Intelligent Buildings the Feasibility of the Intelligent Building Concept in Office Building* [online]. Doctorial Dissertation. University of Technology, Helsinki. Available from: http://www.irbnet.de/daten/iconda/CIB10128.pdf [Accessed 20 April 2014].

Samaraweera, D., 2008. *ICTAD Price Fluctuation Formula for Computation of Price Fluctuation in Construction Contracts*. Colombo: ICTAD.

Sendooran, B., 2005. *Impact of Oil Price in Construction Industry.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

So, A.T.P. and Chan, W.L., 1999. *Intelligent Building System* . Massachusetts: Kluwer Academic Publisher.

Subasinghe, S.K., 2009. *Appropriateness of ICTAD Price Fluctuation Formula for Road Projects.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

Suraweera, E.H., 2001. *Inflation and Dealing with Price Fluctuation.* Unpublished Dissertation (B.Sc.). Department of Building Economics, University of Moratuwa, Sri Lanka.

Yin, R.K., 2003. *Case Study Research: Design and Methods.* 3rd ed. Thousand Oaks: Sage Publications.

APPLICATION OF LEAN CONSTRUCTION PRINCIPLES AND PRACTICES TO ENHANCE THE CONSTRUCTION PERFORMANCE AND FLOW

Upeksha Hansini Madanayake*
School of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Lean thinking has now become a radical philosophy that has permeated and expanded in to several sectors other than just manufacturing. The concept of Lean thinking evolves the optimization of work flow related functions and the possible outcomes with its contribution to sustainable construction. Correspondingly, application of lean theories and principles in to construction sector has the potential to improve the quality of work, aggravate the function related effectiveness, minimize the cost components/ waste and increase the overall profit in both strategic and operational levels. Apparently, it appears that the lean techniques have immensely contributed for many possible cost reductions compared with the traditional project management techniques. However, few barriers for the implementation of lean principles are also on the contrary. The research aims to investigate the effects of Lean Construction applications while identifying the prevailing barriers related to the same. The research has exploited qualitative methods to explore the aforementioned research question. This paper presents an exploratory study from extent literature, predominantly based on a case study of a project management organisation whereas the arguments were strengthened and underpinned by the formation of a conceptual framework to explore the contribution of implementing lean construction techniques in sustainable construction. The research findings would ultimately help different stakeholders on applying lean theories in to practice.

Keywords: *Integrated Project Delivery System; Last Planner; Lean Construction; Lean Manufacturing.*

1. INTRODUCTION

1.1. BACKGROUND AND RATIONAL

Construction industry in UK has the potential to improve its capabilities and efficiency by modernising the industry and increasing users' satisfaction (Egan, 1998). Furthermore, Egan (1998) suggests that Lean Construction (LC) is a way forward that enhances efficiency by smoothening the construction work flow while improving the overall value of a product to achieve the pre-determined goals, where ultimate users' satisfaction is successfully achieved (Marhani *et al.*, 2013). 'Value' is the competent formation of a service provided to the customer at the correct time, at a reasonable cost, in to the correct quality standards (Ballard and Howell, 1998). Lean thinking can also be defined as a goal that is set against a set of measurements of perfections (Diekmann and James, 1994). Perfection may not be attainable in a zero-defect/ zero-waste/ zero-carbon parameter. Nevertheless, it can be achieved in such a parameter where the construction environment represents a sustainable future where defects and wastes are utmost minimised that leads to eliminate cost overruns, delays and avoid inconsistency with the customer expectations (Gregory, 2011).

Lean thinking is constituted with a long history where manufacturing was the sector that lean thinking was initially applied. Over the last 10 years an increasing number of companies have implemented lean construction practices with an intention to improve performance in construction projects (Bertelsen, 2004). However, there is still a need to provide more extensive analysis of the empirical evidence available to assess the impact of the implementation[ii] of lean construction. This paper observes

* Corresponding Author: E-mail - u.madanayake@gmail.com

the applicability of lean construction theories and principles in to Sri Lankan construction practice. The implementation of Last Planner System is in-depth discovered while the impacts of implementation of lean construction techniques are analysed within the case study in to the Sri Lankan context. The paper also discusses difficulties and barriers for implementation, productivity improvements, variability reduction and effectiveness of implementation strategies. To recapitulate, recommendation is compiled with the lessons learned from the research for further improvements.

1.2. PROBLEM STATEMENT

Construction projects are common and well known for being delayed, over-budget and shrank with non-unique quality standards. Hither to, the traditional construction management methods has been successful for some extent in addressing the aforementioned common problems. Nevertheless, it appears that the effectiveness of conventional project management approaches still remain in a neutral-impassive status whereas most of the problems still remain same.

Sri Lankan construction industry is facing many challenges with the recent economic downturns and as well as recent major political revolt. Building and construction sector in Sri Lanka is one of the major sectors that directly effects with the track of Gross Domestic Product (GDP) growth rate. As reported by the Department of Census and Statistics - Sri Lanka, the current (2015 first quarter) GDP in Sri Lanka has declined to 6.40% from 7.7% in the fourth quarter of 2014.

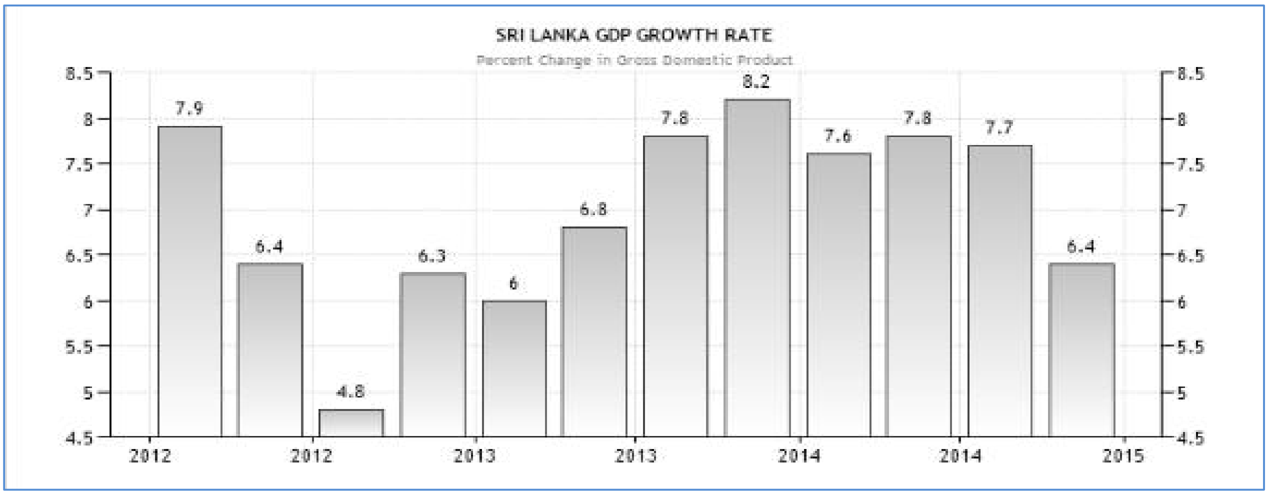


Figure 1: GDP Growth Rate, Sri Lanka (2012-2015)
Source: Department of Senses and Statistics, Sri Lanka (2015)

Due to the instability of the economy which is originated through political revolutions and improper systems, construction industry in Sri Lanka was suffering all through the time. However, despite the economic boom, Sri Lanka was able to withstand with many city development projects as well. Infrastructure, hospital, urban development, town and country planning, hotel and apartment projects were under taking despite this economic boom. Considering the decline of the GDP growth rate and the upturn of inflation, it seems that the unemployment within the country is accumulating in a notable rate. Government policies and strategies, investments, competencies of in-house organisations, foreign aids which are due, available resources and potentiality of getting maximum out of it, sustainable approaches are few of the main factors that determine the way forward of the economy of the country (Central Bank of Sri Lanka, 2015). Filtering in to the construction sector, the construction cost factor is highly determined by some aspects such as labour, materials, equipment, transport, consumption of energy and time related cost factors that augment with delays and disruptions**. *It is conspicuous that the conventional project management techniques are not suitable for complex projects anymore.***

In order to beat this problem in the platform of micro scale; a project must adhere to a set of guidelines that allows both resources and tasks to perform in a contemporary manner to achieve predetermined project goals (Nesensohn *et al.*, 2013). In that case, elimination of non-value-added activities is one major step. This has influenced to initiate this research as a solution to relieve the chronic problems in the industry; introducing a new thinking evolving a significant change in the industry disciplines, professional mind set and beliefs.

1.3. *AIM AND OBJECTIVES*

The aim of this research is “to identify the effectiveness of applying lean construction principles and practices in order to enhance the construction flow in the contractors perspective’’, which is achieved through the following objectives;

1. Determining the current awareness towards lean construction within the Sri Lankan construction industry.
2. Investigating the barriers impeding LC and effectiveness of practically applying lean techniques in to two particular construction organisations from Sri Lanka and UK as a comparative Case Study.
3. Developing a conceptual framework with the trace of barriers identified for the implementation of lean thinking.
4. Verifying the proposed conceptual framework towards enhancement the construction flow that leads project prospects.

1.4. *RESEARCH METHODOLOGY*

The research is soundly based on a multiple case study design which is compiled as a comparative study between two case studies in the platform of mixed research method (qualitative and quantitative); that enquires how effective the application of lean construction principles in to Sri Lankan context is compared to UK. The aim mainly focuses on regenerating the construction management process in Sri Lanka extracting examples from a developed country; United Kingdom which has got the world's fifth-largest economy by nominal GDP (Lincoln and Syed, 2011). A case study is an empirical inquiry that investigates a contemporary phenomenon within its actual context when a clear boundary between aforementioned phenomenon and actual context cannot be drawn in the default situation (Zucker, 2009). Thus, the contemporary phenomenon of lean thinking is extracted from both the case studies to compare the barriers and benefits unambiguously. An extensive literature review is conducted precursory to the research to identify the key barriers to successful implementation of LC. The two case studies ultimately evidently prove the accuracy of those literature review findings.

Precursory, the prevailing awareness of lean construction is investigated within the Sri Lankan construction industry via face-to-face interactive informal interviews and a questionnaire survey.

Since the study has exploited multi method approach to collect data, ‘pragmatism paradigm’ is the chosen philosophy in this study. Inductive theory is employed in this research where as a conceptual framework is derived as an origination of an applicable generic theory with many observations and explorations (Creswell, 2009). As per the research aim and objectives mixed approach is the best fit approach in collecting data placing the investigation under qualitative multiple-design (case study) while the prevailing awareness is captured by a questionnaire survey, which simulates the quantitative method. A conceptual (generic) framework is generated which is capable of applying to any sort of a construction project, not surpassed/ outstripped the scope and delimitation mentioned in the case study. Table 1 below illustrates how the aforementioned objectives are achieved with the use of different research methods.

Finally the research itself asserts a recommendation with few suggestions for continues improvement and for the further development in the applicability of Lean Construction techniques in to practice.

Table 1: Adopted Research Methods Against the Objectives

Research Objectives	Adopted Research Methods						
	Literature Review	**Questionnaire Survey**	**Informal Discussions/ Interviews**	**Web Based Discussion Threads**	**Case Study**	**Secondary Data Analysis**	**Desk Study**
Objective -1	√	√	√				
Objective -2	√		√	√	√	√	
Objective -3						√	√
Objective -4					√	√	√

2. LITERATURE REVIEW

2.1. RATIONALE - ORIGINS OF LEAN

The credit of Lean as a production philosophy authentically goes to the president of Toyota Production System - TPS (Ballard and Howell, 1998). This system (TPS) was initially introduced by Japan after World War II when Japan required producing small batches of cars in many varieties in-divergent to the Ford principle of mass production (many products in same features) (Cho and Ballard, 2011). The Ford principle of mass production was appeared to be inefficient as speculated by Toyota. In virtue of that, Toyota introduced a new theory for production process known as 'Lean Production'- LP (Conte and Sergio , 2002). The main objective of LP is to improve production efficiency and provide the customer with high quality products for the best value (Ballard, 2000). The principles extracted in Toyota production system is consisted of two main pillar concepts as Just-In-Time flow (JIT) and 'Autonomation'- Smart Automation (Anon, 2005).

Koskela (2002) has reported that the adaptation of lean concepts in to the construction industry presented as a paradigm shift to the traditional construction and project management techniques where conceptualized in three complementary ways of transformation, flow and creation of value. Shortened, TFV theory of production is a radical triploid that has led to initiate lean production through a discipline of transformation the prevailing construction process (Luis *et al.*, 2006). Lean thinking differs from every other conventional methods because of its nature that is consisting of clear set of objectives for the delivery process, aimed to maximize the performance with the use of key performance indicators kept as a benchmark and concurrent engineering techniques that collaborate design, production process and delivery at a collaborative platform and fourthly controlling the production process throughout the life cycle (Fayek and Hafez, 2013).

When it comes to waste reduction, it is important to look at the whole stream and have a clear understanding of what the customers sees as value where value added activities are the main focus in the value stream while non- value added activities are deprived from the process soon the identification (Small and Yasin, 2011). Thereupon targets have to be set to eliminate waste and strive for perfection. For continuous improvement, the journey to be carried out on to a specific direction followed by fixed targets and monitor the progress more often resulted by the change.

2.2. LEAN PRINCIPLES

Fundamentals for the elimination of waste

1. ***Identify Customer Value -*** Specify the value from the perspective of ultimate customer. It is essential to meet the required specifications and to deliver the value desired to the end customer. By clearly defining value for product or service, customer value becomes the common focus for parties involved in the project.

2. ***Map the Value Stream* -** Clearly identify the aspects that add value to the customer and the aspects that do not add value to the customer in both production flow and design flow. This is also known as value stream mapping, which also includes eliminating all the non-value added tasks and resources used within the flow.
3. ***Smoothening the Product Flow* -** Taking the remaining value adding steps in to flow without interruption by managing all co-related activities to achieve best sequence of work. This will simultaneously minimize the waste production as well as increase the value.
4. ***Use the Logic of 'Pull'* -** Compile the production line as per the customer demand and when the production is needed, making the production line much speeder.
5. ***Pursue Perfection* -** Pursue perfection by continuous improvement in all possible tasks of the process.

3. LEAN MANUFACTURING TO LEAN CONSTRUCTION

Lean construction was developed by the establishment of Lean project delivery system (LPDS). As per Ballard and Howell (1994), LPDS is consisting of four main domains; definition of the project, lean design, lean supply and lean assembly. Besides, some of the lean techniques are used in construction projects such as; flow variability, process variability, continuous improvement and transparency (Salem *et al.*, 2005). LPDS often incorporated with eliminating waste. Waste in construction process are identified as a non- value added aspect. Types of construction waste include Quality costs (12% of total project cost); Quality cost during operation (4% total project cost); Lack of constructability (6-10% of total project costs); Poor materials management (10-12% of labour costs); Excess consumption of materials on site (10% on avg.); Working time used for non-value adding activities on site (Approximately 2/3rd of total time); and Lack of safety (6% of total project costs) (Issa, 2013). Some of the main causes of Construction Waste can be overproduction, idle-time, transporting, processing, inventory, ineffective operator motions, generation of defective products, task initiation before having sufficient resources in-hand and communication inconsistencies.

Implementing lean production philosophy to construction practise presents similar objectives of delivering a competitive product in the minimum possible time period, with maximum value and quality and at a lesser/ reasonable cost (Gamal, 2013). In that case the application of lean thinking in to construction practise resembles with the lean principles originated form Toyota Production System. Traditional construction practices are always 'contract-centred' where stakeholders naturally act as per their own preference in order to optimize their own assigned set of tasks (Koskela, 1992).The conventional method is to shorten the project duration by accelerating the assigned activities of the program of plan by feeding labour, material and equipment in a much higher rate. The cost-related activities that are emerged from re-work, extended duration along the critical path can be minimized by the application of lean (Ballard and Howell, 1998). Lean construction does not exploit making changes to the schedule or the program of work plan; instead improve the delivery with the means of increasing the ultimate value. Lean planning often involves planning the work flow for a much ahead of time where traditional techniques concentrate more on the pre-determined milestone achieving via the sequence of critical path. Lean thinking is ideal for complex projects that are equipped with higher uncertainties as well as fast track projects.

Table 2 speculates the key aspects of lean construction summarized after an extent literature review.

Table 2: Key Aspects of Lean Construction - Literature Review

Key aspect	Summary	Authors
Just-In-Time (JIT)	Minimum number of inventories made according to the requests only, construction levelling and minimizing the amount of activities. Eliminating waste through continuous improvement	Salem, *et al.*, (2005) Koskela (1992)
Total Quality Management (TQM)	Concept of integrated management system, clear understanding of customers' expectations	Small *et al.* (2011) Summers (2005)
Concurrent Engineering (CE)	Involving right from the design phase, incorporating the constraints of sub-phases in to the inception phase and feeding the essence of change control upon the design process	Koskela (1992)
Last Planner System (LPS)	Minimize the project uncertainty by planning backwards of a target, increasing the commitment of team members that involves with project flow and variables.	Salem *et al.*, (2005)
Value Based Management (VBM)	Ultimate value for the customer is highly concerned while value for the team workers are also concerned as 'process value'	Bertelson (2004)

3.1. Identification of Gap in the Existing Literature - Barriers

Efforts for Lean Construction (LC) management in extant UK appear to be highly rewarding. After emphasizing the concept of Lean thinking by John Egan in his report of 'Rethinking Construction', UK construction industry arose to quest ways of adding more value to their deliverables via improving quality and efficiency. Although it is much consolidated in UK, various countries around the world are now in the quest of seeking more value with this thinking. However, numbers of structural and cultural barriers are to be seen that are militating against its successful implementation despite of the geographical area (Sarhan and Fox, 2013).

Despite these continuous efforts, studies show that the presence of lean culture in the large construction companies in UK is still less than what is professed by literature. More over the study recognizes a significant gap in the LC in other developing countries compared to UK, which evident the immense room to be improved in LC all around the world in general (Bhargav *et al.*, 2013).

Once in the era of late eighties the construction industry has been treated isolated from all the other industries and was claimed to be far different from manufacturing because of the belief that construction is different; with more complex concepts and take place under huge risk of uncertainties and constraints where every product output is unique (Salem *et al.*, 2006). On the other hand, Egan (1998) refuses this fact and claims that the construction industry includes many repeated processes which resembles manufacturing industry which enables to learn lessons from past models and can be used for future improvements. Re-engineering construction and learning from the past modes are the two main points (Egan, 1998). An extensive literature review comprehension was conducted to understand the possible barriers to the successful implementation of LC. Based on that, this study classifies these barriers into ten different categories, as shown below.

Table 3: Barriers to the Successful Implementation of LC

Barrier	How it Impedes the LC	Author/s
Fragmentation and subcontracting	It is essential to establish effective communication between all parties by partnering and integrated team-working. Poor communication will negatively impact on the coordination system as well as inefficiency in project delivery.	(Forbes *et al.*, 2002)
Procurement and contracts	Traditional Procurement methods often create adversarial relationships between parties involvedand can add waste to the process while bypassing the possible lean techniques.	(Mossman, 2009)
Culture and human attitudinal issues	lack of commitment, lack of team work, lack of self-criticism, poor communication, poor transparency, difficulty to adopt the new methodology, fear of risk taking, dependency, lack of incentives and motivation, and contractual disputes are few main aspects falls in to this.	(Common *et al.*, 2000)
Commercial pressures	Tendency of construction firms to apply traditional management concepts (dues to cost pressures) impedes continuous improvement and lessen productivity and quality initiatives.	(Common *et al.*, 2000)
Financial issues	A sufficient funding is required to successfully implement LC in to practice for required tools and equipment, remunerations, HR rewarding systems, training and development, etc.	(Bashir *et al.*, 2010, (Mossman, 2009)
Lack of top management commitment and support	New strategies need to be supported and motivated by top management. They should allowadequate time and resources to develop the strategy as well as manage the changes occur during the process.	(Bashir *et al.*, 2010)
Design/ construction dichotomy	Ignoring the importance of design & planning could lead loss of time, cost and quality. Design and initialization of design are treated separately in conventional methods which creates conflict and as well as waste.	(Common *et al.*, 2000)
Lack of adequate lean awareness/ understanding	Lean is more a conceptual thinking than a consumption of tools and equipment which needs to be very clearly understood. Collaboration, flexibility, commitment, discipline, and a broad thinking are few of them to be transformed.	(Common *et al.*, 2000)
Educational issues	Educational barriers produce greater threat to the sustainability of LC. Some of these barriers include:lack of technical skills, poor HR management, inadequate training, lack of awareness and understanding, lack of team spirit, poor illiteracy and computer illiteracy.	(Bashir *et al.*, 2010)
Lack of customer-focus	Measuring the project performance according to the ultimate client satisfaction is rare in many construction projects. Time-cost-quality focus measurement conventional; which needs to be changed.	(Forbes *et al.*, 2002)

Hence with the aforementioned barriers identified through literature review is evidently cross checked through the two case studies while investigating the benefits in order to generate a framework that can be used ambiguously to apply lean thinking in every construction project.

4. QUESTIONNAIRE

In order to achieve the first objective of ‘determining the current awareness towards lean construction within the Sri Lankan construction industry’, a questionnaire survey was conducted within an organisation; one of the largest construction companies in Sri Lanka. The questionnaire was exploited to investigate the awareness of lean construction among industry people with respect to few main factors that impact the construction flow. Based on this questionnaire and the extent literature review, the problem of the research was identified.

The questionnaires were distributed among construction engineers/ planners/ designers/ quantity surveyors/ project managers within the same organisation. The selected organisation is one of the leading (C-1), established construction firms in Sri Lanka which deliver building construction, infrastructural and design-build solutions. Achieving the Sri Lanka's Corporate Accountability Index Platinum Rating, Second Rank for 2 recent years is one of the major achievements of this company. The company is endorsed with an array of international ventures that confirms the stability organisational management system. The reason behind selecting this company is their tendency to enhance the quality of work by setting up new strategies and policies updated in each year while the HR management is also remains a higher standard.

The sample size was 30 number of heads with a mix of aforementioned disciplines. The questionnaire forms were distributed by hand and the number of respondents received back was 24, which leads to an 80% of respond rate. The questionnaire used was a Likert-type scale from 1 (very low) to 5 (very high). The results showed that (figure-4) 58% of the respondents' awareness of lean techniques and principles were very low (almost no awareness) while 35% of the respondents were moderately knowledgeable about the same. The investigation resulted that more than half of the percentage was not aware of the Lean Concept but was interested on learning withal, having the capability to introduce lean thinking in to practice within their company. The inference of being less knowledgeable about the lean principles leads to way forward of this research to examine a case study that applies lean construction techniques in to the same organisation.

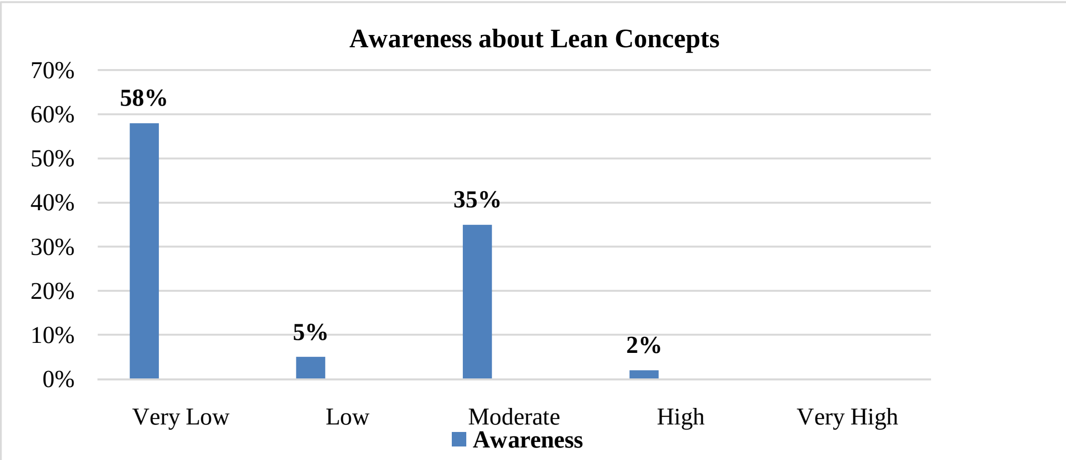


Figure 2: Awareness of Lean Principles

5. CASE STUDY

5.1. CASE STUDY INITIALIZATION

Multiple design longitudinal case-studies is the case study design exploited here. The unit of analysis is 'Construction performance' in which the performance is examined before and after applying lean construction techniques. The main lean construction technique considered here is the Last Planner system. LPS is practically applied in 2 different organisations from UK and Sri Lanka as a comparative study.

The reason for the selection of LPS as the 'application of analysis' is that application of LPS is one of the most effective ways to increase efficiency of construction performance by improving planning and control process (Aziz and Hafez, 2013). One of the best known Lean techniques is the Last Planner System which has proven to be a very useful tool for the management of construction process to repeatedly monitor the performance efficiency, to assist in developing foresight, smoothing workflow variations, and reducing/removing uncertainties in the entire construction process (Aziz and Hafez, 2013).

The findings are finally interpreted with descriptive explanations derived from comparing and contrasting strategy. Data was primarily collected from interactive discussions with professional who are actively engaged with the project. Project related documents; databases were used as secondary data for the analysis of the case study as qualitative data. An extensive literature review is speculated all over the research supporting each and every part of the argument brought in.

5.1.1. CASE STUDY - 1

Table 4: Project Profile (Travelodge)

Project Name	**128 Bedroom Travelodge Hotel, Hounslow, United Kingdom**
Status	Constructed and currently functioning
Employer	Travelodge Hotels Limited
Duration	65 weeks
Project cost	£ 5.7 million
Main Contractor	Barnes Construction

The project comprised the construction of a 128 bedroom Travelodge hotel including regenerating an area that contained a number of derelict dwellings. The project incorporated modern methods of construction and was procured under negotiated design and construct method. This hotel and leisure project sustained a PPC nearly 95% at the last month of the project. The relatively few subcontractors involved during the measurement period may have simplified the coordination problem beyond the norm (Sicat, 2012). However, the skill of well coordination between sub-contractors, client and the main contractor with an extensive involvement of subcontractors especially in planning and constraints analysis is a good point that can be followed by every company.

The two main objectives of LPS are to make better performance to direct workers through continuous learning and corrective action and to cause the work to flow smoothly across the deliverables in the best achievable sequence and rate (Anon, 2005). The last planner integrated components are: master plan, phase planning, look-ahead planning, weekly work planning, Percentage of Promises Completed on time or Percent of Planned Completed 'PPC' (A measure key of the Last Planner System success) (Aziz and Hafez, 2013). PPC only measures the effectiveness of the planning, not productivity. But the effectiveness of planning ultimately makes visible the greater productivity.

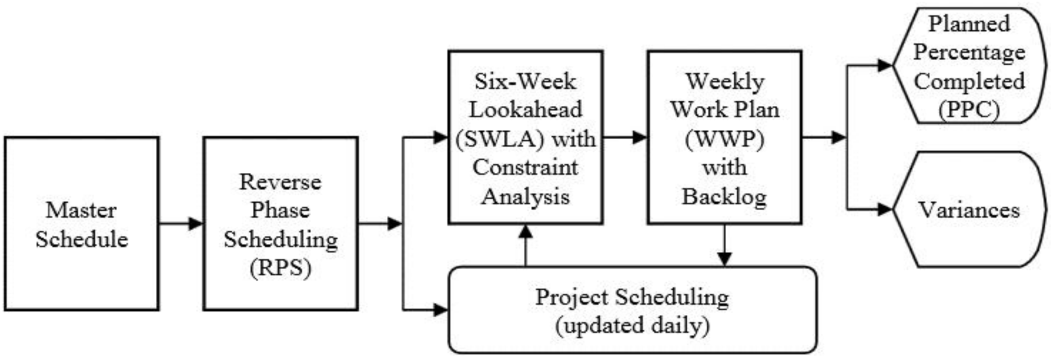


Figure 3: Sequence of LPS
Source: Zimmer (2005)

The figure below illustrates the results of implementation of the LPS on the above project, which clearly reflects the positive impact of the system on budget and productivity. Reported benefits attributed to LPS implementation were as follows: (1) cost reductions, (2) reliable predictions for planning, (3) smoothen the construction flow, (4) reductions in project duration, (5) improvement in productivity, and (6) greater collaboration of work among sub-contractors and client/ main contractor. Challenges faced by project participants when applying LPS were also identified as follows: (1) lack of understanding due to poor training, (2) organisational inertia, (3) resistance to change, (4) poor leadership/ guidance, (5) contractual disputes, and (6) lack of experienced people. Last Planner System (LPS) has four main elements such as; (1) Programming Workshop: Collaboratively creating and agreeing production sequence (and shrinking the sequence when needed); (2) Make-Ready: Making tasks ready so that they can be done when we want to do them; (3) Production Planning: Collaboratively agreeing production tasks for the next day or week; and (4) Continual Improvement: Learning about and improving the project, planning and production processes.

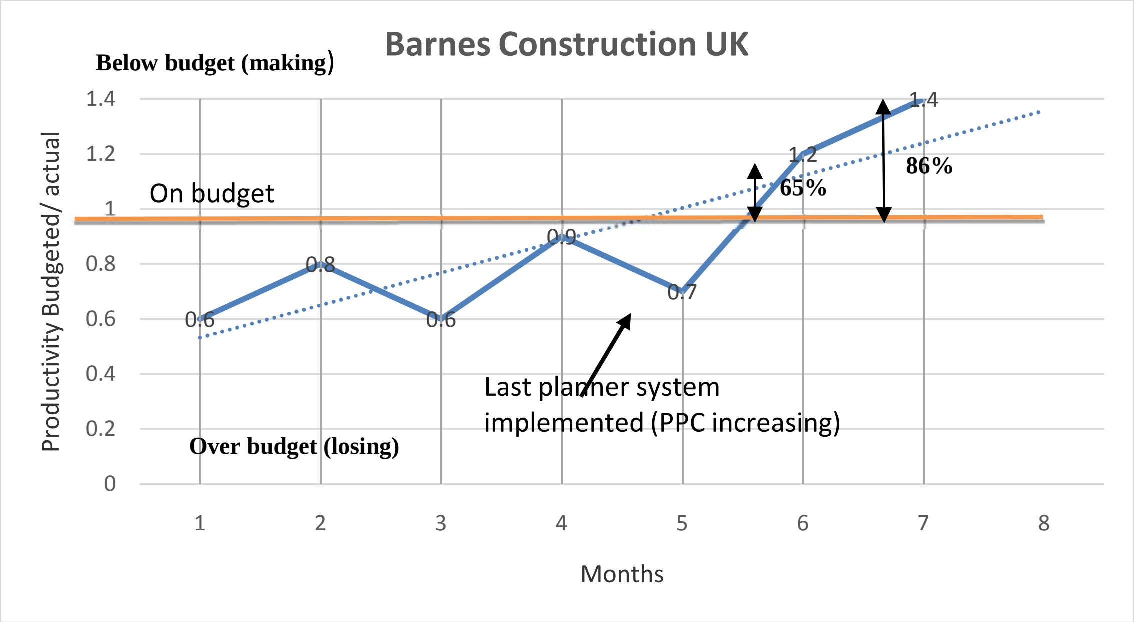


Figure 4: Productivity Improvement Using LPS-Barnes Construction

Look-ahead planning is the process undertaken to achieve possible constraints, free assignment, and cut down uncertainty. In the case study, look-ahead schedules were prepared for the upcoming three weeks in a bar chart format. WWP is produced based on three weeks look-ahead, the master schedule, and field conditions using notes and memos. Look-ahead schedules were updated on a weekly basis during a weekly project meeting. WWP should emphasize the learning process more by investigating the causes of delays on WWP instead of assigning blames and only focusing on PPC values (Ballard and Howell, 1998). On the other hand, PPC is also calculated every week during the project execution. The PPC is the measurement metric of the last planner system. It is calculated as the number of activities that are completed, as planned, divided by the total number of the planned activities. The upward slope between two PPC values indicates that production planning was reliable and vice versa. It is clear from this figure that there is a significant improvement for the values of PPC, with as increase in time, as the PPC values increase.

5.1.2. CASE STUDY - 2

Grand Hyatt Colombo (GHC), formerly known as Ceylinco Celestial/ Celestial Residencies/ Hyatt Regency Colombo is a 43-floor hotel/ apartment projectis Sri Lanka, which is also known as the tallest building in Sri Lanka up until now. The hotel will feature 475 guestrooms and 84 serviced apartments, as well as a lobby lounge, an all-day dining, multi-cuisine restaurant, three specialty restaurants, a bar, eight spa treatment rooms, a fitness centre, a swimming pool, and a Regency Club lounge. Additionally, the hotel will offer more than 17,000 sqft (1,579 sq m) of enclosed meeting space, including a 7,500 sqft (696 sq m) ballroom. The profile of the project is as follow;

Table 5: Project Profile (GHC)

Project Name	**Grand Hyatt, Colombo**
Status	Construction In-progress
Employer	Sri Lanka Insurance Corporation Ltd.
Developer	Sinolanka Hotels & SPA (Pvt) Ltd.
Consultants	Design Consortium (Pvt) Ltd., Archetype Group
MEP Contractor	Transgulf Electro mechanical
Interior Design Consultant	BilkeyLlinas Designs
Height	176 m (577 ft)- Excluding the pinnacle
Number of Floors	43 floors (Tallest building in Sri Lanka as at 2015)

5.2 CASE STUDY ANALYSIS

Grand Hyatt Colombo was expected to be opened and functioned in 2014. The project duration is now notably dragged with the approval of an extension of time. Furthermore, the project is under construction with numerous variations which apparently reports a significant cost over-run than the amount estimated at the tender stage. Hence it is conspicuous that the project is running with a noticeable cost and time over run. As per the face-to-face informal discussions/ interviews had with project managers and the engineers of the project the following points were emerged as some of the main factors that has been caused to result cost and time overrun.

Table 6: Causes of Cost and Time Overrun - GHC

Sort	**Causes for Time and Cost Overrun**
Labour	Higher rate of overtime performance Labour productivity
Material	Fluctuation of prices of materials Shortages of materials Changes in material specification and type Delay in delivery of materials Higher dependency on imported materials (delays in BOI approval)
Machinery/ Equipment	Equipment availability and failure Late delivery of equipment Insufficient number of equipment
Unforeseeable Conditions	Unpredictable weather conditions/ political influences Risk and uncertainty associated with the project
Cost Related Aspects	Financial difficulties of owner (fund approval by the government, SL) Delay payment to supplier/subcontractor Delay in progress payment by owner Cash flow and financial difficulties faced by contractors Poor financial control on site
Project Management	Lack of proper training and experience of PM Complexity of works Lack of appropriate software- use of conventional manual methods Ineffective planning and scheduling of project by contractor
Contractual Aspects	Severe Design changes/inadequate details/ incompleteness of drawings Discrepancies in contract documentation Conflict between project parties Draw-backs of suppliers Not using advanced engineering design software and tools

Howell and Koskela (2000), criticizes the conventional management techniques that are currently used and expostulate that conventional methods are yet insufficient to cope with project complexity and uncertainties. Hence, the research itself suggests the following methods accompanied with lean construction approach to replace the existing method of practice.

Table 7: Traditional Methods that has been Used so far in GHC which can be Replaced with Lean Construction Methods

Function Used in GHC	Conventional Approach Currently In-Use in the Project	Lean Construction Approach
Process control	Corrective actions are taken only after the defective activities are identified in progress meetings	A reliable work flow is created much earlier where possible uncertainties are identified and on-site activities are applied in a virtual platform
Progress measurement	Each activity is treated separately to achieve the optimization	Maximizing value with a minimum waste, treating the whole project as a unit
Definition of value	Lowest cost is always considered as the best value	Customer requirements are carefully met at over the course of the project where best value is not always the lowest.
Task Management	Driven by push where products are almost made even before assessing the customer satisfaction. Over production is always there.	Driven by pull; mostly the outputs are offered only after the demand is received (building what is actually needed only with minimum waste)
Management hierarchy	Decisions are always made by one manager.	The participation of all the people involved in the project is valued in decision making (More transparency)
Back loading	Low flexible for variations and mitigation process is not addressed most of the times	Variations are expected and a provision is made at the early stage where the capacity of the project is made adjustable to absorb all possible variation.
Collaborative wok	Collaboration is very low where all the parties are worked separately with their assigned tasks.	Collaborative work among all the parties is in abundance.
Continuous Improvement	Continuous improvement is not considered and more focused on finishing off the assigned works only.	Continuous improvement is a major concern where future prospects are also aimed.

5.2.1. IMPLEMENTING LAST PLANNER SYSTEM (LPS) TO GHC

Last Planner system was introduced to GHC project to examine the effectiveness of Lean Construction techniques in to practise. LPS is associated with the pull approach that looks ahead of the project and schedules backwards. This assures the reliability and predictability of work flow as well as performance.

Initially the site supervisors were made aware of the LPS and were asked to assign work to the crew as it allows the conversations between the site management and the trade foreman at suitable level of detail preventing critical issues o happen on site. A six week look-ahead schedule was given to the site supervisor and they were asked to prepare a reverse phase scheduling looking at the programme six week ahead. As shown in the figure below, the site supervisors were instructed perform reverse-phase scheduling, Variance Analysis and Percentage Plan Completed Charts. A baseline was formed to measure the actual and planned as previous performance as percentages.

Initially, the last planner system was greeted with disbelief among the site workers as well as superintendents. The interviewees stated that the collaborative approach is in a doubt in which all the performers identify what exactly their duties and responsibilities are plus, what they expect from each other to achieve milestones, which is also called “pull- planning”. The last planner system addresses the scheduled activities in detail, far in advance of when the conditions on site can be known. This actually optimizes the flow rather than trying to optimizing each and every task separately. Examples from Toyota practice is again to be applied hereto, as everybody in the line are responsible to stop the flow where ever a problem is encountered. The last planners are responsible to carry on the flow if only each and every activity is performed safely, efficiently and according to required quality standards. Defective inputs or mid-assignments are always bound to reject just as in Toyota production line.

When the integrated project team uses pull-planning to schedule the work flow related activities identified through value stream mapping strengthens the flow as everybody in the line learn to make clear requests to the other while making reliable promises as well. This ensures that installations are error free and can be constructed/ installed safely, efficiently and according to the particular standard by the assigned performer line. Therefore, the quality becomes the responsibility of designer, craft workers to managers, not just quality controllers and inspectors. In that case the documentation must be very clear and understandable. The output must meet the customer requirements and must fit with all the other components and assemblies as per visualized in the virtual design.

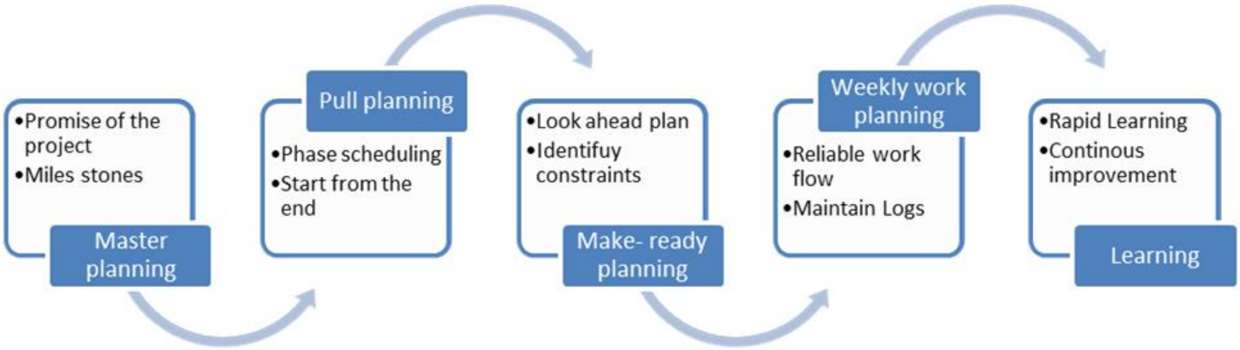


Figure 5: Last Planner System
Source: Zettel (2008)

After implementing last planner system, the performance of a particular trade was observed and the following were the competencies achieved; summarised as per the observation; Weekly accomplishment is measured as Percent Planned Complete (PPC) which is the number of completed assignments divided by the total number of assignments. The aim is to have tasks completed as planned. The project manager and site supervisors involved in controlling the process. Site supervisors seemed encouraging workers to be successful with their efforts.

Table 8: Lean Construction Tools Applied and Achievements

Scope	LC Tools Applied and Achievements	Achievement
Waste Reduction 42%	The concern to reduce the non-value added activities in the project	√
	The range of material waste in construction site	√
	The awareness of the employees about waste elimination	√
	The concern about unneeded movements when locating the inventory on site	√
	Material waste quantification	-
	Productivity loss quantification (labour/equipment)	√
	underutilized people on project considered as a waste	√
Transparency 85%	Visual management system at site	√
	Clarifying the whole method of construction to employees on site	√
	Communication channels with all the project stakeholders	√
Reduce Variability 67%	standardize the construction/design process	-
	communicate standard process to workers	√

Scope	LC Tools Applied and Achievements	Achievement
	reviewing the design drawings at early stages	√
Flow Variability 58%	visualization tools on site/project to improve work flow	√
	just-in-time method to decrease the volume of inventory on site	√
	collaboration with the suppliers to assure the delivery of material on time	√
	the work flexibility on site	√
	Schedule look-ahead to improve the work flow	√
	Management system to guarantee that the information flows smoothly	√
	The importance of the information flow, material and equipment on site	√
Continuous Improvement 66%	Quantification of the unused ordered material on site	-
	Pre-fabricated material on site	√
	Monitoring the production on site and record performance benchmarks	√
	Proactive actions or set quality plans to prevent defects at source	√
	The lesson-learned gained from your previous experience	√
	the employees contributing in the process enhancement	√
	Continuous education programmes or courses for the employees	√
	Consider the customer feedback to improve the process	√
Process Variability 63%	Start of the day meeting for all the employees in the project	√
Customer Focus 88%	The flexibility to meet the customer's changes & requirements	√
	Communication between the contractor and the customer	√

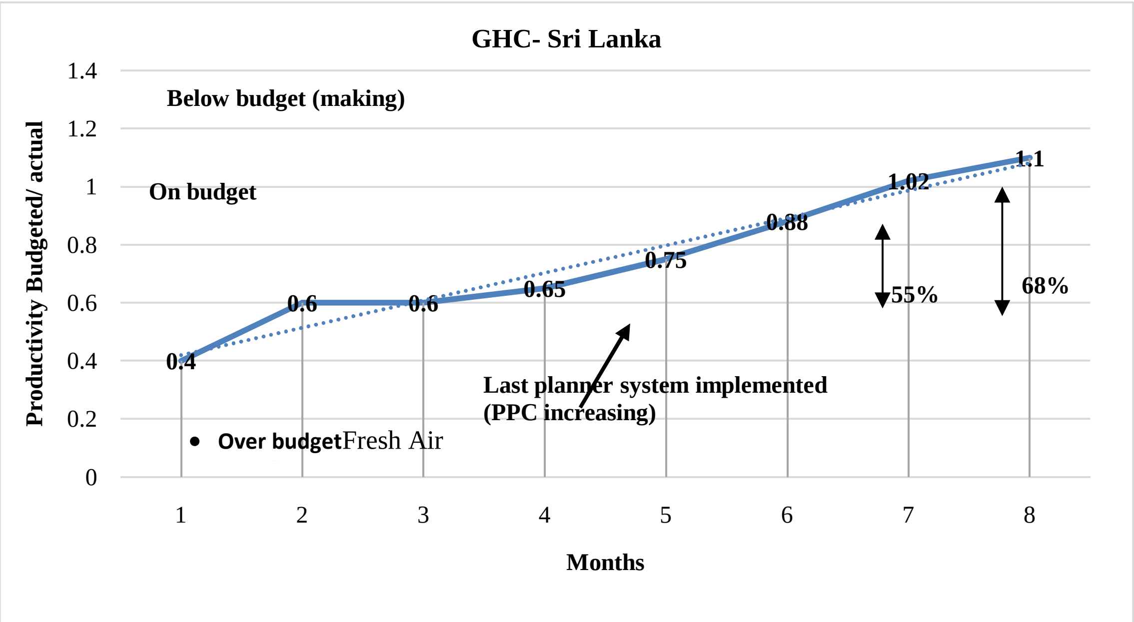


Figure 6: Productivity Improvement using LPS - GHC

5.3. FINDINGS OF THE CASE STUDY

It is found that the construction waste have been brought up to minimal with the increment of employee involvement. Leading time was minimized and a better way of utilizing the staff was identified. The quality of construction outputs were reported in an outstanding level more than it used to be. Returns were increased and the competitive position of the project was increased as benefits of lean application to the project. Use of LPS has actually helped making labour and resources maximally productive while allowing the project to accommodate variables and smoothens the work flow. Since traditional working methods encourage the establishments of time frames against set targets, LPS encourages the establishment of value added tasks that are necessary for the project completion. With the decentralized decision making process, allowed the flow to efficiently match the labour with materials and resources. Reworking was minimized in to a very lower level.

Results from the study indicate that there are several benefits associated with implementation of lean construction methods. The overall perspective of professionals within the chosen case study indicates improvement in corporate image of the company, enhancement in process flow and productivity, sustainable development and increased compliance with customer's expectations are identified as the benefits. The study also identifies a connection between lean application and sustainability that is achieved through waste reduction, perusal of best value to the customer as well as the workers involved and overall satisfaction.

However barriers/ draw backs were also identified as the implementation was bit complex because of lack of management commitment and the fear of practising new methods.

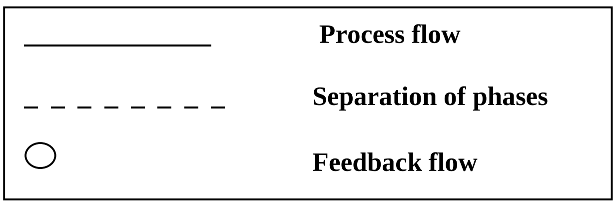
Evidence of the use of lean thinking has shown that there are many benefits to be made from applying lean principles to construction. These benefits claimed include: improved productivity, increased reliability, improved quality, more client satisfaction, increased predictability, shortened schedules, less waste, reduced cost, enhanced build-ability improvements to design, and improved safety.

Although project time has been reduced as a result of using lean construction techniques, not all factors are affected by these techniques. Price fluctuation, delay in monthly bill settlement and approval of payment to the main contractors design errors and adaptability to the environment, and poor quality of local materials were few attributes not affected by the application of LC. More research areas are open to study using a time-overrun quantification model; a PET analysis can be done to measure the effectiveness of LC application.

6. CONCEPTUAL FRAMEWORK

With all the findings a generic conceptual framework is formed to apply the same LC principles in a much familiar way. Lean techniques that associate waste elimination have the potential to reduce the overall duration of the activities and reduce the causes of delays and disruptions. The Framework is developed show how effective the implementation of LC practices can be acquired to in to the Sri Lankan construction industry. The framework is more suitable for projects that are full of uncertainties and that are in-need up speeding up.

Figure 7 illustrates the developed, proposed conceptual framework for Lean Construction implementation.



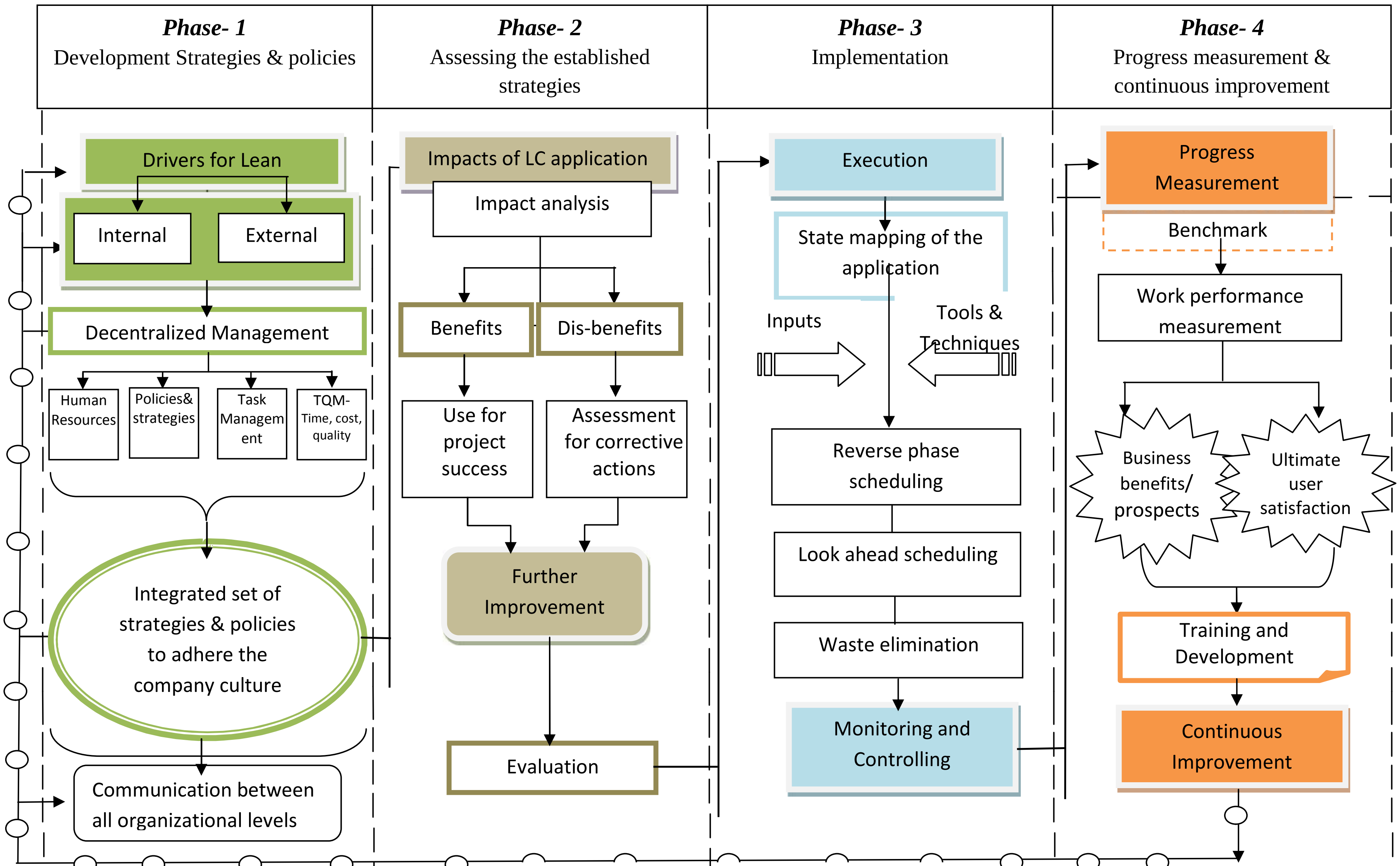


Figure 7: Conceptual Framework for LC

7. CONCLUSIONS AND RECOMMENDATIONS

Lean construction (LC) efforts evidently prove to be highly rewarding for the UK construction industry while it is still in the developing level (awareness raising status) in Sri Lanka. Although various countries around the world have gained numerous benefits by adopting the lean concepts, it does not seem to be rigidly applied in Sri Lankan construction industry as well as the awareness remains meagre. Numbers of structural and cultural barriers are browsed that cause hindering the construction performance towards achieving the lean approach. This study assessed number of barriers to the successful implementation of LC from an extensive literature review and three were identified and proven as significant, according to the two different case studies. Lack of adequate lean awareness and understanding; Lack of top management commitment; and Cultural & human attitudinal issues were the top three barriers identified in UK context, while financial issues, Lack of adequate lean awareness and understanding and Lack of top management commitment are the three main barriers identified in the Sri Lankan context. However despite the geographical location an organisation has the ability to gain profound benefits with the application of LC. Application of LPS is one significant step that has the potential to make a major fruitful change. Increment in project performance/ productivity is outstanding amongst them. Finally a generic framework was developed after identifying the pluses and minuses of LC practical application. Further research is required to verify the reliability and validity of this framework. Generation of Much detailed performance monitoring model is left for further research opportunities and actions.

The findings of this study could be used to help researchers, practitioners and companies to focus their attention and resources on the significant issues necessary to support the implementation of LC concepts.

8. REFERENCES

Anon, P., 2005. Lean Principles in Construction. *Construction Industry Institute (CII),* 101(1), 10-16.

Aziz, R.F. and Hafez, S.M., 2013. Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal,* 15(4), 14-17.

Ballard, G., 2000. *Lean Project Delivery System.* s.l.: Lean Construction Institute.

Ballard, G. and Howell, G., 1998. *Implementing Lean Construction: Understanding and Action, Group for Lean Construction (ILGC) Proceedings.,* s.l.: s.n.

Ballard, H.G., 2000. *The Last Planner System of Production Control,* s.l.: Faculty of Engineering, The University of Birmingham.

Bashir, M.A., Suresh, S. and Gameson, R., 2010. *Barriers towards the Sustainable Implementation of Lean Construction in the United Kingdom,* s.l.: s.n.

Bertelsen, S., 2004. *Lean Construction: Where are We and How to Proceed,* s.l.: s.n.

Bhargav, D., Koskela, L., Kiviniemi, A. and Tzortzopoulos, P., 2013. *Lean Construction and BIM,* London: Elsvier.

Central Bank of Sri Lanka, 2015. *Research Studies,* s.l.: s.n.

Cho, S. and Ballard, G., 2011. Last Planner and Intergrated Project Delivery. *Lean and Integrated Project Delivery special issue,* 21(1), 69-72.

Common, G., Johansen, E. and Greenwood, D., 2000. *A Survey of the Take-up of Lean Concepts among UK Construction Companies.* Brighton, United Kingdom, s.n.

Conte, A. and Sergio, I., 2002. *Lean Construction- From Theory to Practice.* Gramado, Brazil: IGLC-10.

Creswell, J.W., 2009. *Research Design: Qualitative, Quantitative and Mixed Methods Approaches.* 3rd ed. s.l.:Thousand Oaks, CA: Sage Publications Inc..

Department of Senses and Statistics, Sri Lanka, 2015. *Gross Domestic Product, Sri Lankan Economy 2015,* s.l.: s.n.

Diekmann, M. and James, D., 1994. *Application of Lean Manufacturing Principles to Construction. Construction Industry,* s.l.: s.n.

Egan, J., 1998. *Rethinking Construction: The Report of the Construction Task Force to the Deputy Prime Minister John Prescott, on the scope for improving the quality and efficiency of UK construction,* HMSO, London: s.n.

Fayek , R. and Hafez, S., 2013. Applying Lean Thinking in Construction and Performance Improvement. *Alexandria Engineering Journal,* 52(4), 675–694.

Forbes, L.H., Ahmed, S.M. and Barcala, M., 2002. *Adapting Lean Construction Theory for Practical Application in Developing Countries.* Stellenbosch, South Africa., s.n.

Gamal, M., 2013. *Improving Project Performance Using Lean Construction in Egypt,* Cairo: s.n.

Glenn, B. and Greg, H., 1994. *Implementing Lean Construction: Stabilizing Work Flow, Reducing Inflow, 2nd Annual Conference on Lean Construction.,* s.l.: s.n.

Gregory, N., 2011. *What is the Last Planner System?,* Sheffield: s.n.

Howell, G.A., 1999. *What is Lean Construction.* California, USA, University of California, Berkeley, CA, USA.

Howell, G. and Koskela, L., 2002. *The Theory of Project Management: Explanation to Novel Methods,* Gramado, Brazil: s.n.

Howell and Koskela, 2000. *Reforming Project Management,* s.l.: s.n.

Issa, U., 2013. Implementation of Lean Construction Techniques for Minimizing the Risks Effect on Project Construction Time. *Alexandria Engineering Journal,* 52(3), 602-611.

Koskela, L., 1992. *Application of the New Production Philosophy to Construction Technology,* 21-25: CIFE.

Lincoln, F. and Syed, A., 2011. Lean Project Delivery and Integrated Practices- Taylor and Francis, USA. *Modern Construction Journal,* 8(21), 4-12.

Luis, A., Sven, D., Oscar , R. and Rodrigo, C., 2006. *Assessing the Impacts of Implementing Lean Construction.* Santiago, CHILE, s.n., 29-32.

Marhani, A., Jaapara, A., Bari, A. and Zawawi, M., 2013. Sustainability through Lean Construction Approach: A Literature Review. *Procedia - Social and Behavioral Sciences,* 101(3), 90– 97.

Marhani, A., Jaapar, A. and Bari, A., 2012. Lean Construction: Towards Enhancing Sustainable Construction in Malasia. *Social and Behavioral Sciences,* 68, 89-92.

Mossman, A., 2009. Why isn't The UK Construction Industry Going Lean With Gusto?. *Lean Construction Journal,* 5(1), 24-36.

Nesensohn, C., Demir, S. T. and Bryde, D. J., 2013. Developping the True North Route Map as a Navigational Compass in a Construction Project Management Organisation. *Lean Construction Journal,* 4-6.

Salem, O., Solomon, J., Genaidy, A. and Luegring, M., 2005. Site Implimentation and Assessment of Lean Construction Techniques. *Lean Constructio Journal,* 9(6), 3-7.

Salem, O., Solomon, J., Genaidy, A. and Minkarah, R., 2006. Lean Construction: From Theory to Implementation. *Journal of Management in Engineering,* 13(4), 8-11.

Sarhan, S. and Fox, A., 2013. Barriers to Implementing Lean Construction in the UK Construction Industry. *The Built & Human Environment Review,* 6(3), 8-11.

Sicat, S., 2012. *Lean Construction Management* [online]. Available from: http://www.fgould.com/north-america/articles/lean-approach/ [Accessed 27 April 2013].

Small, H. and Yasin, M., 2011. Assessing the Implementation and Effectiveness of Process Management Initiatives at Technologically Consistent Firms Business Process Management. *Construction Project Management Journal,* 20(6), 32-36.

Summers, D.C., 2005. *Quality Management,Creating and Sustaining Organisational Effectiveness.* Upper Saddle River, New Jersey: PEARSON Prentice Hall.

Zettel, G., 2008. *Transforming Turner Projects with Last Planer System,* s.l.: Turner Construction Company.

Zimmer, S., 2005. Application of Lean Manufacturing Principles to Construction. *Lean Construction Journal,* 5(4), 5-9.

Zucker, D. M., 2009. *How to do a Case Study Research,* Amherst: s.n

ASSESSING THE IMPACT OF EXPERIENCED PROJECT TEAM MEMBERS IN GREEN BUILDING PROJECTS

Vignesh Venkataraman and Jack C.P. Cheng*
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong

ABSTRACT

Project experience is generally regarded as highly valuable in the architecture, engineering and construction industry. This is also true for green building projects, which often need to deal with new building technologies and processes. This paper attempts to study the importance of experienced project team members for successful planning and executing of green building projects. Certified LEED green building projects in Canada were studied in this research. Project information, project team information, green building certification grade, and certification year were collected and analyzed using a link analysis technique. Organisations that have been involved in multiple green building projects and their inter-organisational interactions were identified. The results show that projects certified with higher green building certification grades often involve more experienced project team members, and that working with experienced team members can reinforce mutual experience as compared with working with less experienced member.

Keywords: *Green Building; Organisational Ranking; Page Rank; Project Team.*

1. INTRODUCTION

The design, construction and management of a green building project are different from a traditional construction project. When stakeholders approach a green building project, more emphasis is given to (i) considering the whole life cycle of the building and its components, (ii) consuming less energy and water, and (iii) providing better user satisfaction (Glavinich, 2008). Owners and investors are willing to invest more upfront for operational savings. Energy conserving technologies and equipment are installed to achieve these goals. This requires design and construction practices that are different from traditional construction practices. The complexity in its design and construction requires a green building project to have specialized role players in their project team with little or more green building experience (Kibert, 2007). A traditional construction project has a design and construction team working together or separately to execute the design and construction activities. In addition to the design and construction team, a green building project team has participants including (i) a green building consultant, who advises on the green building technologies and green building grade; (ii) a commissioning agent, who ensures that a building or facility is designed, constructed and operated to meet the requirements; (iii) green building material suppliers, and so on. While some traditional construction projects also have specialized design consultants, their roles and involvement are different from those in green building projects. A green building project team consists of participants from various disciplines and often requires frequent collaboration during design and construction. The diversity in the project team poses a serious challenge for collaboration which is a key factor in determining the success of a green building project (Robichaud and Anantatmula, 2010). Therefore, to successfully execute a green building project, the project team needs to be experienced and collaborative in nature. This paper aims to analyse project team combinations and rank organisation based on their green building experience. Organisational rank is determined based on the organisations' green building experience (no of green building projects involved) and their collaboration with experienced organisations.

* Corresponding Author: E-mail - cejcheng@ust.hk

The construction industry has limited practice storing organisational/project team information; therefore, it becomes tedious to collect project team information. In this study, the Canadian green building database was used as the data source because it is an official database that is trustworthy and provides credible project/team information for analysis. All the collected projects from the database are LEED certified buildings by the Canadian Green Building Council (CaGBC). Projects in different locations may have different construction practices, or involve regional green building organisations. Hence, instead of considering the entire project data as a whole, projects were categorized based on their location to get more accurate results. Collected data include project name, location, grade obtained and team information. The page rank algorithm, a link analysis technique, is then used on the project team data to rank the organisations and examine how the rank affects the outcome of the project. The impact of an organisations' rank in a project team was then compared with the green building certification to identify any relations between them.

2. LITERATURE REVIEW

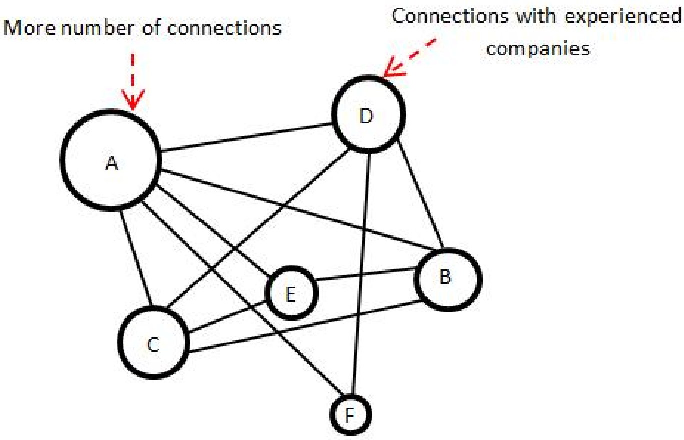
The Literature on organisational analysis has proven that project participants have a certain impact on the outcome of the project. For example, Wang and Huang (2006) suggested that the stakeholders' project performance positively correlates with each other and the owner plays a key role in project success. It also discussed the importance of the effect of project managers as the single point of responsibility and the coordinator for successful projects. Organisational analysis in construction not only stops with analysing the collaboration among participants and their inter-organisational relations, it also extends to analysing individual organisation's metrics and the project team combination. Shokri-Ghasabeh *et al.* (2010) proposed a model based on a company's previous experience in selected projects during its project selection. Reed and Gordon (2000) concluded that the integrated design process encompasses cross-disciplinary teamwork thus enabling improved and effective sustainable design. The importance of key players like owners, designers and contractors to the success of the construction project is well documented by (Chan and Chan 2004; Albanese 1994). The relevant literature provides sufficient evidence about the importance of the project participants and their collaboration in construction projects. It has also established the existing differences between a green building and a traditional construction project. However, there have not been any studies carried out to find the impact of project teams on the outcome of a green building project. Since previous studies have shown the importance of project participants and project team to project success, this study attempts to determine the influence of the project team in green building projects.

Construction researchers have previously adopted various methods to conduct organisational analysis. Gransberg *et al.*, (1999) proposed a quantitative method to identify the success of partnering in construction projects. Shokri-Ghasabeh *et al.*, (2010) proposed a multi criteria selection model on a company's previous experience in selected projects during its project selection. Since this paper focuses on analysing project teams' collaboration, a link analysis technique was selected. In network theory, link analysis is a data-analysis technique used to evaluate relationships (connections) between nodes (objects). Relationships may be identified among various types of nodes, including organisations, people and transactions Chakrabarti *et al.*, (1999). Application of link analysis includes; Investigation of criminal activity, Computer security analysis, Search engine optimization, Market research and Medical research (Neville and Jensen 2000; Xu and Chen 2004; Lu and Getoor 2003). It can be seen that link analysis techniques have been applied to different areas of research but they are seldom applied in the construction industry. Link analysis techniques can offer valuable insights on issues relating to nodal relationships and nodal rankings. Potential construction applications include analysing organisational relationships, communication and information exchanges, organisational ranking in a project team, innovative applications in construction scheduling, task allocation, etc. This paper focuses on analysing the collaboration of organisations involved in green building projects and ranks them based on their strength of collaboration and green building project experience. It is then compared with the final green building certification of the project to identify any relationships between project team combination and green building certification. To achieve these purposes, the page rank algorithm was chosen for this study. The page rank algorithm and the methodology to analyse collaboration patterns in project teams are discussed in detail in the following section

3. METHODOLOGY

3.1. *PAGE RANK ALGORITHM*

After exploring various link analysis algorithms, the page rank algorithm was selected for this study. The page rank algorithm is based on the concepts that if a page contains important links towards it, then the links of this page towards the other pages are also considered to be important (Page *et al.*, 1999). Since the page rank algorithm ranks its objects based on its connections and the strengths of those connections, it was found appropriate to use it in this study. An example is illustrated in Figure 1. The illustrated network contains six nodes and each node has a link with the other nodes, as illustrated. In this network, nodes are treated as organisations and the connections between them are treated as collaboration. As shown in Figure 1, node A (i) has more connections than the other nodes and (ii) has connections with nodes that have a higher number of connections. Therefore, node A is highly ranked. In another case, nodes B, C and D have connections with four other nodes but node D is rated higher than nodes B and C because node D has connections with nodes that have more connections.



Node	Rank
Org A	1
Org B	3
Org C	3
Org D	2
Org E	5
Org F	6

Figure 1: Page Rank Example

The same principle has been applied to green building projects and, in this case, organisations were ranked based on their experience and their collaboration with experienced participants. The equation used to calculate the page rank score for each organisation is shown below. Equation 1 calculates the rank of an organisation A.

$$R(A)_i = \sum_{x \in B_A} \frac{R(X)}{N(X)} \qquad \text{(Eq:01)}$$

where, R(A) refers to the rank value of organisation A, which is dependent on the rank values for each organisation X, denoted by R(X); N(X) represents the number of organisations collaborated with A; and B_A represents the set that contains all the organisations collaborated with A.

3.2. *CANADIAN GREEN BUILDING DATABASE*

Green buildings projects are increasing in numbers in developed countries thus making the market very mature. Canada adopted the LEED standard in 2003 and has certified over 4000 projects so far. CaGBC has introduced a variety of assessment standards including new construction, existing buildings, schools, interior designs, commercial interiors, neighbourhood development and homes. This longevity and evolution of the standard has raised the growth of green buildings in Canada and made the market more mature. Many organisations are involved in green building projects and possess valuable green building experience. The Canadian green building database contains rich information about all the LEED certified projects in Canada. The database contains information like, project name, location, certification level, registration year, certification year, green building technologies, scorecard, project team information, etc. This is why the Canadian green building database was used in this study for collecting project team information. The collected information includes project name, location, certification level, registration year, certification year, and project team information. Out of the 4531 available project profiles in the database, only 229 projects provided project team information. The 229 projects were distributed into 10 provinces. In construction, the location of a project can have an impact on the construction practices, cost and team selection (Kaming *et al.*, 1997). Considering the scope of the study, we extracted project team information by location. The data was first classified according to different provinces before conducting the analysis. This location-based classification helps identify regional collaboration and makes the analysis more meaningful. Provinces with at least 25 projects were chosen for the analysis, as fewer projects will not provide enough collaboration details for a strong analysis. With that criterion, projects from Alberta province and British Columbia province were chosen for the analysis. The CaGBC introduced a new green building standard in 2009 and since changes in green building standard brings changes in design priorities and construction tasks, projects registered up to 2008 was chosen in this study. This helps to maintain standardization among the selected projects and treats them all equally. Project team data from all of the projects in Alberta and British Columbia provinces were collected. Firstly, involvement of organisations in all green building projects was found. A collaboration matrix between organisations was then formed based on their involvement in green building projects. The page rank algorithm was later applied to the collaboration matrix to identify the rank of each organisation. Organisational ranks were then matched with each project team to understand their impact on the project's green building certification. The organisational rank and their impact on projects are discussed in the following section.

4. RESULTS

In this study, Alberta had 19 projects in total and a total of 103 unique organisations participated in those projects. British Columbia had 31 projects in total with 178 organisations involved in the 31 projects. Table 1 represents the organisations with the top 10 page rank scores (PR Score) from both the provinces. The PR Score was calculated to identify the highly ranked organisations in each province. A higher PR Score indicates that the organisation has more number of green building project experience and/or collaboration with experienced organisations. Anonymity of organisations was maintained to preserve the confidentiality of the organisations involved. The calculated page rank score of the organisations was then mapped with the project team of all the collected projects to identify the relationships between the organisational rank and green building certification.

Table 1: Organisational Ranking Results Using Page Rank Algorithm

Alberta		**British Columbia**	
Company	**PR Score (till 2008)**	**Company**	**PR Score (till 2008)**
Total No. of Companies	103	Total No. of Companies	178
Company A10	6.13	Company B7	9.40
Company A23	4.84	Company B8	4.76
Company A22	2.69	Company B36	3.33
Company A27	2.55	Company B53	2.60
Company A3	2.14	Company B24	2.43
Company A21	1.91	Company B39	2.41
Company A33	1.61	Company B16	2.40
Company A83	1.60	Company B61	2.09
Company A50	1.52	Company B54	2.07
Company A41	1.48	Company B42	2.07

4.1. *FULL PROJECT TEAM ANALYSIS*

This section analyses the rank of the full project team of all the projects from both provinces. Organisational rank of every organisation was matched with the project team to identify the relationships between project team rank and the final green building grade of the project. The analysis does not simply consider the sum of the PR score for the whole project team and compare the sum score with green building grade. Instead, a more detailed study on the collaboration patterns of the organisations was examined to investigate the impact on the final green building grade. To understand the impact of collaboration patterns, the project team composition of the highest (Platinum) and lowest (Certified) certified projects were examined. 'Platinum' is the highest and 'Certified' is the lowest available green building grades in the LEED Canada certification system. Table 2 lists all the Platinum projects from both the provinces and identifies the presence of the top 25 and top 10 organisations. The total number of organisations in almost all the Platinum projects was more than 10. Only two projects had total participants of less than 10, one with 9 and the other with 5. From the organisational rank, we matched the values to the whole project team to find the presence of the highly ranked organisations in the platinum case study projects. Among the 7 Platinum projects, all the projects had a top 25 member and top 10 members. In all the 7 projects, at least one to four top 10 organisations were involved. This shows the importance of collaboration among top organisations in a green building project team. It also iterates the fact that the experience of the organisation is a huge factor and can have a positive effect in determining the final green building grade of the project.

Table 2: Platinum Case Study Analysis

Project	Province	Total Organisations	Top 25 Organisations	Top 10 Organisations
Vento Residences	Alberta	10	6	3
Child Development Centre (University of Calgary)	Alberta	12	7	3
Energy Environment Experiential Learning Building, University of Calgary	Alberta	11	4	2
Operations Centre, Gulf Islands National Park Reserve	British Columbia	12	4	3
Dockside Phase 1 - Synergy	British Columbia	11	5	4
Centre for Interactive Research on Sustainability	British Columbia	9	3	3
Creekside Community Recreation Centre	British Columbia	5	1	1

Table 3 lists all the certified projects from both provinces and identifies the presence of top 25 and top 10 organisations. Certified is the lowest rating available in the LEED green building certification standard. Among the 7 certified case studies from both provinces, only two had a total organisation of more than 10. The involvement of top 25 organisations in all the certified projects was very few, ranging from a minimum of 0 to a maximum of 2 organisations. 6 projects have only 1 organisation in the top 10 list and 1 project has no organisations in the top 25 and top 10 list. This shows the lack of collaboration among top companies in the certified projects and this could be one of the reasons for achieving a lower grade.

The results from the two tables show the importance of collaboration among the top organisations in green building projects. While collaboration can be found in the top organisations in Platinum projects, certified projects have weak to no collaboration of top organisations in their project team. The numbers of top organisations involved in the certified projects were substantially lower than the Platinum projects paper despite not having a major difference in the total number of organisations involved in the project team. From a numbers perspective, the average number of organisations involved in Platinum and

Certified projects was 10 and 8, respectively. The Platinum projects have an average of 40% of participants from the top 25 organisations and 27% of participants from the top 10 organisations. On the other hand, certified projects have an average of only 17% and 12% in their top 25 and top 10 organisations, respectively. This shows the impact of experienced project participants in green building projects. Green building projects involves execution of green building tasks that are complex and different from a traditional construction project. Organisations with more experience in green building projects are well prepared to meet the challenges of a green building project, whereas organisations with less green building experience are less prepared to tackle the challenges faced in green building projects. Therefore, collaboration between top organisations can have a positive effect on the final green building grade and a lack of collaboration between top organisations might yield a lower green building grade.

Table 3: Certified Case Study Analysis

Project	Province	Total Organisations	Top 25 Organisations	Top 10 Organisations
Glenmore Filtered Water Pump Station Renovation	Alberta	8	1	1
Spruce Grove City Hall	Alberta	5	2	1
Livingston Place 8th floor	Alberta	6	2	1
Czorny Alzheimer Centre	British Columbia	10	1	1
Phase 2 Studio Building (Electronic Arts Inc.)	British Columbia	9	1	1
Faculty of Management Centre	British Columbia	8	1	1
Time Marketplace - 180 West Esplanade	British Columbia	9	0	0

5. CONCLUSIONS

The impact of the project team on the outcome of a green building project has been given limited attention in green building research. This study attempts to fill the gap by investigating the impacts of experienced project participants in green building projects. This pilot study proposes the use of the page rank algorithm, which is a link analysis technique, to measure organisational rank in green building projects. The impact of the organisational rank in green building project teams and the final green building grade was then studied. Key findings of this study show that projects with a higher green building certification grade often involve more experienced project team members, and that working with experienced team members could reinforce mutual experience as compared with working with less experienced members.

This study has proposed an innovative method to analyse organisations for project team selection and helps identify the strategies to form an efficient project team. Owners and managers in the green building industry can adopt this technique and strategies during project team formation to get improved performance. The authors used a mathematical technique to rank organisations in green building project teams, but the lack of completeness in organisational data of certain green building projects means that the calculated rank is not directly correlated with the reputation of the organisation or the project. The lack of project team data limited the sample size of projects in this study. The impact of the results also highlights the importance of preserving organisational data in the construction industry. Future study can focus on analysing the key role players in a project team and developing an improved algorithm to study multiple parameters of the project team characteristics. Projects with different owner types, building types and certification types (Gold and Silver certification) will be studied to find similar or different trends in project team combinations. Discussions with project team members can be conducted to support the results and relationships with different performance metrics like cost, schedule, quality, etc. can also be studied.

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6. REFERENCES

Albanese, R., 1994. Team-building Process: Key to Better Project Results. *Journal of Management in Engineering,* 10, 36-44.

Chakrabarti, S., Dom, B.E., Kumar, S.R., Raghavan, P., Rajagopalan, S., Tomkins, A., Gibson, D. and Kleinberg, J., 1999. Mining the Web's link structure. *Computer,* 32, 60-67.

Chan, A.P. and Chan, A.P., 2004. Key Performance Indicators for Measuring Construction Success. *Benchmarking: An International Journal,* 11, 203-221.

Glavinich, T.E., 2008. *Contractor's Guide to Green Building Construction: Management, Project Delivery, Documentation, and Risk Reduction*. John Wiley and Sons.

Gransberg, D.D., Dillon, W.D., Reynolds, L. and Boyd, J., 1999. Quantitative Analysis of Partnered Project Performance. *Journal of Construction Engineering and Management*, 125, 161-166.

Kaming, P.F., Olomolaiye, P.O., Holt, G.D. and Harris, F.C., 1997. Factors Influencing Construction Time and Cost Overruns on High-rise Projects in Indonesia. *Construction Management and Economics,* 15, 83-94.

Kibert, C.J., 2007. *Sustainable Construction: Green Building Design and Delivery*. Wiley.

Lu, Q. and Getoor, L., 2003. Link-based Classification, *ICML*, 496-503.

Neville, J. and Jensen, D., 2000. Iterative Classification in Relational Data. *Proc. AAAI-2000 Workshop on Learning Statistical Models from Relational Data*, 13-20.

Page, L., Brin, S., Motwani, R. and Winograd, T., 1999. *The Page Rank Citation Ranking: Bringing Order to the Web* [online]. Available from: http://ilpubs.stanford.edu:8090/422/1/1999-66.pdf [Accessed 15 April 2014].

Reed, W.G. and Gordon, E.B., 2000. Integrated Design and Building Process: What Research and Methodologies are Needed?. *Building Research and Information,* 28, 325-337.

Robichaud, L.B. and Anantatmula, V.S., 2010. Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, 27, 48-57.

Shokri-Ghasabeh, M., Chileshe, N. and Zillante, G. From Construction Project Success to Integrated Construction Project Selection. In: *Construction Research Congress*, 2010. 1020-1029.

Wang, X. and Huang, J., 2006. The Relationships between Key Stakeholders' Project Performance and Project Success: Perceptions of Chinese Construction Supervising Engineers. *International Journal of Project Management*, 24**,** 253-260.

Xu, J.J. and Chen, H., 2004. Fighting Organized Crimes: Using Shortest-Path Algorithms to Identify Associations in Criminal Networks. *Decision Support Systems,* 38, 473-487.

BARRIERS TO THE IMPLEMENTATION OF CONCURRENT ENGINEERING PRACTICES WITHIN THE UK CONSTRUCTION INDUSTRY

Anupa Manewa*
School of Built Environment, Liverpool John Moores University, United Kingdom

Mohan Siriwardena
Scott Sutherland School of Architecture and Built Environment, Robert Gorden University, United Kingdom

Andrew Ross
School of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

Concurrent Engineering (CE) is considered as one of the emerging methods in the UK construction industry. The product and process optimisation through 'integration' is a key concern of CE. The integrative aspect is tri-fold, which comprises an integration of product(s), integration of process and most importantly the integration of supply chain. A correct adoption of the concepts and principles of CE into construction practice provides significant benefits to project stakeholders, such as reduced time and costs while improving the quality of products and process efficiency. However, its implementation is not optimised to its full potential within the construction industry. Therefore, this paper aims to identify the key factors that hinder the implementation of CE practices within the UK construction industry. Data were collected from an extensive literature review, observations and semi-structured interviews and thematic analysis was adopted to analyse the collected data. The findings indicate that the inability of parties within the construction project settings to communicate effectively is the most significant high level barrier for achieving a wider application of CE practices within the UK construction industry. In total 4 high level barriers, 13 medium level barriers and 38 low level barriers to the implementation of CE with the UK construction practices were identified. The findings of this study will benefit construction organisations, who wish to implement CE practices within their practice.

Keywords: *Barriers; Concurrent Engineering; Construction Industry; Integration; UK.*

1. INTRODUCTION

Construction is a complex, fast changing industry which requires its organisations to adapt for emerging technologies and new practices to survive in the competitive markets. Concurrent Engineering (CE) (also known as Simultaneous Engineering) is relatively a new ideology, which brings number of benefits to construction industry stakeholders, who have different levels of interest and influences towards the project. CE is a partial temporal overlaps of the activities involved in a design and construction of new product (Azzone and Bertele, 2014). The approach is identified as an attempt to optimise the design and construction processes to reduce lead times, improve quality and cost by maximising concurrency and collaboration in working practices (Evbuomwan and Anumba, 1998). The traditional procurement practice frequently follows 'silo' practices whilst CE looks for 'integration /collaborative' approaches through product, process and supply chain integration, which of course minimises the design variations, cost and time overruns. An effective implementation of CE practices within construction projects provides better value for client's investment. The approach is practical and robust. However its implementation process has proved somewhat difficult. Literature suggests that there are enormous

* Corresponding Author: E-mail - R.M.Manewa@ljmu.ac.uk

benefits that can be expected from acorrect implementation of CE. However it is noticed that the application of CE practices is seemingly poor within the UK construction industry. Therefore, this paper aims to explore the key barriers to the implementation of CE with the UK construction practice.

2. CONCURRENT ENGINEERING

Construction is a major contributor to the United Kingdom (UK) Gross Domestic Product (directly 8.5% in 2008, rising to 10% overall when the entire value chain is considered) and a driver of historical GDP growth (National Construction Statistics, 2013). To survive in the future competitive markets, construction industry needs to recognise the complex adaptive nature of it, and be prepared for the future changes (technological innovation, new practices etc.). CE is a practical approach, which creates less chaotic environment while optimising time, cost, flexibilityand quality of construction product/process. The fragmentednature of the industry has a negative effect on its performance; therefore 'integration' and 'communication' areconsidered as two of criticalelements of CE towards a successful product / process delivery.

2.1. INTEGRATION

Integration is vital for the progression of construction projects operations. In specific to construction context, integrating can be identified within three domains, which are products, process and supply chain (team) integration. Product integration is to assemble the product from the product components, ensure that the product, as integrated, functions properly, and deliver the product (Carnegie Mellon University, 2008). Process integration seeks the possibilities for integrating the disconnected stages of product life cycle, which are design, procurement and construction (Thabet, 1999). Supply chain integration is a close alignment and coordination within a supply chain, often with the use of shared information systems. The supply chain integration covers both internal and external integration (Cao *et al*, 2015). Latham report (1994) strongly emphasised that there must be an integration of the work of designers and specialists and the more integrated the construction process can become the better the end result will be. In principal, successful projects are the product of well integrated teams (Ibrahim, Costello and Wilkinson, 2013). Integrated ICT systems are becoming a more popular tool to facilitate 'integration' (product – process – team) within the construction projects. For example, Building Information Modelling (BIM) is considered as one of innovative approaches to design, construction, and facility management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format (Eastman, 2008). A successful application of BIM software increases productivity in building design, construction and in-use.

2.2. COMMUNICATION

Effective communication is a vital consideration in CE practices. Communication affects individuals, group and organisational performance. Literature identified levels of communication which includes 'intrapersonal', 'interpersonal', 'group', and 'mass' levels (Emmitt and Gorse 2003). Intrapersonal communication involves the cognitive process of an individual to understand information and interpersonal involves communication between two people enabling relationships to be formed involving the transmission of signals and messages between both parties. Small group communication means the communication between more than two people and multi group communication involves communication across different groups; this is now moving into organisational communication. Mass communication is the communication through mass media where there is little control on who or how many receive the message. New technology is radically changing patterns of organisational communication; the advances of integrated computer systems within organisations means information can be communicated faster. Some may be of the opinion that this aids the effectiveness of communication in that it provides all members with the same message however, the use of computer integrated systems and perhaps the use of email could put a hindrance on the social interaction aspect of a company and make the workplace very impersonal. Ochiengand Price (2009) emphasised the importance of high-quality communication between the main project offices and on-site are a must to reduce the complexity of the design implementation process. CE comprises the element of effective communication, which helps to form a well-informed design. The advantage of a well-informed design means fewer errors at the construction phase,thereby producing cost savings. However, it should also be considered that if a design is detailed down to the lowest levels, then it leaves less room for error. Likewise, if the construction teams have all put together their needs and this has been incorporated into the programme, then it leaves less time spared. Therefore, CE encourages better communication to improve time, cost and quality.

The application of CE practices can be identified within few construction projects UK; however the technique is not that much popular within majority of construction projects. The extent to which CE is exploited to benefit processes and procedures is limited, and as such the reasons behind this need to be identified.

3. ADOPTED RESEARCH METHODS

An in-depth literature review was undertaken to identify the core principles of CE and a construction project was observed at three different time periods to understand the supply chain engagement in a typical construction project. In addition, eleven semi structured interviews were carried out among the industry professionals of leading construction companies in the UK to identify the barriers to implementation of CE. The selected interviewees were from architecture (1), engineering (1), project management (4) and quantity surveying (5) disciplines and their longevity of experience varied from less than 10 years to more than 30 years, thereby demonstrating a good spread of experience. Thematic analysis was used to cluster the data and to form high, medium and low level themes (barriers) that influence in implementation of CE practices within the UK construction industry.

4. DATA COLLECTION AND ANALYSIS

In addition to the literature review and three-point observation of the selected construction project, empirical data were collected to investigate the barriers. Interview questionnaire was developed and piloted among four postgraduate students from the built environment disciplines to check the clarity and readability of interview questions. All the interviews (11) were recorded and transcribed to generate the structured (high – medium – low level) themes. The Thematic analysis used to form 4 high level, 13 medium level and 38 low level barriers to implementation of CE within the UK construction industry (see Table 1).

Table 1: Thematic Analysis of Barriers to Implementation of CE Within the UK Construction Industry

High Level Themes	Medium Level Themes	Low Level Themes
Environment(e.g. organisational / project setting) (91)	Collaborative working (41)	Fragmentation and proximity (13)
		Breakdown/lost in communication (13)
		Meetings (12)
		Sharing space (3)
	Blame culture (22)	Fear of accountability (15)
		Cost implications (7)
	Roles and responsibilities (17)	Gap in roles/responsibilities (9)
		Competent professionals (4)
		Job specification (4)
	Integration and communication (11)	Commercial issues (11)
Personnel (88)	Project team (45)	Leadership (15)
		Effective communication (10)
		Resistance to change (7)
		Lack of experience (6)
		Lack of good working relationship (5)
		Proximity (2)
	Client involvement (32)	An engaged client (21)
		Detailed brief (11)
	Conflict (11)	Commercial issues (4)

High Level Themes	Medium Level Themes	Low Level Themes
		Confusion and misunderstanding (4)
		Change (3)
Technology (77)	Good in theory (34)	Independent folders (12)
		Individual goals (8)
		Data input (6)
		Variance in workforce abilities (4)
		Need for verbal communication (4)
	Change management (24)	Time, cost and quality (9)
		Fast and easy visibility (9)
		Time consuming (6)
	Building Information Modelling (19)	BIM proactivity (9)
		Resistance to change (6)
		Time consuming and costly (4)
Practice (58)	Planning and past experience (29)	Modern methods/prefab (14)
		Learn from past projects/complex adaptive nature (8)
		Poor planning (7)
	Traditional vs Concurrent engineering (16)	Traditional approach (8)
		Good in theory (8)
	Individual goals/objectives (13)	Organisational priorities (13)

The frequency of each word appeared in the transcription was numbered and inserted within the bracket. The barriers to implementation of CE were categorised into the domains of 'environment' (both organisational and project), 'personnel', 'technology' and 'practice'. As a result of the above analysis, environment emerged as the most influential barrier toimplement CE practices within the UK construction industry. These high-level themes were further evaluated within their sub themes.

4.1. *COLLABORATIVE WORKING*

The problems associated with the fragmented nature of the industry were prominently discussed within the interviews. One interviewee emphasised*"fragmentation; that is the biggest sole destroyer of integration and communication"*. However, most of the construction teams / supply chain are reluctant to work together unless there is a special commitment on project goals. The nature of current construction team was also highlighted by one interviewee *"you put the team together and disperse them afterwards"*. Overall, the hindrances posed by geographical locations of the construction teams and the inevitability that construction teams are purpose built for a project and then dismantled once a project is completed means that communication and integration is difficult to build and/or maintain due to the attitudes and work commitments of construction professionals. The interviewees further noted positive and negative consequences of meetings. Majority of the interviewees referred to routine meetings which are scheduled on a weekly or fortnightly basis but one interviewee highlighted that often *"meetings can be badly planned in our industry which means they can be unnecessary and quite often go on far too long and not actually achieve any end goal"*. By contrary, another interviewee said in order to have effective communication, regular meetings are the key. Only one interviewee made reference to networking and said his organisation *"have a lot of inter-divisional events that enable networking and getting to know other people"*. Although networking and social events facilitate the integration and communication, no one else in the interview process encouraged this idea. However, the use of shared office space and its benefits to integration, communication and attitudes were highlighted.

4.2. *BLAME CULTURE*

The fear of accountability was the most significant issue identified under the theme 'blame culture'. This theme was supported by all interviewees, meaning it is commonly thought that there is a fear of accountability in the industry which affects people's attitudes and actions. One interviewee suggested *"people will generally try and hide if they have done something wrong"*. Another interviewee was more specific and pointed *"Health and Safety laws; obviously they have been brought in to try and reduce death and injuries which is a great thing but ultimately an individual can be responsible for something or held accountable"*. Blame culture may also be a result of the cost implications associated with responsibility. Blame culture is 100% present in the construction industry and *"when it comes down to a lot of damages as we are part of fit-out, a lot of the decision is whose responsibility is it to rectify it so everybody tries to pass the buck onto someone else because of the cost implications"*. This comment provides an insight into the link between the fears of accountability and potentially the reasons for this, namely cost implications, which leads to blame culture being a common attitude of construction professionals.

4.3. ROLES AND RESPONSIBILITIES

The gap in roles and responsibilities was the most influential issue under the theme of roles and responsibilities. It was mostly identified that some people understand what is required of them and some do not, with one interviewee noted, *"things often fall under 'the too difficult to handle' or, 'I don't fancy that aspect', so then it falls into a grey area so there is a gap"*. This topic was evenly prominent across the different construction professionals. The idea that some areas of work offer*"poor job specification"* is linked with the gap in roles and responsibilities. Interviewees felt that professionals often feel that something is not their job and with someone else also dismissing it, creates a gap. Specialisation was raised as an issue. Construction professionals are often too specialised in their field and do not want to move away from that, but construction requires that. For instance, a quantity surveyor needs to have sufficient technical knowledge to understand and fulfil their role effectively in the same way a construction manager also needs to understand the commercial implications of works to fulfil their job role successfully. On the other hand, required competencies of professionals were highlighted by two interviewees. This low level theme is in contrast to the gap in roles and responsibilities as it enforces that people do understand their roles and responsibilities in the industry.

4.4. INTEGRATION AND COMMUNICATION

Commercial issues were identified as a major barrier to effective integration and communication. Many interviewees believed that maintaining a competitive edge involves holding back commercial information which goes against integration and many could not identify a way forward, and that organisations need to make profits so this issue would always be present. One interviewee stated *"it is a very competitive industry so everyone wants to make money"*. Though this is necessary, full integration of construction parties seems difficult to achieve.

4.5. PROJECT TEAM

The resistance to change was perceived to be a barrier to CE. It was identified that the industry employees a variety of people in terms of age, background and culture. The bringing together of construction professionals with tradesmen and so on means that some are ready to embrace new technologies, whereas others wouldn't even consider the idea, leading to very different approaches. Proximity of people is another barrier to CE. The geographical location of the construction parties would influence the ability to work concurrently. Two interviewees within the sample identified proximity as a barrier to CE is that many interviewees work in joint client/contractor offices and so did not encounter this as a difficulty in their own experiences. Lack of leadership was identified as the most significant barrier to implementation of CE. One interviewee highlighted that *"the barriers in most cases are not the concepts of CE but how things are set up to run it and the leadership"*. It was highlighted that for CE to be effective, all must know what is required of them and need to be brought on board to a concurrent way of working. The way in which to do this is through leadership. The effect of a lack of experience/know-how is another barrier to CE. In this data set, interviewees felt that designers lacked experience of pressures on site, many construction professionals were *"too specialised"* and did not have a good enough general technical knowledge to perform their roles effectively and work towards a project goal concurrently.

Communication was seen to not have been strong enough within the industry for CE to work effectively, with some suggesting implementing communication systems to overcome this barrier. With so many tasks being conducted at once in construction, being able to manage these effectively using CE, coordination was seen to be the key and this requires effective communication. Lack of good working relationships were viewed as a barrier to CE as concurrency could not take place without established working relationships. The industry's inability to form good working relationships could be due to the longevity of the industry and teams being dispersed after a specified period of time.

4.6. CLIENT INVOLVEMENT

The need for an engaged client was discussed by all interviewees and was brought to attention in many different perspectives. *"Client involvement usually brings success to a project if you have somebody who can communicate exactly what it is they want"* was the viewpoint of one interviewee. Throughout the interviews it was recognised that client involvement is significant. However, it can lead to frustrating situations when decisions cannot be verified within the time constraints. The importance of a detailed brief and its clarity was something which is scarce in the industry and in particular, the need for a client to communicate their requirements effectively was emphasised.

4.7. CONFLICTS

Confusion and misunderstandings lead to conflicts. For example one interviewee noted that instructions which say *"make good floor in a particular room. Now what the contractors impressions of making good a floor and the clients impression of making good a floor might be two completely different things"*. The interviewees felt there is a lot of confusion and misunderstandings in the industry and this leads to conflict when people are not clear on what is required. The continual design change involved in construction projects was also thought to lead to conflict. It should be noted, by construction professionals, that CE aims to reduce change. Commercial issues seem to have a strong connection with conflicts. Four interviewees stated that they believed CE could never be 100% successful due to the commercial aspect of all businesses: Profits come first.

4.8. GOOD IN THEORY

The significance of independent folders within integrated ICT systems was emphasised during the eleven interviews. One interviewee stated "we have a site and project wise for CAD, obviously not everything can be open to everyone so we have different areas". Supportively, another interviewee stated that "limited integrated systems enables things of a personal nature to be kept private" demonstrating the need for organisations to keep certain aspects of the business operations private, meaning integrated IT systems will never be fully integrated.

Individual goals proved to be a key player of what stands in the way of integrated IT systems. One interviewee noted that*"people a lot of the time have their own singular objectives rather than one joint goal. It should be that the aim is to build the job and everybody works towards that. But that's not always the case"*. The overall theme established was that integrated IT systems do not have the ability to overcome the fact that each party has their own individual goals and are most of the time working towards these rather than as a joint effort to get the job done. The importance of the data input into integrated IT systems was seen to dictate how useful they are by interviewees. It was maintained that the system was only as good as the data put into it in determining its effectiveness. One interviewee described some systems as *"slow and sluggish"* whereas another interviewee says their integrated system helps their organisation to *"monitor and manage everything centrally"*.

On the other hand a need for verbal communication and variance in workforce abilities were noted as of equal important. It was maintained that integrated IT systems will never document everything and verbal communication is a core to the progression of projects. In regards to variance in workforce abilities, one interviewee addressed the financial capabilities of the subcontractor in terms of integrated IT systems. In contrast to this, another interviewee identified variance in workforce abilities as the different levels of skills of people of varying ages, background and the lack of training provided for the ever-evolving IT system.

4.9. *CHANGE MANAGEMENT*

Time, cost and quality, and fast and easy visibility in relation to integrated IT systems were the most discussed facts by the interviewees. The benefits of integrated IT systems were noted by a number of interviewees by highlighting *"speed, efficiency and maybe even cost"* which contradicts previously quoted interviewee describing the IT systems as *"slow and sluggish"*. From this it can be derived that professional opinions on integrated IT systems largely vary and this could be down to the different systems employed within organisation and their performance. In terms of fast and easy visibility, designers were most forthcoming with this theme and *"swiftness of visibility"* was linked to the ability to *"see problems before they occur and being in the position to do something about them"* with early warnings and contractual communications being issued on integrated IT systems. The time consuming element of change management felt that updating information on integrated IT systems and so on took too long with one interviewee even describing it as *"counter productive"* and another calling it *"frustrating"*. It appears that there are mixed feelings on IT systems, proving there is room for improvement for many.

4.10. *BUILDING INFORMATION MODELLING*

The awareness of the benefits of BIM seems to have made its way to industry and is continually increasing. However, the resistance to change still appear within the use of BIM and this is an identified obstacle which needs to be overcome. The reasons for BIM resistance is*"because people are still used to working in an old style methodology"*, and *"there are such extremes within the industry in terms of technology and how things are actually done still so there is a long time before we are fully there"*. The transition from old style methods to BIM will be an ongoing concern and the flow of development to all parties needs to be addressed. Another issue highlighted was the time consuming and costly element (training, licence, ownership of model etc.) of BIM. The commercial professionals were most concerned with this issue with one interviewee stating that in one of the projects they had produced *"six or seven estimates before even seeing the BIM model because people weren't as quick as necessary in getting the information across"*. It was also raised that the BIM model is only as good as the information input into it, therefore, this research highlights that this is something which needs to be managed; time on data input.

The introduction of BIM for construction projects seems as a positive driver for integration and CE. A few benefits of BIM include clash detection and mitigation, faster drafting without loss of cost and quality and most importantly to the movement of CE; co-ordination and collaboration. BIM and CE work hand in hand in the progression they aim to achieve in terms of reduced design time, effective management, and improved quality and reduced costs. For the implementation of BIM to be as successful as possible, the identification of challenges is imperative. It should be recognised that the merging of BIM into the construction industry will not be without its challenges, but the professions cannot afford to be outside of the BIM loop (Martin, 2012).

4.11. *PLANNING AND PAST EXPERIENCE*

The importance of prefabrication and its impact on time, cost and quality was highlighted by interviewees as using forward planning to get ahead on a project. One interviewee noted *"getting the design resolved a lot earlier in the process so we can manufacture as much of our building off site as possible"* with another interviewee enforcing the time saved using prefabrication, *"we are building 30% quicker than anyone has ever built a hospital before and have taken 30 weeks off the programme which gives us massive savings prelims wise."* It can be inferred from the interview process that prefabrication is a key associate of CE for interviewees, and has the support of the industry. The lessons learnt from past projects taking into account constructions complex nature are not reflected in new projects. Three interviewees noted that the construction industry is unique and complex with others stating that these projects have been built before, and the barriers posed by past projects are still present on current projects. Interestingly one interviewee explained that *"CE is developed as a result of poor planning; works have to start on site with an incomplete design due to time restraints, however this is never the intention"*.

4.12. TRADITIONAL VS CONCURRENT ENGINEERING

Interviewees urged that a design should be completed before construction commence and that this is the way construction should work and it would eliminate many problems. However, this is never the case. One interviewee stated *"it would be much simpler if it was traditional that client gave us a design and we built it but we are developing the design whilst we are building it and proposing solutions"* at the same time. The idea of a concept being good in theory but not practical, which was raised as part of another theme earlier in this paper, has proved to be relevant again within the theme of traditional vs concurrent engineering. When describing CE in practice, interviewees often used phrases such as *"it's nice in theory"* or *"it doesn't work like that"*.

4.13. INDIVIDUAL GOALS/OBJECTIVES

It was identified that internal goals took preference over all parties working in unison towards one goal on a project. One example given by an interviewee of a hospital project summed up this theme accurately, *"the problem we have here on a hospital is that the client doesn't want to make a decision on equipment till the last minute in case any new equipment comes out but us as the contractor needs the decision really early on equipment so we can get hold of it and get it installed into the building and that might have an effect on some of the other systems we put in for example, the routes of cables or installation of walls"*. It was also identified that to satisfying everyone's requirements with so many parties involved can be challenging.

5. CONCLUSIONS

The aim of this research was to explore the barriers for implementing concurrent engineering within the UK construction industry. The research revealed that CE practices within construction projects seem to be employed to a certain degree. However, many construction professionals are not familiar with the term. The findings explain the understanding of fundamental principles of CE; integration and communication, are weak in the industry both in building and infrastructure and therefore many felt CE's application was not at its best. The key advantages of CE are immense. Time savings, once design and construction activities are coordinated effectively, thus leading to cost savings and quality assurance, improved working relations and making the industry a more productive place. The limitations identified that in order to coordinate design and construction, integration and communication is vital and this is one of the construction industry's major weaknesses. Amongst other limitations, individual goals and objectives of organisations, particularly commercial goals, stood in the way of integration, preventing the successful implementation of CE. The most critical finding of this investigation was the identification of four high level barriers, 13 medium level barriers and 38 low level barriers for implementing CE with the UK construction industry. The similarity could be identified with Ibrahim, Costello and Wilkinson (2013) studies which was based in New Zealand as their studies also identified 'focusing on goals and objectives', 'trust and respect', 'free flow communication', 'no blame culture', 'commitment from top management', 'team flexibility and responsiveness to change', 'collective understanding', 'seamless operation with no organisational boundaries', 'sharing information' and 'encouraging initiative' as relationship oriented indicators, and 'creation of single team location', 'innovation and improvement', 'integrated ICT system', 'effective management of health and safety' and 'client care team' as non-relationship oriented indicators that influence in team integration. As such, it appears that further research is necessary to explore how to overcome the barriers for implementing CE in order to harness its full potential.

6. REFERENCES

Azzone, G. and Bertele, U., 2014. Techniques for comparing the economic effectiveness of concurrent and traditional engineering, Leondes, C.T., ed. *Concurrent Engineering Techniques and Applications: Advances in Theory and Applications*. Elsevier.

Cao, Z., Huo, B., Li, Y. and Zhao, X., 2015. The impact of organisational culture on supply chain integration: A contingency and configuration approach. *Supply Chain Management: An International Journal*, 20(1), 24-41.

Carnegie Mellon University, 2008. CMMI® for Development, Version 1.2 [online], Product integration, Pittsburgh. Available from: http://chrguibert.free.fr/cmmi12/cmmi-dev/text/pa-pi.php [Accessed on 20 April 2014].

Eastman, C. M., 2008. *BIM handbook: a guide to building information modeling for owners, managers, designers, engineers, and contractors*. Hoboken, NJ: Wiley.

Emmitt, S. and Gorse, C., 2003. *Construction Communication*, Oxford, Blackwell.

Evbuomwan, N.F.O. and Anumba, C.J., 1998. An Integrated Framework for Concurrent life-cycle Design and Construction, *Advances in Engineering Software,* 5(7/9), 587-597.

Ibrahim, K.I., Costello, S.B. and Wilkinson, S., 2013. Key practice indicators of team integration in construction projects: a review, *Team Performance Management*, 19(3/4), 132-152.

Latham, M., 1994. Constructing the Team, Joint Review of procurement and contractual arrangements in the United Kingdom construction industry, HMSO.

Martin, J., 2012. UK Government Building Information Modelling (BIM) Strategy, BCIS - The building Cost Information Service COBRA, Las Vegas.

National Construction Statistics, 2013. Building and Constructio [online]. Available from: http://www.statistics.gov.uk/hub/business-energy/production-industries/building-and-construction/index.html [Accessed on 18 January 2014].

Ochieng, E.G. and Price, A.D., 2009. Framework for managing multicultural project teams, *Engineering, Construction and Architectural Management*, 16(6), 527-543.

Thabet, W., 1999. *Design-construction integration through virtual construction for improved constructability*, Berkeley – Stanford CE&M Workshop, Stanford.

BIM AS AN EFFECTIVE INFORMATION MANAGEMENT TOOL FOR ACHIEVING KEY PERFORMANCE INDICATORS IN CONSTRUCTION PROJECTS

K.A.D.N.C. Wijekoon*, Anupa Manewa, Andrew Ross and Dianne Marsh
School of Built Environment, Liverpool John Moores University, United Kingdom

ABSTRACT

The UK Government mandates the implementation of Building Information Modelling (BIM) for all centrally procured Government contracts from 2016. This of course challenged the industry to shift away from the traditional 'silo' practices to 'collaborative' working environments. BIM provides a collaborative platform to share information between project stakeholders and also guides to deliver products/processes effectively and efficiently. However, what strikes for the practitioners to move for a BIM platform is how it will support the achievement of project specific Key Performance Indicators (KPI). There are massive information generation and heterogeneous flows can be identified throughout a project lifecycle and the value of that information is enormous. From the definition itself, BIM has the capability of absorbing every benefit which can be obtained through information management.

This paper explains the use of BIM as an effective information management tool for achieving the KPIs in construction projects. Initially, an extensive literature review was conducted to identify the application of BIM in construction project lifecycle and its role as an effective information management tool. In addition to six (6) numbers of interviews were conducted among the construction industry professionals to identify the practical use of BIM in construction projects and its effectiveness in achieving project KPIs. The findings of the study illustrate the BIM driven construction project KPIs and their importance in achieving project goals.

Keywords: *Building Information Modelling (BIM); Construction Projects; Information Management; Key Performance Indicators (KPI).*

1. INTRODUCTION

Building Information Modelling (BIM) is a fascinating concept that has been defined in wide range of aspects by different people as it has mean to them (Demian and Walters, 2014). BIM was initially for the design and construction stages of construction projects (British Institute of Facilities Management, 2012) yet, the impact of implementation can be achieved throughout the building life cycle (Eadie *et al.,* 2013). BIM is continuously expanding its potentials with information processing by moving from 3D modelling to facilities management (FM) (Royal Institute of British Architects, 2012). Capturing and storing information related to the building is the initial success factor for a well-planned facility management (Akcamete *et al.*, 2011) and data stored in BIM are beneficial for most of the FM tasks (Becerik-Gerber *et al.*, 2012). Despite, most of the construction projects do not handover the 3D model and CoBie (Construction Operations Building Information Exchange) dataset at the commissioning which prevents the grasping of BIM advantages in FM (Eadie *et al.,* 2013).

The application of BIM in construction industry has expanded significantly while BIM has translated into a support tool for various tasks in construction phase (Ding *et al.*, 2014). In UK, construction industry has a higher potential growth and the Government is in interest to support its growth (HM Government, 2013). In fact, BIM has become a good technique to speed up this growth. Government has set its vision to reach efficiency and technically advanced construction sector by 2025 by promoting "smart

* Corresponding Author: E-mail - K.A.Wijekoon@2015.ljmu.ac.uk

construction" and "digital design" (HM Government, 2013). Smith (2014) emphasises that the success factor to BIM implementation is the government initiation or leadership. As a result, Government has mandated that all centrally procured government contracts should adopt BIM by 2016 (HM Government, 2013; Eadie *et al.,* 2015).

In a typical construction project, time and cost overruns are frequent issues, which bring negative outcomes for the construction industry (Olawale and Sun, 2015). When a multi-disciplinary team is working together complexity, conflicts and uncertainties are experienced more often (Khosrowshahi and Arayici, 2012). Lack of information management techniques used in the construction industry has led to a complex data flow through the project life cycle and consequently has resulted most of these common issues (Masood *et al.*, 2014). BIM is identified as an effective tool to overcome most of the problems in construction industry. The findings of many researchers reveal that BIM positively support the project KPIs and also enhance the collaboration (Bryde *et al.*, 2013; Masood *et al.*, 2014).

2. BUILDING INFORMATION MODELLING

BIM has given a plethora of definitions by different researchers (Ding *et al.*, 2014). Masood *et al.* (2014) explain BIM as a process of creating and implementing a digital model to integrate the phases of building life cycle. Barlish and Sullivan (2012) emphasise that BIM is a platform which carries complete building life cycle information without being bias to a group of stakeholders. In construction aspect, BIM is the process of creating and making use of created information through building life cycle (McGraw-Hill, 2009). In facilities management perspective, BIM is a holistic approach to be applied throughout building life cycle (British Institute of Facilities Management, 2012). Having considered many of those definitions, National Building Specifications (2013) explain BIM as "an efficient process for effective management of building information, which are created during the pre and post-construction stages of particular asset" (Construction Products Association and NBS, 2013).

BIM is developed with many features and it keeps expanding its potential. Three Dimensional (3D) modelling is the well-known feature of BIM (Construction Products Association and NBS, 2013). It is an important basic achievement for BIM to deliver high project performance (Eadie *et al.,* 2013). Structured data is the strongest feature in BIM which attracts popularity (Construction Products Association and NBS, 2013). Although there are many other solutions available in the practice, information richness with smart objects is the key difference of BIM compared to other 3D modelling (Ding *et al.,* 2014; Demian and Walters, 2014; Howard and Björk, 2008). Moreover, BIM simplifies many tasks occurring throughout building life cycle (Czmoch and Pękala, 2014). BIM cannot be considered as an isolated tool since its implementation may have influence on all the processes within the project lifecycle (Eadie *et al.,* 2013). BIM maturity model explains how BIM was conceived from CAD and then developed into a rich information model (Royal Institute of British Architects, 2012). It keeps expanding its dimensions and Figure 1 illustrates development of these dimensions under different BIM maturity levels.

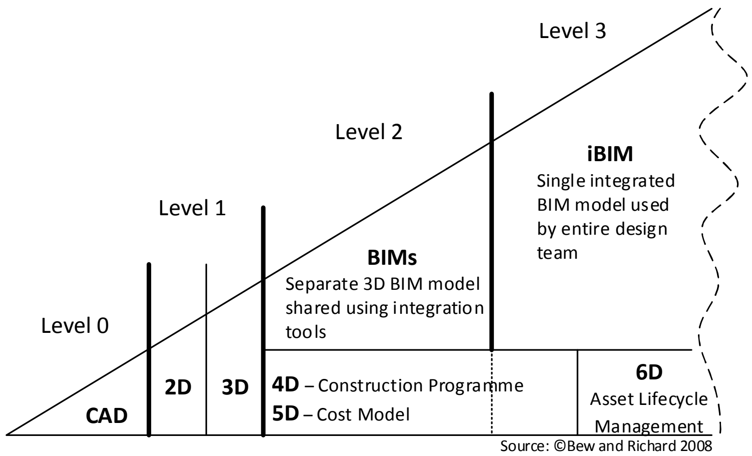

Figure 1: BIM Maturity Model
Source: Monaghans (2013)

Starting from 3D modelling, it has extended to project scheduling (4D), cost estimation (5D) (Bryde *et al.*, 2013), sustainability (6D) and currently most updated feature of Facilities Management (7D) (Construction Products Association and NBS, 2013). However, the outcome of each of the extension is based on the accuracy and the availability of robust information.

3. INFORMATION MANAGEMENT IN CONSTRUCTION INDUSTRY

The BIM Task Group together with Royal Institute of British Architects (RIBA) developed the stages of assets in the built environment from its creation to operation and end of life (Manning, 2014). Manning, (2014) explains that RIBA Plan of Work 2013 is a rout through the development of asset information through the built asset life cycle. Accordingly, information is being created throughout these stages in different quantities. These information is managed through PAS 1192-2 (Manning, 2014).

From the earliest stages in building construction the need for communication within the project team can be identified as a primary requirement (Construction Products Association and NBS, 2013). For many centuries they used 2D paper based drawings (Czmoch and Pękala, 2014) and there are many conflicts with the traditional practice (Khosrowshahi and Arayici, 2012). Initially CAD (Computer Aided Design) change this process (Czmoch and Pękala, 2014) yet, technology by itself could not make a complete difference (Khosrowshahi and Arayici, 2012). Therefore, industry is keep moving fast from CAD to information rich Building Information Modelling (BIM) (Malsane *et al.*, 2015).

With regard to information exchange Demian and Walters (2014) pointed out that electronic mails (E-mails) remain to hold the popularity among the construction industry for information and document exchange regardless of the new technology. Although, to manage project information, that is to create, store and use; BIM has been captured as the best and fastest growing solution. Ma and Liu (2014) explain how BIM can be used to move into automated cost estimation and accruing accurate construction information. BIM has become a solution for the adhering to the compliance making it much easy by promoting automated compliance checking (Malsane *et al.*, 2015). BIM promotes early creation of critical information related to design, coordination and logistics which brings a significant progress on later phases of project life cycle (Demian and Walters, 2014). This feature is much beneficial at the construction stage. Further, even the asset information management standards are extending its areas to be align with BIM (Hayes *et al.*, 2014). Construction industry is heading towards sustainable practices and BIM is a powerful tool which assist sustainability in construction projects (Antón and Díaz, 2014).

According to NBS (2014) BIM awareness level is increasing and organisations are getting involved in BIM more frequently. Demian and Walters (2014) noted that necessary precautions should be taken when generalizing the benefits of BIM as an information management tool. Time, cost, quality are the most important KPIs of a construction project (Toor and Ogunlana, 2010). The success of the project is benchmarked with the KPIs (Ali *et al.*, 2013). Therefore, to have reflect on the project benefits made through BIM adoption, they should reach the project KPIs. The overall benefit of BIM is not yet completely identified and construction project stakeholders are still struggling to make the decision on BIM (Barlish and Sullivan, 2012). Looking deep into the situation, there are many research highlighting the benefits of BIM but they are in much broader and technical view. The large number of Small and Medium Enterprises (SMEs) are still reluctant to adopt BIM in their agenda.

4. ADOPTED RESEARCH METHODS

This preliminary paper is highly based on a literature review on construction project KPIs and BIM contribution towards improving project KPIs. Firstly, the project based KPIs and application of BIM in construction projects were identified through an extensive literature review. In addition,6 interviews were conducted among construction professionals (3 Quantity Surveyors, 2 Project Managers and an Engineer) to identify how BIM could be utilised as an effective tool to achieve project KPIs. Also same set of interviews were used to identify the challenges and future potentials for BIM in construction projects. The interviews were analysed through content analysis using NVivo10 software. Content analysis was used to determine the most significant negative and positive factors.

5. DATA COLLECTION AND ANALYSIS

Data collection was undertaken in two phases. Initially the data was gathered through existing literature and they were presented to the industry practitioners for validation and trace their impact on project KPIs. Interview questionnaires were developed and piloted among few academics who have industry exposure to identify clarity and readability of questions before circulation. Seven participants were invited for interviews however, six of them did so. All of the interviewees have a perceived understanding of BIM in industry and each has extensive experience in their profession. The respondents' experience varied from 5 – 20 years by giving a good spread.

The pool of interviewees consisted with 3 quantity surveyors, 2 project managers and an engineer. As the respondents are from a variety of locations and professional backgrounds, working on different projects, a wide range of views and perceptions were expressed, also leading to some conflicting opinions. Through these interviews, the main areas of concern have been recognised and analysed in particular groups in order to accurately compare and highlight the opinions conveyed, giving the researcher a wider overview in which to derive an overall conclusion.

The interview guideline was used to structure the interviews, which mainly consisted two sections. The first section of the interview guideline was structured with few introductory questions to make the interviewee more comfortable with the interview. The second sections of the interview consisted with three main questions to gather the participants' view on project KPIs and BIM contribution and also to identify challenges and benefits of implementing BIM in construction projects.

All six interviewees' responses highlighted that collaboration feature of BIM is the most useful in a construction project as it involves multi-disciplinary team members, who are working on a single project model. It is the key factor which stimulates the consequent benefits of BIM. Quality improvements of the end product is the final outcome of the BIM adoption. Quality is improved through information availability, automated corrections made through the BIM process and creating a good platform for decision makers by allowing knowledge sharing. The fact to admire in BIM adoption is, unlike other quality improvement techniques, BIM reduce the project cost while enhancing the quality. The improved decision making platform reduce the excess labour cost and rework. As it brings instant cost reductions in construction; the quality built facility will reduce the operation and maintenance cost in long term. There were both positive and negative reactions towards the time factor. The negative reactions on time was especially related to the initial few projects or time requirement for BIM adoption. For instance, the time target should be achieved as in theory things should be built quicker. Since, fewer resources will be needed to do what 2 or 3 other people were doing 10 years ago. By contrary, achieving the time target could be problematic as it is difficult to get sign-off on the model. BIM modelling phase of the project will probably extend and it will potentially delay getting projects on the ground. However, time was influenced mostly by all considered BIM features. Likewise, it's clear from different viewpoints; by improving in timely delivery cost of construction and quality of the end product can be improved from the first project itself with BIM.

6. FINDINGS AND DISCUSSION

In the initial stages of implementing BIM into a construction project requires a BIM Execution Plan and it is essential for the success and smooth running of the project. It is seen to be advantageous as the main personnel involved in the project at the early stages to discuss and define what is wanted from the model. If this is done correctly, then, most of the benefits are beyond deliver.

Another benefit was the ability to perform clash detection tests in order to identify any practical issue that may occur during construction. A clash detection test is commonly performed when integrating models to make one collaborative model using a software package such as Navisworks. In theory through the use of this concept, it should eradicate any issues on site, as they are dealt with at the design stage through the model. This method checks buildability prior to committing resources and materials to site, saving time and money.

Decision-making is a key benefit that is currently experiencing by BIM users. The final advantage that was agreed among the respondents was the 'visualisation' that BIM offers. This provides the answer to the problem with people taking 2D drawing and trying to represent that in 3D in their mind. This allows the navigation within the model and trace the things which cannot be traced in a drawing. The benefit of visualization makes the process easy when dealing with clients who have difficulty interpreting the construction processes off a 2D drawing, and acknowledges that BIM completes this process for them.

BIM should be something that everyone can use in terms of logistics, sequencing and quantities; all the way through to the end user, and facilitating through the lifecycle of the project. In essence BIM brings a value for money for every stakeholder, who has different level of interest and influence towards the project goal.

BIM entails openness and transparency if utilised correctly. This is the desired result if it is ensured that everyone is working on the same model, using a BIM execution plan and collaborating at the early stages. It is important that there is an effective change management system, so that if a design is changed on the BIM model, it automatically updates and this will further improve decision making and release professionals to perform other tasks. Ultimately this allows the project to always have readily available information. In a nutshell BIM enables to be more proactive than reactive.

6.1. PROJECT KPIS AND BIM CONTRIBUTION

If the BIM model is set up properly at the early stages of a project and if efficient information management processes is in balance, effective decisions can be made and KPIs should be achieved; they should only be capable of being improved. Literature reveals the key benefits that can be gained through BIM. Yet, it is rare to find research on how to gain these advantages or how BIM becomes negative to certain organisations. Rather than just understanding the advantages of BIM, this paper illustrates how different features of BIM brings positive impacts on project KPIs. However, few significant KPIs (time, cost and quality) were selected to analyse on how BIM implementation would help to achieve those KPIs effectively. According to the research findings, it was evident construction project time being the most influential consideration on BIM implementation compared to other project KPIs. Time has been emphasise since it has instant progress with BIM implementation and every improvement is visible and quantifiable. Consequently, quality seems to be untouched not because BIM has less or no impact on quality but because the quality improvements are not instant and cannot identify as a direct improvement made by a single fact. However, it carriers both negative and positive impacts. The findings of the interviews used to identify/confirm BIM positive and negative factors towards project KPIs (see Table 1). However those factors were not in a priority order as 6 numbers of interviews were not sufficient to rank them in a priority list.

Table 1: Impact on BIM in Project KPIs

KPI	BIM Positive										BIM Negative						
Time Cost Quality	Collaboration & Communication	Visualization	Details on building performance	BIM execution plan	Automated information	Design error identification(Clash Detection)	Information for future projects	Improved documentation	Simultaneous access	Complying to Government rules	Additional Effort	BIM execution plan	Design liability	Not completely developed	Business process changes	Risk of quality of information	Process / Technology implementation & training
Ref. No.	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	N1	N2	N3	N4	N5	N6	N7

As noted in Table 1, multiple BIM based factors influence positively and negatively on time, cost and quality of a construction project. Referring to the BIM positive, the most common and basic features which will bring a positive impact has been lined up by analysing the interviewees' opinions. Similar to the previous findings in literature, collaboration and communication (P1) is a key feature in BIM. BIM reduces the time spent on collaborating the ideas and work of different parties involved in the construction process by making information available to all the parties in construction process and bringing them onto a single platform. This will also reduce the construction cost because every party in the team understand each other and avoid contributions which can be costly from another angle. As a result, it improves the quality of final product since BIM creates space to interact and correct each parties' work before it goes on the ground. Similarly, P2 - visualization and details on building performance have a positive impact on the all three KPIs directly through supporting the decision making process and reducing rework. As a result, 3D visualization and detailed information on building performance make positive impact on time, cost and quality.

BIM execution plan (P4), automated information generation (P5), design error identification (P6) and providing information for future projects (P7) do make a positive difference to the project time and cost. Specifically, BIM execution plan (P4) helps the smooth flow of the construction work once started since the planning is done for the time ahead. It makes the team to think about the time ahead and will generate a clear picture on how the project will flow. Being aware about the upcoming tasks is directly helpful for supplier handling and cost planning which brings cost reduction and timely completion of the project. Yet, referring to the N2: BIM execution plan as a negative factor, it delays the start date of a project. Although it is theoretically advantageous, in practice contractors look forward to take over a project and finish it within least time in order to move out to the next project. A delay in the project start date is a consideration. Even this time gap can be catch up from the total project duration, in practice it is preferred to look for time savings in the moment they are working on. Next, improved documentation (P8), simultaneous access (P9) to the drawings and project details primarily make an impact over the project completion time. Finally, P10 brings the advantage of government support. Since the Government has mandated to comply with BIM by 2016, getting involved with BIM will save time at the project handing over stage converting the project details into BIM platform.

Almost every feature carries it positive and negative impacts. Similar to the BIM positive, it explain how each of the feature negatively effect on time, cost and quality. To adopt into the BIM culture organisations need to invest money, time and human resource (N1). This additional efforts have been always holding back any organisational change. Also, with the simultaneous access there is a rising issue on liability for the final product or on a certain failure (N3). On the other hand, the features and capabilities of BIM is not yet fully developed (N4). This will limit the full experience of BIM advantages as mentioned in theory. Similarly, business process change (N5) and process implementation together with training (N7) consume time and incur a cost. Also, the benefits of BIM highly depend on the information fed into the process (N6). Therefore, there is a risk of the quality of information. BIM will deliver the output based on its input.

It is clear that, time is the KPI which is most impacted yet, quantitatively the time delay which occurs through negative impacts are far much less than the time saving made through positive impacts.

6.2. CHALLENGES FOR IMPLEMENTING BIM IN CONSTRUCTION INDUSTRY

The most conversed challenges of BIM are related to the cultural changes. Getting the industry to change or getting people to change is probably one of the most difficult things. These theories have further been backed up by the old-school supervisors and the old-old generation of managers and foremen who still rely upon hard-copy drawings etc. and are not computer literate.

Another challenge disclosed on the implementation of BIM is related to the start-up and finances needed to introduce BIM into a company, no matter how large or small. The initial costs of setting up these projects for the client has been more expensive. It will drive up supply chain costs as they try to get up to speed with the right people and the right training. The larger supply chain should be able to cope with the transition but the smaller contractors and perhaps even SMEs won't be able to afford it, ultimately limiting the supply chain.

Also, there is an issue with software that companies are holding back as they are unsure of the best software package to buy into. Further to this, everyone is using different operating systems and the government won't actually move forward and identify one type of software that will be compatible for all organisations. As a result of this issue, companies are not integrating BIM, therefore are not embracing the full concept of BIM. Even with the BIM software installed, the computers have to be renewed in order to cater for a full integrated model and therefore are too very expensive to upgrade or renew.

Although the issue of adequate training can be overcome in due course as the colleges are offering courses in BIM, and consultancies are running BIM academies try to equip professionals with the adequate skills to deliver projects in BIM it was noted that there are more students attending these events than contractors any other profession, therefore this highlights to that the interest in adopting BIM into organisations still needs to be looked at and enforced.

Another issue comes up in practice is integrating separate models into one combined model. Again this leads to the issue of software. Currently Navisworks is being used as an integration tool, but for larger projects and more complex projects this software is not suffice for the intricacy of the projects. It is thought that in the BIM execution plan, a specific software should be determined for all the designers to use, therefore when it comes to integrating the models, it should be '*all singing, all dancing'*.

Now, in respect of the actual BIM models, there are models with too much information, sometimes needless, but on the other hand there are a lot of models that don't actually have enough data in them for the project team to work with. This issue is caused due to the clients and clerical teams for clients being all over the place, and they don't actually know what they want from the model, which leaves the model very vague. This leads to the model developed being of no use to the contractor or client as it is not built up properly and cannot be used. An exception to these is the large clients who generally know what they want from a model. Other organisations should take notes of their execution plans in order to achieve their desired project goals. However, it was clear that many firms are burying their head in the sand and are afraid of adopting BIM, therefore are in no urgency to buy into it. It is not the issues in BIM hold them back.

7. CONCLUSION

BIM has a value to every aspect of the construction industry and all professionals should embrace the modernity and innovative concept of BIM. The advantages that stem from effective information management through BIM are; speed, speed of decisions, therefore saving time and the accuracy of these decisions will then improve costs. It gives programme certainty as players can do simulations and do a two or four week look-ahead to forecast productivity and costs. In relation to quality, the model moves towards design for manufacturer and assembly, therefore resulting in better quality. Theory issues can be eradicated through the clash detection, leading to a better quality finish and fitting on-site. In further, quality is improved due to the seamless design where everything is fully integrated.

The findings of this study suggest that BIM has major influence in project KPIs. In fact project performance can be improved through a proper application of BIM and this will lead to improve the project profitability. As BIM provides a great platform by replacing silo concept through collaboration all the stakeholders may get good opportunity to involve in the project however their interests and influence may different. This will provide win-win solution to each project stakeholder.

8. REFERENCES

Akcamete, A., Akinci, B. and Garrett, J. H., 2011. Potential utilisation of building information models for planning maintenance activities. *In:* Tizani, W. ed. *International Conference on Computing in Civil and Building Engineering.* Nottingham University Press.

Ali, H.A.E.M., Al-Sulaihi, I.A. and Al-Gahtani, K.S., 2013. Indicators for measuring performance of building construction companies in Kingdom of Saudi Arabia. *Journal of King Saud University - Engineering Sciences,* 25(2)**,** 125-134.

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

Barlish, K. and Sullivan, K., 2012. How to measure the benefits of BIM — A case study approach. *Automation in Construction,* 24(1)**,** 149-159.

Becerik-Gerber, B., Jazizadeh, F., Li, N. and Calis, G., 2012. Application areas and data requirements for BIM-enabled facilities management. *Journal of Construction Engineering and Management,* 138(3)**,** 431-442.

British Institute of Facilities Management, 2012. BIM and FM: Bridging the gap of success, British Institute of Facilities Management (Herts).

Bryde, D., Broquetas, M. and Volm, J.M., 2013. The project benefits of Building Information Modelling (BIM). *International Journal of Project Management,* 31(7)**,** 971-980.

Construction Products Association and NBS 2013. *BIM for the terrified*, London: Construction Products Association and NBS.

Czmoch, I. and Pękala, A., 2014. Traditional Design versus BIM Based Design. *Procedia Engineering,* 91, 210-215.

Demian, P. and Walters, D., 2014. The advantages of information management through building information modelling. *Construction Management and Economics,* 32(12)**,** 1153-1165.

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

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

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

Hayes, A., Watts, J., Pocock, D. and Shetty, N., 2014. Leveraging the relationship between BIM and asset management. *Infrastructure Asset Management,* 1(1)**,** 5.

HM Government, 2013. Construction 2025: Industrial Strategy for Construction HM Government (London).

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

Khosrowshahi, F. and Arayici, Y., 2012. Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management,* 19(6)**,** 610-635.

Ma, Z. and Liu, Z., 2014. BIM-based Intelligent Acquisition of Construction Information for Cost Estimation of Building Projects. *Procedia Engineering,* 85, 358-367.

Malsane, S., Matthews, J., Lockley, S., Love, P.E.D. and Greenwood, D., 2015. Development of an object model for automated compliance checking. *Automation in Construction,* 49(1)**,** 51-58.

Manning, R., 2014. The Asset Information Model Using BIM, (London).

Masood, R., Kharal, M.K.N. and Nasir, A.R., 2014. Is BIM Adoption Advantageous for Construction Industry of Pakistan? *Procedia Engineering,* 77, 229-238.

McGraw-Hill, 2009. *The business value of BIM: getting to the bottom line* New York: McGraw Hill Construction.

Monaghans, 2013. *Level 2 BIM is Coming* [online]. Trebbi Family. Available: http://www.monaghans.co.uk/post.php?s=2013-04-09-level-2-bim-is-coming [Accessed 15 April 2015].

NBS, 2014. National BIM Report (London).

Olawale, Y. and Sun, M., 2015. Construction project control in the UK: Current practice, existing problems and recommendations for future improvement. *International Journal of Project Management,* 33(3)**,** 623-637.

Royal Institute of British Architects, 2012. *BIM Overlay RIBA Plan of Work Embargoed,* London: RIBA Publishing.

Smith, P., 2014. BIM Implementation – Global Strategies. *Procedia Engineering,* 85, 482-492.

Toor, S.U.R. and Ogunlana, S.O., 2010. Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects. *International Journal of Project Management,* 28(3)**,** 228-236.

BUILDING DEMOLITION WASTE MANAGEMENT PRACTICES – AN INDIAN CASE STUDY

V. G. Ram and Satyanarayana Kalidindi*
Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India

ABSTRACT

Sustainable development has become an increasing concern throughout the world in the last two decades. Construction industry generates a huge quantity of waste, which is termed as construction and demolition (C&D) waste. C&D waste constitutes a major portion of the total solid waste generated in a society. Therefore, adoption of sustainable practices in C&D activities is vital for a society to move towards sustainable development. Moreover, demolition is a phase of construction that produces a large quantity of waste and hence requires explicit attention. During the past few decades, considerable amount of C&D waste is recycled in the developed countries. However, there are very few actively functioning C&D waste recycling facilities available in India. This signals the magnitude of the problem that needs to be addressed with respect to C&D waste management in India. In this paper, a case study research methodology is adopted to study the demolition waste management practices being adopted in Chennai city and the barriers that prevent the recycling of C&D debris have been discussed. The practices were found to be driven purely by economic incentives and unauthorized disposal of C&D waste is prevalent. There is a lack of awareness regarding the recycling possibilities among the stakeholders. Moreover, there are no records containing details on the quantity of C&D waste getting generated. Lack of appropriate policies, rules and strategies to address the C&D waste management have also been found to be some of the major barriers for the lack of C&D waste recycling initiatives in India.

Keywords: *Barriers; C&D Waste; Demolition; Recycling; Waste Management Practices.*

1. INTRODUCTION

Infrastructure is considered to be one of the important drivers of the economic growth of a country. As per the Twelfth Five Year Plan (2012-2017), India’s Planning Commission has projected an investment of around 1 trillion US dollars for the infrastructure sector. It is believed that 45 percent of that investment is towards construction (Deloitte, 2014). Construction activities contribute around 8% to India’s GDP. Moreover, the number of demolition activities is steadily increasing in the urban areas in order to make way for development. The main reasons for demolition includes obsolescence of the built facilities, change in expected requirements from the facilities, expansion due to economic growth etc. While the construction industry significantly contributes towards the development of a society, it is also seen as a major contributor to environmental degradation (Poon *et al.*, 2007). Some of its negative impacts on the society are land depletion, energy consumption, solid waste generation, dust and gas emission, noise pollution, and consumption of natural resources including non-renewable resources (Lu and Yuan, 2010). The waste that is generated during construction and demolition activities is generally termed as Construction and Demolition (C&D) waste. C&D waste also include those wastes that arise due to activities such as renovation, site clearance and land excavation.

Researchers around the world have reported that C&D waste constitutes around 30% to 35% of the total solid waste generated in a society. The US generated around 128 million metric tons of building related C&D debris in the year 1996 (Franklin Associates, 1998). The European Union as a whole (EU-15 countries) reported around 180 million metric tons of core C&D waste generation in the year 1999 which excludes excavated soil and other such kinds of waste (Symonds, 1999). The annual generation of C&D

* Corresponding Author: E-mail- satyakan@iitm.ac.in

waste in Hong Kong was around 20 million tons in 2004 (Poon, 2007). The absolute quantity of the C&D waste getting generated signals the need for explicit attention and management in order to move towards a sustainable society.

C&D waste includes concrete debris, brick masonry debris, reinforcement steel, broken tiles, wood, paper, plastics, electrical wires, sanitary fittings etc. Most of this waste is inert in nature. It is reported that over 50 % of C&D waste is mainly confined to concrete and masonry debris (Cochran *et al.,* 2007). This debris can be crushed and processed to produce recycled aggregates that can be substituted for natural aggregates in the production of concrete and other construction materials. However, they end up getting dumped in landfills or unauthorized places.

On the other hand, the need for aggregates in the construction industry is increasing. However, the supply is getting restricted due to the ban imposed on quarrying of aggregates in many states in India. On account of such a ban, many construction projects face shortage of aggregates and are forced to look for alternative resources. The use of materials recycled from C&D waste can address this issue to some extent. However, the quantity of C&D waste recycled in India is negligible.

In India, there are very few C&D waste recycling facilities available to process the C&D waste generated. The lone facility operating in the National Capital Region (NCR) of India has a capacity to process about 500 tons of C&D waste per day. On the other hand, Netherlands has around 120 C&D waste recycling facilities with an average capacity of 400 tons per day (Symonds, 1999). The population of Netherlands is about 16.9 million (2015 estimate) whereas the population of NCR is about 54million (2011 estimate). This statistic illustrates the magnitude of the problem to be addressed with respect to handling of C&D waste in India. Therefore, there is a need to investigate the reasons for such a low recycling activity in India. The waste management practices of the industry need to be studied in order to evaluate various policies and strategies that can induce sustainable practices in the industry.

A study was undertaken to investigate the demolition waste management practices being adopted in Chennai city by conducting case studies on demolition projects. The barriers being faced in setting up recycling facilities have also been discussed. The practices adopted in demolition projects were only studied and the study of construction waste management practices is beyond the scope of this study. The rationale for choosing to study only the demolition projects is that the quantity of waste generated during demolition is almost ten times of that generated during a construction project (Duan *et al.*, 2015). The study was conducted in Chennai city, the fourth largest metropolitan city of the country. Chennai city is the capital of the state of Tamil Nadu and is spread over an area of about 426 km^2 with an estimated population of about 8.7 Million.

The paper is organized as follows. In the next section, the best practices, strategies and policies of some countries that have successfully implemented C&D waste recycling initiatives have been reviewed. In the third section, the findings of the case studies conducted on demolition projects in Chennai city have been discussed. The waste management practices being adopted in Chennai city have been compared with international best practices. The barriers posed because of unsustainable practices have also been discussed in the next section. Finally, the paper closes with the concluding remarks and the future work that has been planned.

2. REVIEW OF WASTE MANAGEMENT PRACTICES, STRATEGIES AND POLICIES

C&D waste management literature suggests three waste management strategies that are desirable: reduce, reuse and recycle. Even though these strategies are environment friendly and contribute to the sustainable development of a society, the construction industry is mainly driven by economic incentives (Begum *et al.,* 2006). Moreover, there are many other barriers that prevent the construction industry participants from carrying out practices that favour reuse / recycle. Hence, the government and policy makers in various countries enacted policies and adopted strategies that induced sustainable waste management practices in the industry. The quantity of C&D waste recycled out of the total quantity of C&D waste generated in some of the developed countries is shown in the Figure 1. It can be observed that the percentage of recovery is quite high in certain developed countries. The characteristics of the environment prevailing in those countries have certainly favoured the growth of the recycling industry. In this section, the practices, strategies and policies adopted in various countries has been reviewed.

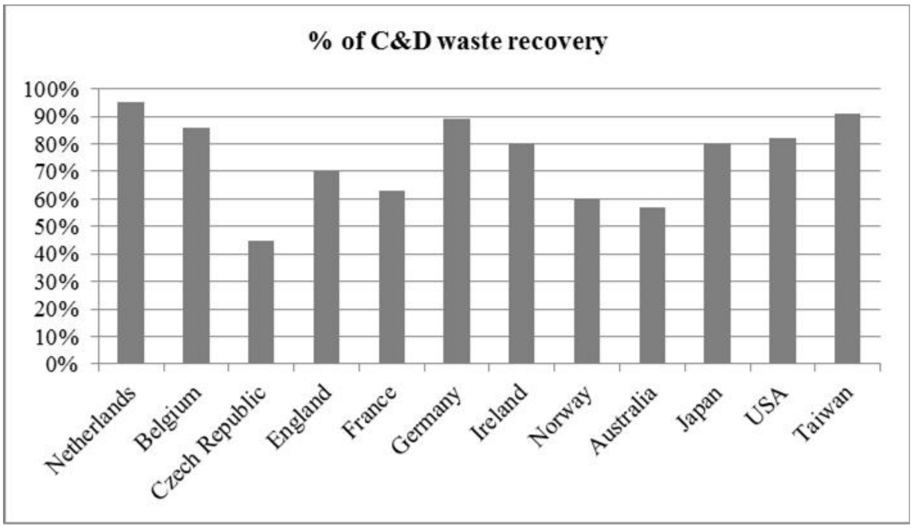

Figure 1: Percentage of C&D Waste Recycled Out of Total Quantity of C&D Waste Generated
Source: CSI (2009)

2.1. EUROPEAN UNION

European Union is estimated to be generating about 450 million tons of C&D waste annually and out of this, concrete and masonry debris alone constitutes around 180 million tons (Symonds, 1999). Among the EU countries, Netherlands, Belgium and Denmark are recycling more than 80% of the total C&D waste being generated every year. These EU countries have set up a target of 70% for recycling according to the Waste Frame Directive (2008/98/EC). The percentage of recycling showed an increasing trend in the other EU countries too (Engelsen, 2013). Till the late 1990s, the C&D debris were primarily put to use in non-structural applications such as engineering fill and road sub-base. In Netherlands, the landfilling of reusable C&D waste is banned throughout their country. Similar ban on land filling C&D waste were also noted in countries such as Belgium and Germany (Symonds, 1999). Although the land filling ban might not be the only reason for higher recycling ratios in these countries, it might have contributed a major part in achieving higher recycling ratios irrespective of the kind of use to which they have been put. Wherever landfill ban is absent among the EU countries, landfill taxes are high in order to discourage the land filling of C&D waste.

In order to enhance value of the C&D debris and use the recycled aggregates produced out of them in higher grade applications, the onsite sorting of debris is essential. Having acknowledged this, the selective demolition and onsite sorting of waste has been made mandatory in Norway and other Scandinavian countries (Engelsen, 2013). The specific set of guidelines for selective demolition and onsite sorting have been framed and enforced through the Norwegian Waste Handling Rules in Norway. The implementation and enforcement of this initiative helps in easier processing as well as in achieving high quality recycled product in an economically viable manner.

In Spain, the problem of illegal dumping of C&D debris at illegitimate places is addressed through a waste management model called as Alcores model (Jaime *et al.*, 2009). As per the model, the developer needs to deposit a certain amount of money with the local body depending on the type of work involved and furnish an estimate of the quantity of waste that might be generated. Later as the work begins, the developer must dump the waste at the recycling facility approved by the local body. In order to retrieve the deposit made, the developer must furnish a certificate issued by the concessionaire of the recycling facility certifying the compliance. The facility recycles the waste and the products are sold back in the construction materials market.

2.2. HONG KONG

In Hong Kong, it has been reported that around 20 million metric tons of C&D waste has been generated annually during the period 1993 to 2004 (Poon, 2007). Realizing the importance of the need for managing the waste in a way to reduce their impact on the environment, the Government of Hong Kong introduced a series of policies. Hong Kong adopted the polluter pays principle and enacted a waste disposal charge scheme and thereby encouraging better waste management philosophies such as reduce, reuse and recycle before disposal. Similar to Norwegian guidelines, it has also mandated the preparation of waste management plan for the contractors, wherein the contractors need to set their waste reduction targets and programmes accordingly before the commencement of site operations. Moreover, the practice of onsite sorting of waste is encouraged through a differential charging scheme based on the sorted nature of the waste at the point of disposal (Lu and Tam, 2013).

The government has developed three types of facilities which accept the waste from the waste generators as depicted in the Figure 2. A waste generator can send the waste to a landfill facility, an offsite sorting facility or a public fill reception facility depending upon the nature of the waste to be disposed of. The charges are high if the waste is disposed in landfills and minimum if it is disposed in public fill reception facilities. However, these facilities have rigid criteria on the type and composition of materials in the waste in order to accept the waste from the generators. For example, the offsite sorting facilities will only accept those wastes which are composed of at least 50% of inert materials. Moreover, a public fill reception facility will only accept inert materials such as sand, bricks and concrete which can later be used for land reclamation. The Trip Ticket System (TTS) was introduced in 2003 in order to prevent illegal dumping of C&D waste in Hong Kong (Lu and Tam, 2013). Through the TTS, the tracking and monitoring of waste is made possible thereby making it impossible for the transporters of the C&D waste to dump it illegally.

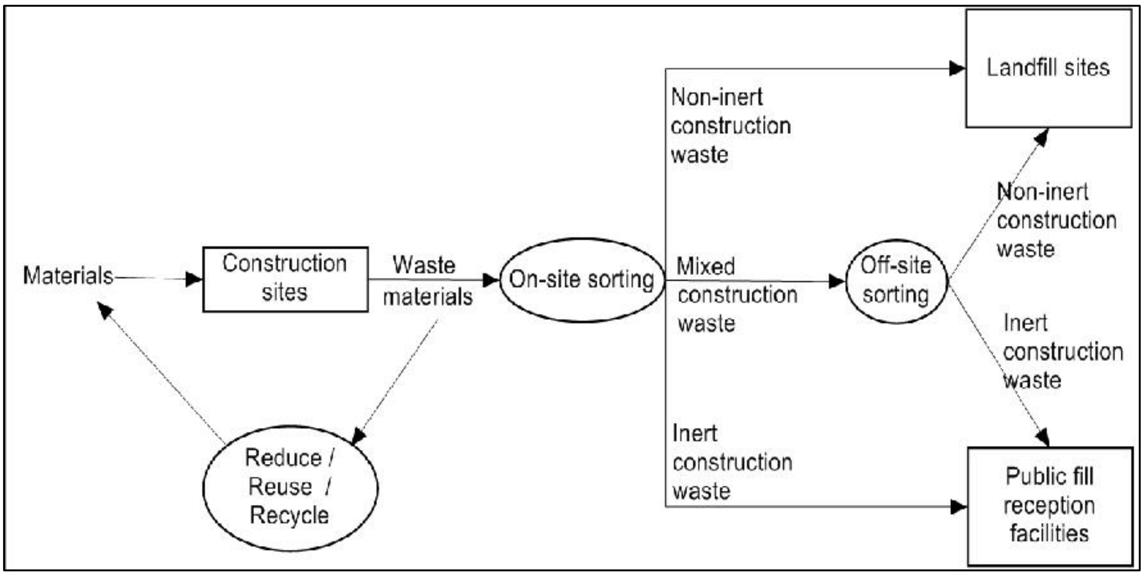

Figure 2: A Schematic Representation of Waste Management Plan of Hong Kong
Source: Lu and Tam (2013)

2.3. UNITED STATES OF AMERICA

In USA, the individual states have drafted and enforced their own regulations for managing the C&D waste stream. For example, The North Carolina Solid Waste Management Act of 1989 mandates the separation of C&D waste from the municipal solid waste. Moreover, the C&D waste needs to be further segregated into recyclable and non-recyclable materials. The inert wastes such as concrete, brick, soil, concrete blocks and gravel are required to be recycled and reused as fill materials (Duan *et al.*, 2015).

2.4. *ISRAEL*

In Israel, although there is a lack of legislation favouring recycling of C&D waste, the problem of illegal dumping of C&D waste is addressed through a vehicle impoundment (VI) policy (Seror *et al.,* 2014). The practice of illegal dumping has both environmental consequences as well as economic implications. In order to counter this practice, Israel Ministry of Environment Protection (IMEP) has empowered the inspectors of Green Police (the law enforcement division of IMEP) to impose fines upon truck drivers who engage in illegal dumping of C&D waste in open areas. Even after this initiative, the quantum of C&D waste getting illegally dumped did not reduce. Therefore, Israeli government sought to do vehicle impoundment, one of the common punishments adopted to prevent traffic violations. In Israel, through the enforcement of the VI policy to curb illegal dumping, the inspectors of the Green Police would be able to confiscate the vehicle of the offender on the spot for a period of up to 30 days without the need to bring in regular police force. This policy was found to be effective in reducing the quantum of illegally disposed C&D waste (Seror *et al.*, 2014).

2.5. *JAPAN*

In Japan, C&D waste is considered as a construction by-product instead of waste (Nitivattananon and Borongon, 2007). The incorporation of permission to use recycled aggregates produced from C&D waste in specifications and national codes is essential to gain acceptability in the market. In Japan, there was a progressive development in the standardization of usage of recycled aggregates. In 1977, Building contractors society framed a set of guidelines to help in quality control. The subsequent revisions were triggered by the research activities and the developments in recycling techniques. In 2007, Japan Industrial Standards Committee formulated three classes of recycled aggregates: Class H, Class M and Class L. The classification was according to the material properties of the recycled aggregates. The scope of application was limited with respect to the class of the aggregates. There is no restriction for use of Class H aggregates in concretes up to M45 grade whereas Class L aggregates were allowed to be used only in backfilling concrete and blinding concrete (Noguchi, 2012).

3. METHODOLOGY

A case study research methodology has been adopted in this study (Yin, 2003). A total of ten case studies have been conducted on randomly selected building demolition projects. The projects included demolition of three residential buildings, five commercial buildings and two institutional buildings. In terms of the type of construction, four of them were RCC framed structures and the rest were load bearing brick masonry structures. For data collection and analysis, information about the administrative procedures of the Corporation of Chennai, the urban local body governing the development activities in Chennai city was collected through interviews of the engineers of the corporation. Direct observation of the demolition process and transcripts of semi-structured interviews of the demolition contractors have been collated to prepare the case studies of demolition projects. Interviews were also conducted with the prospective recyclers to understand the barriers in setting up a recycling facility in Chennai city. Case studies have been analysed using open coding technique. Secondary sources of data such as newspaper articles and other publicly available data have also been content analysed to map the waste management practices.

4. DEMOLITION WASTE MANAGEMENT PRACTICES IN CHENNAI CITY

In this section, the current scenario of the various practices being adopted by the stakeholders of demolition industry in Chennai city has been discussed. The waste management practices in demolition projects have been categorized into three phases: Pre-demolition, Demolition, and Post-demolition phases and the predominant practices that have been observed in the each of the phases of demolition are summarized below.

4.1. PRACTICES DURING PRE-DEMOLITION PHASE

The Corporation of Chennai is the governing body for development activities in Chennai city. The corporation has a Town Planning Department that looks after the sanctioning of permits for all the construction, renovation and demolition activities in Chennai city. Chennai Corporation is divided into three regions namely North region, Central region and South region. Each region is again divided into five zones thereby making a total of 15 zones in Chennai city. Demolition applications are categorized into two types: demolition only permit and demolition & reconstruction permit. As the name depicts, the former deals with those permits where only demolition is sought and the latter deals with those permits where demolition proposal is accompanied with a reconstruction proposal.

In order to obtain a demolition permit, the following details have to be furnished with supporting documents: master plan of the building that is to be demolished and the details of the ownership of the building. There is a demolition fee that has to be paid to the Chennai Corporation in addition to furnishing the above mentioned details. Before sanctioning the permit, an engineer from the corporation visits the site and validates the details submitted. It is to be noted that the applicants are not required to furnish information relating to the amount of waste that might be generated during the construction / demolition activities and plans to manage that waste. Moreover, the details such as area of the building, type of materials used / to be used are not being explicitly documented. Such records would be very useful in estimating the quantity and composition of waste getting generated.

4.2. PRACTICES DURING DEMOLITION PHASE

The demolition technique adopted by most of the contractors closely resembles to selective demolition. Selective demolition is a technique in which each component of a building is carefully dismantled in order to facilitate reuse / recycle. As the demolition contractors bag the project by paying a lump sum amount to the owners, they try to recover the materials that have economic value through which they can fetch money in return for their investment. A typical residential building’s sequential demolition is discussed below.

Any building that has to be demolished will be stripped off its various components thereby leaving the frame of the building alone in its place. This can be seen in the Figure 3. Electrical wires are the ones that get immediate attention due to their high economic value as well as ease with which they can be removed. It has been estimated that the copper from these electrical wires fetches around 300 Rs/Kg. Aluminum from the electrical wires fetches around 40 Rs/Kg in the secondary market. Switch boards are carefully removed and sold. PVC pipes are also separated and sold in the secondary market.

The wooden doors and windows are removed and stacked separately during demolition as shown in the Figure 4. It was interesting to know that these wooden doors and windows are sold in the secondary market of Mumbai city which is approximately 1300 Kilometers from Chennai city. The point to be noted here is that the supply chain of secondary market has a very strong network across the country and the recovered materials are sold in those places where they fetch maximum revenue. The revenue depends on the quality of the wood and it is estimated that the superior quality ones can fetch as much as 150 Rs/ft^2 while the ones of inferior quality can fetch around 30 Rs/ft^2. Glass windows are also carefully separated and stacked for transport to the secondary market. Plumbing components such as PVC pipes, wash basins and metal / plastic taps are also removed and stored separately to be sold.

Figure 3: Salvaging Materials Having Economic Value

Figure 4: Recovered Doors and Windows

Once all the components and materials that have economic value are removed, the frame of the building composed of concrete and brick masonry (as shown in the Figure 3) remains in its place. The frame of the building is then demolished either using hydraulic breakers or manually using hammers and rods. Since the latter method consumes a lot of time, it is employed only in the case of small residential buildings mainly made of brick masonry. Hydraulic breakers are commonly adopted in other cases as the work can be completed in few hours. Almost all of the projects that are studied, with an exception of a few, have employed hydraulic breakers to demolish the frame of the building. In all of the cases studied, the debris such as brick masonry, concrete, plaster and paint were never separated from each other while demolishing the building.

4.3. PRACTICES DURING POST-DEMOLITION PHASE

After demolishing the building using breakers/hammers, the reinforcement steel used are also recovered from the debris with the help of gas cutters. The process of salvaging steel from the debris is laborious and also time consuming. However, the economic incentive is high enough for the demolition contactors to adopt the process of salvaging. The concrete and masonry debris that remains at the site has a seasonal value attached to them. During rainy seasons, they are found to be in demand in low lying places. Some construction sites collect the brick masonry debris to be used as the base material for site access roads. However, it has been found that the debris getting dumped in either legitimate or illegitimate disposal sites is predominant. Moreover, the quantum of debris getting dumped in the legitimate disposal sites is small and a huge fraction of them is found to be dumped on road sides, parks, canals and marsh lands. This type of illegal dumping affects the ecosystem severely and gives a negative image to the solid waste management system of the city. There have been many articles in the newspapers addressing the issues mentioned above. As the Chennai Corporation handles solid waste management in the city, the debris that are illegally dumped, are collected and transported to landfills located in Kodungaiyur and Perungudi.

C&D debris are voluminous in nature and hence, they occupy a large space in the landfill. The Chennai Corporation incurs huge expenses, both for transporting the debris to the landfills as well as for land filling them. The problem for Chennai Corporation is not only that it incurs costs for waste disposal but also that the landfill spaces are getting depleted at a rapid pace owing to land filling this voluminous debris. Hence, there is a pressing need for an alternative solution to debris disposal. However, the C&D debris recycling facilities are not available in Chennai city. The barriers that prevent the setting up of C&D debris recycling facilities and the usage of recycled aggregates are discussed below.

5. BARRIERS FOR RECYCLING C&D DEBRIS

Recycled aggregates (RA) could be produced from C&D debris by crushing the debris and size classification using sieves in a similar manner by which natural aggregates are produced from quarried rocks. The composition of C&D debris is one of the many factors that affect quality of the recycled aggregates. The quality of RA produced from concrete debris is relatively high compared to those produced from mixed debris containing both concrete and masonry debris. The quality gets affected also because of the presence of old mortar getting adhered to the surface of RA produced. The technology used for the production of RA influences the amount of mortar adhering to the surface of RA. Predominantly, the RA produced have been put to use in non-structural applications such as engineering fill and road sub-base materials. In the recent years, the trend of quantity oriented recycling has shifted towards quality oriented recycling in many of the developed countries and the recycled aggregates produced are being used in structural applications also. However, there are very few recycling facilities available in India to produce recycled aggregates from C&D debris. Based on the ten case studies and numerous interviews of the demolition contractors and Chennai Corporation personnel, the barriers for the setting up of C&D debris recycling facilities have been identified and are discussed briefly below.

Lack of awareness **-** The awareness of the recycling possibilities of C&D debris is very low among the stakeholders. Even the TIFAC survey reported that around 70% of the people surveyed were unaware of the recycling possibilities and around 30% were not aware of the recycling techniques that are available to produce aggregates in a cost-effective manner from C&D debris. The lack of awareness on the environmental implications of using natural aggregates has also been attributed to the lack of recycling initiatives in the Indian urban areas (Rao *et al.*, 2006).

Unavailability of reliable estimates **-** There are no reliable estimates available on the quantity of C&D waste getting generated in the Indian urban areas. Unlike some local bodies in developed countries, there are no records available with the Chennai Corporation containing details regarding the quantity of waste generation from C&D activities. As this estimate is crucial for planning the capacity of recycling facilities as well as formulating the policies and strategies that can orient the practices towards reuse / recycle, generating estimates needs to be one of the top priority steps towards sustainable C&D waste management. The records of details regarding the quantum of C&D activities occurring in the region would prove useful in generating estimates and the urban local bodies need to augment their existing system to facilitate such documentation.

Prevalent illegal dumping **-** The practice of C&D debris disposal in unauthorized places such as road sides, public parks, canals and marsh lands is prevalent in Chennai city. The problem of illegal dumping is not specific to Chennai city and has been reported to be occurring in various countries worldwide. This practice affects the economic viability of recycling the debris as the costs for collection and the associated transportation from illegal dump sites to recycling facility becomes substantial. In Chennai city, there is a fine of Rs. 2000 imposed upon those truck drivers who are caught in the act of illegally dumping C&D waste. However, the fine is not adequate enough to deter this practice and there is a dire need for the revision in this fine structure. There is a need for more stringent action towards violations in order to curb this prevalent practice. Moreover, the enforcement needs to be strict and severe punishments for violations have been reported to be effective in addressing this problem. The policies that have been found to be effective in other countries to minimize illegal dumping could serve as guidance while enacting one for the local scenario.

Quality of recycled products - Any recycled product is expected to perform as its primary counterpart. Since recycled concrete aggregates are produced by crushing concrete debris, there is a layer of porous cement mortar that remains adhered to the surface of the recycled aggregates (Rao *et al.* 2006). This adhered mortar renders the recycled aggregates into a substandard quality as compared to the natural aggregates owing to increased water absorption and inferior mechanical properties comparatively. The quality gets worsened if the constituents of C&D waste were not pre-sorted. From the case studies, it has been observed that the debris were all mixed together and the practice of onsite sorting of debris was absent. This can prove to be a significant barrier as it influences the acceptability of recycled aggregates. The practice of on-site sorting of debris could also help in reducing the cost of producing good quality recycled aggregates and thereby imparting economic viability. Therefore, the enforcement of certain demolition guidelines that could induce such practices among the demolition contractors is needed in order to enhance the possibilities of C&D debris recycling.

Lack of government support - Profitability of C&D debris recycling is observed to be one of the major concerns among the prospective recyclers. Lack of appropriate regulations and policies that enhance the economic viability of recycling is observed. Moreover, the demand for recycled aggregates in the market is unknown which leads to a considerable amount of risk perceived in setting up recycling facilities. The presence of government support in terms of incentives and policies could serve the establishment of recycling industry. The recycling facility in New Delhi was also established with the aid of government in terms of low lease rates for land and tipping fees for collection and transportation of C&D debris from the collection centres to recycling facility.

Acceptability of recycled aggregates - It has been observed that the usage of recycled aggregates was not explicitly allowed in the 'Indian Standard Specification for Coarse and Fine Aggregates from Natural Sources for Concrete' (IS 383-1970). Many developed countries have framed specifications for the use of recycled aggregates produced from C&D debris and have incorporated them in their codes and standards too. While there is a need to set up recycling facilities to produce recycled aggregates, the permission to use the recycled aggregates through standards and specifications could certainly boost the rate of development of such facilities and the acceptability of recycled aggregates in the market will also be enhanced.

6. DISCUSSION

From the study, it can be observed that waste management practices can have a substantial influence on all the three stages of C&D waste recycling: collection, processing and utilization. In the Indian urban areas, there are no reliable estimates available regarding the quantity of C&D waste getting generated (CAG, 2008). The statistics available in several other countries shows the extensive amount of surveillance on the C&D waste stream which is lacking in India. The unavailability of the estimates has kept the C&D waste stream in the dark and the situation demands a change in the system. The urban local bodies need to augment their documentation in order to record the data regarding the C&D waste getting generated and thereby can facilitate in estimating the total quantity of waste generation. The review of international cases has shown that the policies and strategies adopted have induced sustainable practices among the stakeholders of the construction industry.

The development of appropriate incentive mechanisms and supporting infrastructure in Hong Kong and other countries have favoured the practice of on-site sorting of waste. However, in India, C&D waste often gets mixed with municipal solid waste and constrains the economic viability of recycling significantly. Moreover, the prevalent practice of illegal dumping observed in Chennai city must also be countered. Some innovative strategies such as vehicle impoundment and Alcores model from Spain could be evaluated for implementation in Chennai city in addition to levying fines from the truck drivers indulging in illegal dumping. Moreover, several countries have restricted the type of waste that can be disposed in landfills stressing the need to conserve the natural resources. Recyclable materials must not be allowed to get dumped in landfills in order to bring a change in the mindset towards conserving resources among the stakeholders. The traditional practice of land filling the C&D waste needs to be changed in Chennai city. The Corporation of Chennai has to play an enabling role and the international success stories can serve the local body in establishing an effective system for managing C&D waste in Chennai city.

7. Summary and Concluding Remarks

A review of international practices, strategies and policies of several countries which aligned the waste management practices towards the growth of C&D waste recycling industry is presented. Based on the case studies on demolition projects in Chennai city, it was observed that the practices adopted in demolition projects were purely driven by economic incentives without taking environmental effects of such action into consideration. A widespread practice of unauthorized disposal of C&D debris in road sides, canals and other water bodies was observed. Lack of awareness of recycling possibilities of C&D debris is found to be one of the major reasons for lack of recycling initiatives in Chennai city. Some of the other barriers for the setting up of C&D debris recycling facilities are lack of reliable estimates, absence of government support, practice of illegal dumping, absence of on-site sorting of debris and lack of standards for the usage of recycled aggregates.

To conclude, there is a need for appropriate policies and strategies in order to induce sustainable waste management practices in Chennai city. Once the waste management practices are aligned towards sustainability, it will greatly enhance the amount of C&D waste recovery in India. Since the lack of reliable estimates needs to be addressed as the first step, the future work of this study aims at developing an estimation model that better fits the local scenario. The data regarding the quantum of C&D activities occurring in Chennai city will be collected and the quantity of C&D waste getting generated will be estimated. The strategies and policies that are needed to enhance C&D waste recovery in the local scenario will also be studied in the future.

8. References

Begum, R.A., Siwar, C., Pereira, J.J. and Jaafar, A.H., 2006. A Benefit–cost Analysis on the Economic Feasibility of Construction Waste Minimisation: The Case of Malaysia. *Resources Conservation and Recycling,* 48(1), 86-98.

Cement Sustainability Initiative (CSI), 2009. *Recycling Concrete* [online]. Available from: htttp://www.wbcsdcement.org/pdf/CSI-RecyclingConcrete-FullReport.pdf [Accessed 27 April 2014].

Cochran, K.M., Townsend, T.G., Reinhart, D. and Heck, H., 2007. Estimation of Regional Building- Related C&D Debris Generation and Composition: Case Study for Florida, US. *Waste Management,* 27(7), 921-931.

Comptroller and Auditor General (CAG) of India, 2008. *Performance Audit on Management of Waste in India* [online]. Available from: http://www.saiindia.gov.in/english/index.html [Accessed 21 May 2013].

Deloitte, 2014. *Infrastructure and Construction Sector - Building the Nation* [online]. Available from: http://www2.deloitte.com/content/dam/Deloitte/in/Documents/IMO/inimoinfrastructure_and_construction_sectors_building_the_nation-noexp.pdf [Accessed 27 April 2014].

Duan, H., Wang, J. and Huang, Q., 2015. Encouraging the Environmentally Sound Management of C&D Waste in China: An Integrative Review and Research Agenda. *Renewable and Sustainable Energy Reviews,* 43(3), 611-620.

Engelsen, C.J., 2013. Recycled Aggregates Processed from Construction and Demolition Waste - Best Practice. In: *International Workshop on Construction and Demolition (C&D) Waste Recycling,* IIT Madras, Chennai 5-6 August. 33-49.

Franklin Associates, 1998. *Characterization of Building-Related Construction and Demolition Debris in the United States* [online]. Available from: www.epa.gov/epawaste/hazard/generation/sqg/cd-rpt.pdf [Accessed 20 March 2013].

Jaime, S., Marrero, M., Maria, V.M. and Antonio, R.A., 2009. A Spanish Model for Quantification and Management of Construction Waste. *Waste Management,* 29(9), 2542-2548.

Lu, W. and Yuan, H., 2010. A Framework for Understanding the Waste Management Studies in Construction. *Waste Management,* 31(6), 1252-1260.

Lu, W. and Tam, V.M.Y., 2013. Construction Waste Management Policies and their Effectiveness in Hong Kong: A longitudinal Review. *Renewable and Sustainable Energy Reviews,* 23(7), 214–223.

Nitivattananon, V. and Borongan, G., 2007. Construction and Demolition Waste Management: Current Practices in Asia. In: *Proceedings of the International Conference on Sustainable Solid Waste Management*, Chennai 5-7 September. 97-104.

Noguchi, T., 2012. Sustainable Recycling of Concrete Structures. *Indian Concrete Institute (ICI) Journal*. 13(2), 40- 53.

Poon, C.S., 2007. Reducing Construction Waste. *Waste Management*. 27(12), 1715–1716.

Rao, A.,Jha, N.K. and Misra, S., 2006. Use of Aggregates from Recycled Construction and Demolition Waste in Concrete. *Resources Conservation and Recycling.* 50(1), 71-81.

Seror, N., Hareli, S. and Portnov, B.A., 2014. Evaluating the Effect of Vehicle Impoundment Policy on Illegal Construction and Demolition Waste Dumping: Israel as a Case Study. *Waste Management,* 34(8), 1436-1445.

Symonds, 1999. *Construction and Demolition Waste Management Practices and Their Economic Impacts* [online] Available from: ec.europa.eu/environment/waste/studies/cdw/cdw_chapter1-6.pdf [Accessed 10 July 2013].

Yin, R.K., 2003. *Case Study Research – Design and Methods*. 3rd ed. Thousand Oaks, CA: Sage Publications.

COMPARATIVE ANALYSIS OF ADJUDICATION AND ARBITRATION METHODS IN SRI LANKAN CONSTRUCTION INDUSTRY

Mahesh Abeynayake*
Department of Building Economics, University of Moratuwa, Sri Lanka

Buddini Chatumaduri Dharmawardhana
Attorney-at-Law

ABSTRACT

Construction claims are more technical intensive and multifaceted than other commercial disputes. The construction industry needs a fast and cost effective method for dispute resolution. Although the area of dispute resolution has been widely discussed and heavily researched, few studies have been conducted with respect to this research area in the Sri Lankan context. The aim of this study is to compare and contrast adjudication and arbitration methods use in Sri Lankan construction industry. To accomplish this aim, a literature survey would be conducted to find out available dispute resolution methods and the extent to which research has been carried out on arbitration and adjudication method. The developed questionnaire would be used to gather primary data from the professionals and the collected data would be analyzed using of statistical tools. Further, factors that can be used to compare arbitration and adjudication methods are presented in the latter part of the literature review. Semi structured interviews were carried out using the factors identified from literature review. The results of this research enable researchers to gain a better understanding on the current adjudication and arbitration methods, recognize significance of critical factors and suggestions for the development of adjudication and arbitration methods in the construction industry of Sri Lanka. The findings of this research indicate that the professionals who involve in the construction industry have overall average level of satisfaction on the current practice of adjudication and arbitration, however they believe that adjudication is an effective mechanism for dispute resolution rather than arbitration. It further revealed that the modernised stair-step model of dispute resolution strategy is the best. The research further makes recommendations in order to make ADR methods more effective and efficient.

Keywords: *Adjudication; Arbitration; Dispute Resolution; Success Factors.*

1. INTRODUCTION

Alternative Dispute Resolution (ADR) methods are a term usually used to refer to informal dispute resolution processes in which the parties meet with a professional third party who helps them to resolve their disputes in a way that is less formal and often more consensual than what is done in the courts. ADR methods can be used to reach an agreement fair to all parties in an atmosphere of co-operation and mutual respect. Institute for Construction Training and Development' (ICTAD) (Now named as Construction Industry Development Authority - CIDA) introduced the adjudication process to Sri Lankan construction industry as an immediate step of construction dispute resolution in their first revised edition of 'Standard Biding Document' (SBD) in 2007. According to ICTAD conditions of contract, the adjudicator is 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 would be appointed by ICTAD. Arbitration is also a commonly used method to resolve construction disputes in Sri Lanka. Arbitration, in the law, is a form of alternative dispute resolution specifically a legal alternative to litigation whereby the parties to a dispute agree to submit their respective positions to a neutral third party for solution. Most construction contracts contain arbitration clauses requiring the parties to refer any dispute to arbitration (Cheung, 1999).

* Corresponding Author: E-mail - abey92@hotmail.com

1.1. RESEARCH PROBLEM

In Sri Lanka, most of the construction contracts are based on Standard Bidding Document (SBD) of ICTAD (2007) or Conditions of Contracts of *Federation Internationale Des Enginieurs* (FIDIC) (1999). Most of the construction contracts stated that appointment of Dispute Adjudication Board (DAB) or arbitration clauses. Frequently the question is how to systematically determine whether DAB or arbitration adopt the nature of dispute. Therefore it gives rise to the question that "What are the critical factors affecting adjudication and arbitration considering the nature of the disputes arises in Sri Lankan construction contracts?" Although the topic of dispute resolution has been heavily researched in Sri Lanka, no researches have been conducted with respect to this question.

2. RESEARCH METHODOLOGY

To accomplish the aim of this study, a literature survey was conducted to find out the available literature and the extent to which research has been carried out on adjudication and arbitration method. A survey was conducted among group of construction industry experts who are closely engaged with dispute resolution in the construction industry. The developed questionnaire was used to gather information from the professionals who are engaged in the construction industry. Collected data was analysed using statistical tools.

2.1. SCOPE AND LIMITATIONS

This research is limited to evaluate the arbitration and adjudication method in the construction industry of Sri Lanka. However, legislations in other countries were referred in order to study their applicability to Sri Lankan construction industry. Data was collected from the professionals who are having experience on construction dispute resolution in Sri Lanka.

3. LITERATURE SYNTHESIS

Andrew (1986) and Harmon (2003) have stated that construction industry is generally considered complex and have resulted in increasingly complex contracts. Turner and Turner (1999) stated that the factory production is a line of work, going through people and a site production like construction work is a line of people going through work. That requires the coordinated effort of a multiple member organisation of many discrete groups. This situation was analyzed in case called *Emson* Eastern vs. EME Development Co (1991) 55 BLR 114. In this case, the court held that *'…the building construction is not like the manufacture of goods in a factory. The size of the project, site conditions, use of many materials and the employment of various kinds of operatives make it virtually impossible to achieve the same degree of perfection that a manufacturer can……..'*. Therefore, not only within the contractual relationship in between client and contractor, some disputes that occur with the neighbour of such construction.

3.1. DISPUTES IN THE CONSTRUCTION INDUSTRY

The unresolved disputes can lead to project delay, increased tension, and can damage long term business relationships as a result (Cheung and Suen, 2002). Sir Michel Latham concluded his *'constructing the team'* report (1994 cited Turner and Turner, 1999, p.4) that the number of disputes that arose in the industry was a major factor which perpetuated poor relationships and poor performance in the industry. The most important prerequisite for successful ADR method is the desire for the parties to explore the possibility for settlement. There are other certain prerequisites which are and adopted by the users. According to Brown and Marriot (1999) the philosophical prerequisites of ADR method can be identified as follows:

- All ADR methods are compromise.
- ADR methods must involve a "win/win" solution to the dispute.
- Parties must be realistically aware that ADR methods arebest alternative to negotiated agreement.

- There must be realistic administrative procedures to encourage ADR methods.
- ADR methods will be inappropriate where one party does not want a settlement.

There are two groups of ADR methods in construction industry as formal- binding methods and informal-nonbinding methods. Binding ADR method is predominantly arbitration, and in some extent Adjudication. Nonbinding ADR methods include basically negotiation and mediation. When considering the suitability of ADR method, it is suitable for technical disputes where a third party can choose with a technical ability.

4. ALTERNATIVE DISPUTE RESOLUTION METHODS

Brown *et al.* (1998) suggested that the term "ADR" method is often used to describe a wide variety of dispute resolution mechanisms that are short of, or alternative to, full-scale court processes. Cheung (1999) is developed model for use of different ADR methods and it is shown in Figure 1.

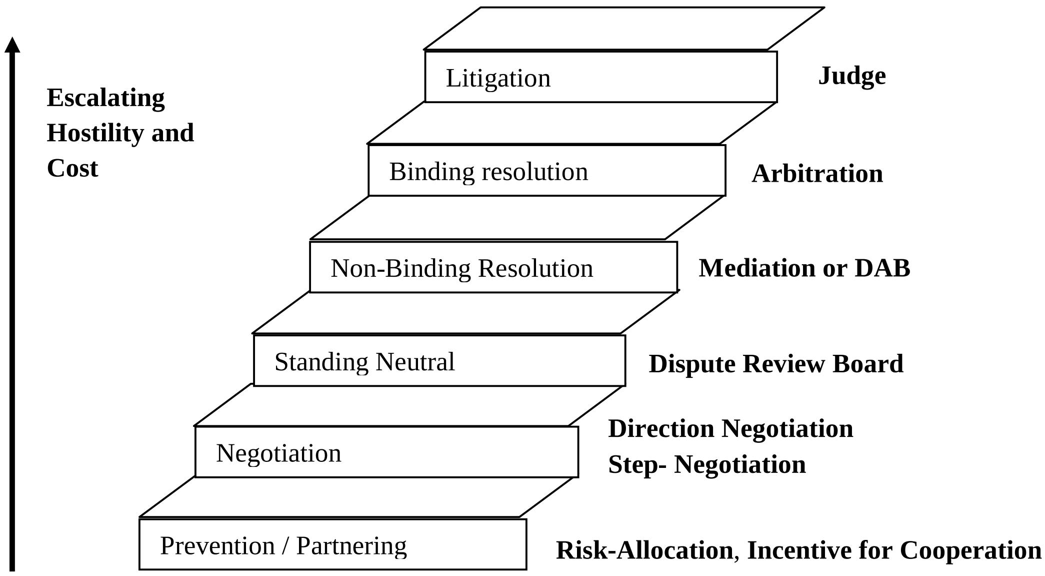

Figure 1: Construction Dispute Resolution Stair Step Model

4.1. ADJUDICATION

Adjudication is an ADR method by which disputes are referred to the neutral third party, for a decision which is binding on the parties only until the dispute is finally resolved by arbitration or litigation. Statutory Adjudication has been created in England by Housing Grants, Construction and Regeneration Act 1996, which came into force on 1st May 1998. However, in Sri Lanka there is no such statutory authority for adjudication and the adjudicator’s award has no legal recognition. However, adjudication is recognised by the newly enacted Construction Industry Development Act of Sri Lanka No. 33 of 2014.

In Sri Lankan construction industry, Adjudication practically proceeds mostly according to FIDIC and ICTAD conditions of contract. At the commencement of the contract, parties agree to the appointment of an adjudicator known as the Dispute Adjudication Board (DAB) or as sole adjudicator. Most significant factor of adjudication is that the adjudicator or the DAB is required to act as impartial experts and not as arbitrators. Therefore the adjudicator must only be a person suitably qualified to interpret technical and contractual matters.

ICTAD Conditions of Contract provide for reference of any dispute arising between the parties of any kind what so ever to a DAB comprising one or three persons for decision, which is to be given within 84 days or such other time as is proposed by the DAB and approved by the parties. The decision is to be reasoned and, as with other forms of adjudication, is binding until resolved by one of the other methods of dispute resolution provided for in the conditions. If either party is dissatisfied with the decision, or the

DAB does not deliver its decision within the specified time limit, it may give notice of dissatisfaction to the other party within 28 days after the decision or after the specified time limit, and the dispute will be referred to the next stage which is called as arbitration. According to the FIDIC conditions if either party does not refers the dispute to the arbitration within specified time period, the Adjudicators' decision becomes final and binding upon the employer and the contractor. According to *Azis vs. Thondaman* case this kind of enforcement can argue by courts of law. ICTAD conditions 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 dispute within 28 days or such other period agreed by the parties - of receipt of such notification of a dispute.

4.2. ARBITRATION

The Arbitration can be defined as, the submission of a dispute to one or more impartial persons for a final and binding decision. According to the Arbitration Act No. 11 of 1995 provides for a legislative framework for the effective conduct of arbitration proceedings in Sri Lanka. The desirable features of arbitration are fast, inexpensive, fair, simple, flexibility, confidentiality, minimum delay. The main feature of arbitration is that it is consensual in nature and private in character. Sri Lanka Arbitration Act No 11 of 1995 stated different arbitration principles and UNCITRAL Model Law. The Arbitration Act of Sri Lanka stated that how to resolve disputes arise in any industry. The Act stated that an arbitration agreement shall be in writing. The main objectives of this Arbitration Act are as follows.

- To make comprehensive legal provisions for the conduct of arbitration proceedings and the enforcement of arbitral awards.
- To make legal provision to give effect to the convention on the recognition and enforcement of foreign award.

4.2.1. CONTENTS OF ARBITRATION ACT NO.11 OF 1995 IN SRI LANKA

According to Kanag-Isvaran (2006), followings are the basic contents of the Arbitration Act No. 11 of 1995 in Sri Lanka,

- ***Enhancing its finality*** - No review of an arbitral award thus enhancing its finality. There is only a possibility of having it set aside on very narrowly defined grounds as per Section 32 and 34.
- ***Waive appeal by exclusion agreement*** **-** Right to waive appeal to the Supreme Court by exclusion agreement as per Section 07, 10, 11, 13, 20, 21 and 39.
- ***Arbitration agreement bar to court*** **-** valid arbitration agreement constitutes a bar to court proceedings if so pleaded. Court cannot ignore such agreements as per Section 5.
- ***Limited court intervention*** **-** Once arbitration has commenced, court intervention is limited to specific instances supportive of arbitration Section 05 section 32, 34.
- ***Party autonomy*** **-** Party autonomy is a golden tread that runs through the web of arbitration law. Acceptance of parties autonomy to the largest extends is possible in conducting the arbitration. As per section 6, 7, 16 and 17 parties have autonomy to decide number of arbitrators, the procedure for appointing arbitrators, the place of arbitration and procedure to be followed by arbitral tribunal respectively.
- ***Recognition and enforcement*** **-** Clear, unambiguous and efficient procedure for the recognition and enforcement of foreign arbitral awards as provided for by the New York Convention of 1958.

In Sri Lanka arbitration is a legally enforceable ADR method backed by the Act No 11 of 1995. 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. Further there are some cases which were decided by Superior Courts of Sri Lanka and now those have become a part of arbitration law as a judicial precedent. As an example ***Southern Group civil construction private limited vs. Ocean Lanka private limited*** case discussed the grounds for setting aside an arbitral award and the time limitation for challenge the arbitrator's award. In State Timber Corporation vs. Moiz Goh (pvt) Ltdcase, court held that the district court has no jurisdiction to enter in to the arbitration proceeding.

5. Critical Factors of Arbitration and Adjudication

Several researchers attempted to identify the selection criteria of dispute resolution strategies based on identical factors such as cost, time duration, degree of control by the parties, flexibility, confidentiality, voluntariness, enforceability, binding decision, privacy etc. (Cheung and Suen,2002). Considering the factors of dispute resolution identified by researches, comprehensive list of factors affecting ADR methods can be summarized as in Table 1.

Table 1: Summary of Success Factors

Success Factor	Explanation of the Factor
1. Confidentiality of the information and the process	Parties to the dispute, control the process by avoiding expose any information or material to business community .
2. Consensus agreement	Ability of working within a common ground throughout the dispute resolution process
3. Control by parties	Degree to control the process, format and the content of the resolution by parties
4. Cost	Total amount of direct indirect and hidden cost
5. Creative solution	Does the solution satisfy the needs of both parties?
6. Enforceability of the decision	Binding nature of the decision
7. Fairness	Ability of both parties to disclose the relevant facts
8. Flexibility in the proceedings	Degree of using strict rules and procedures in the process
9. Overall duration/ Speed	Amount of time taken to resolve the dispute
10. Preservation of relationship	Ability to protect the relationships between the parties after the final decision of the dispute resolution process
11. Professional culture and ethics of parties	Culture and ethics of the professionals involve in the dispute resolution process
12. Time required of parties	Time for submissions, to prepare submissions and to react according to the proceedings is strict or not

For this research detail survey and semi-structured interviews were conducted to collect data from the industry. The data collected from literature review was the guidance to define the sample for the detail questionnaire survey and semi-structured interviews. Many professionals who have got more experiences on construction industry and they have clear understanding on present adjudication and arbitration practices.

6. Satisfaction of the Current Practices of Adjudication and Arbitration

Current practice of adjudication and arbitration methods are evaluated according to the seven most critical factors identified from questionnaire survey. The results are shown in Tables 2 and 3.

Table 2: Satisfaction of Current Practice of Adjudication Considering the Critical Factors

Rank	Critical Success Factor	Adjudication (Mean)
1	Fairness	4.47
2	Flexibility in the proceedings	3.84
3	Confidentiality of the information and the process	3.74
4	Preservation of relationship	3.26
5	Creative solution	2.58
6	Overall duration/ Speed	2.58
7	Enforceability of the decision	1.11

Table 3: Satisfaction of Current Practice of Arbitration Considering Critical Success Factors.

Rank	Critical Success Factor	Adjudication (Mean)
1	Enforceability of the decision	4.95
2	Fairness	4.74
3	Confidentiality of the information and the process	3.63
4	Overall duration/ Speed	2.16
5	Preservation of relationship	1.68
6	Creative solution	1.58
7	Flexibility in the proceedings	1.47

It was identified that four out of seven success factors scores the weighted mean greater than 3.00 in adjudication. Only three factors have scored weighted mean greater than 3.00 in arbitration. Also out of that four, only “Enforceability” and “Fairness” scored greater weighted mean in arbitration than adjudication. So, by evaluating critical factors, adjudication can consider as best method to resolve disputes.

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

7. RECOMMENDATIONS TO IMPROVE THE ADJUDICATION AND ARBITRATION METHODS

Most of the professionals in the industry have overall average satisfaction of both methods. It was revealed that both adjudication and arbitration should be improved to achieve the utmost outcomes of the processes to enhance the satisfaction. Most of the experts suggest to having a professional statutory institute for construction adjudication and arbitration practices.

In the light of the experts’ interviews and the results of the questionnaire survey, the following recommendations can be made to enhance the standard of arbitration and adjudication methods in Sri Lankan construction industry.

- Arbitration is costly and requires longer duration for the award. Therefore it should be reviewed and modified.
- Introduction of DAB from concerned professional institutions to settle disputes.
- Require immediate review of existing standard conditions of contracts practiced in the construction industry. Without implementing international standard conditions alone, it is required to assess the suitability of those conditions to the Sri Lankan construction industry.

- Instead of having several sets of rules by several institutes, for construction disputes, ICTAD (CIDA) must have dominant set of rules for govern construction dispute resolution using by adjudication and arbitration.
- Introduce well-structured professional courses on dispute resolution, adjudication and arbitration practices for the universities and construction training institutions.
- Awareness is the finest way of empowerment. Conduct awareness programmes on adjudication and arbitration related to the construction industry regularly.
- In the construction industry in Sri Lanka, there does not appear to be much concern given as to how the fundamentals of engineering and law must be used in the process of managing these disputes. Importance of adopting fundamentals of engineering principles as adopted in other aspects of construction processes must be emphasised in every instance of the dispute management process as well. There has to be a contribution to the industry by way of using scientific methods for programming, monitoring, evaluations, analyses which should form the basis of scientific dispute resolution. The professionals should persuade the stakeholders to adhere to the fundamentals of engineering, law and ethics in the process of dispute management in order to have a more sustainable and healthy construction industry.
- Introduction of sensible dispute management practice is important to negotiate disputes and settle disputes quickly. If a settlement cannot be achieved through negotiation, arbitration or adjudication methods should be considered.
- Partnering works well to prevent disputes. According best adjudication or arbitration approach for construction projects would be start with partnering and relay on direct negotiation.

8. CONCLUSIONS

The detailed analysis of identified critical factors of adjudication and arbitration practices were carried out relating to the construction industry of Sri Lanka based on the preliminary data and secondary data gathered through the questionnaire. According to the rank order seven most critical factors were "Overall duration (Speed)", "Flexibility in the proceedings", "Enforceability of the decision", "Preservation of relationship", "Confidentiality of the information and the process", "Cost" and "Fairness". It was identified that most experts are preferred to resolve dispute through adjudication rather than from arbitration, according to their experience and knowledge. From the results of the survey also revealed and emphasised that adjudication is better than arbitration as a dispute resolution.

A pivotal conclusion of this research is that the stakeholders in the construction industry prefer "adjudication" as an ADR method. Professionals had a low level of satisfaction on the current practice of arbitration. It was revealed that construction industry expects quick remedy on than the less cost solution. It further revealed that the modernised stair-step model of dispute resolution strategy is the best.

9. REFERENCES

Democratic Socialist Republic of Sri Lanka, 1995. *Arbitration Act No 11, 1995*. Sri Lanka.

Abeysekara, L., 2006. Arbitration-Party autonomy. *In*: Kanag-isvaran K., and Wijeratne S.S. eds. *Arbitration law in Sri Lanka*. Colombo: ICLP, 85-99.

Aziz vs. Thondaman, n.d. *61 NLR 217*.

Brown, H. and Marriot, A., 1999. *ADR principals and practice*. 2nd ed., London: Sweet and Maxwell.

Cheung, S.O., Suen, H.C.H. and Lam, T.I., 2002. Fundamentals of alternative dispute resolution process, *Construction engineering and management*. 128(5), 409-417.

De Zylva, E., 2007. Alternative dispute resolution systems for construction contracts. In: Kanag- Isvaran, K. and Wijeratne, S.S., eds. *Arbitration law in Sri Lanka*. Colombo: ICLP, 117-138.

FIDIC, 1999. *Conditions of contract for building and engineering works designed by the employer*. Geneva: International federation of consultant engineers.

Emson Eastern vs. EME Developments case, 1991. *55 BLR 114*.

Institute of Construction Training and Development, 2007. *Standard Bidding Document - 02*. Colombo: ICTAD.

Kumaraswami, M.M., 1997. Conflicts, claims and disputes in construction. *Engineering, Construction and Architectural management*, 4(2), 95-111.

Southern group civil construction private limited vs. Ocean Lanka private limited, 2002. *SLR (1) 190.*

State Timber corporation vs. Moiz Goh (pvt) Ltd, 2000.SLR (2)316.

Wijeratne, S.S., 2006. Arbtration in Sri Lanka. In: Kanagisvaran, K. and Wijeratne, S.S., ed. *Arbitration law in Sri Lanka*. Colombo: ICLP, 1-7.

Wimalachndra, L.K., 2007. Alternative methods of dispute resolution. *Junior Bar Law journal*, 2/3, 55-70.

COMPARATIVE STUDY OF WATER EFFICIENCY IN GREEN AND NON – GREEN BUILDINGS IN APPAREL INDUSTRY IN SRI LANKA

Sudeepa N. Silva*, K.G.A.S. Waidyasekara and D.M.P.P. Dissanayake
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

At present, the amount of water demanded exceeds the water quantity that remains as a resource and it becomes scarcer each year. When it comes to water consumption in buildings, apparel buildings consume a considerable amount of water for both production processes and to fulfil the requirements of a large number of occupants. However, there are different perceptions towards water efficiency. As an example, one party is aimed at adhering the green building concept in order to retrieve water efficiency while another perception focus towards achieving water efficiency through various methods without giving consideration for adaptation of green status. Therefore, this study looks at how water efficiency is addressed and what benefits have being received for green buildings compared to non-green buildings.

Initially, a comprehensive literature review was carried out with the purpose of getting familiarized with research areas. Case study method was used to compare water efficiency status in green and non-green buildings in apparel industry. Two cases are selected from each building type for the data collection purpose. Semi structured interviews were carried out with respective industrial personnel and findings of case study was analyzed using the Nvivo.

Research findings revealed that both green and non-green building are having similar purviews on the consideration towards the water efficiency and integrated with high quality water efficient practices to enhance the water efficient performances of the buildings. However, certain good practices could be observed in green buildings compared to non- green buildings. That is, individual commitment of the organisation together with third party commitment is making the building more towards water efficient. Finally, the study provides recommendations for good practices towards water efficient practices in the apparel industry.

Keywords: *Apparel Industry; Green Buildings; Non-Green Buildings; Water Efficiency.*

1. INTRODUCTION

Water is essential to life and it is a finite resource for the human and the rest of the living world (United States Environment Protection Agency, 2013). According to Vorosmarty, Green, Salisbury and Lammers (2000) there is an imbalance between the available fresh water supply and demand, which results in "water scarcity". As per the World Business Council for Sustainable Development (2006), buildings contribution towards the total water consumption is at a considerable level. Smith (2007) states that compared to non-green developments, supply of green alternatives are effective and demands for those alternatives are continuously increasing. However, Roy and Gupta (2008) describe that even though green building is an effective and efficient concept by providing benefits such as use of less energy, water and natural resources, still it is conflicted by the price constraints. According to the Singapore's National Water Agency (2008), it provides guidelines to water efficiency in building designs not only limiting to green buildings, but also for non-green buildings as well. Thus, Society has different perception to achieve water efficiency. While some parties achieve this through the green building concept others develop their systems without considering about the green concept although they too gain different benefits in terms of water efficiency. Therefore, this condition creates an argument of whether water efficiency in green buildings is more efficient and effective than non-green buildings. On the other hand,

* Corresponding Author: E-mail - sdpsilva0@gmail.com

there are many scholars conducted researches on water efficiency in green buildings and non-green buildings separately. Yet, there is a lack of concern on a comparative study regarding the above subject area. In respect to the above proclamations, it engenders a new problem between the gap of water efficiency in green buildings and non-green buildings. The study focused on apparel manufacturing companies. This study is therefore aimed to identify whether green buildings are truly water efficient than non-green buildings achieving the following objectives.

- To identify the water consumption in apparel industry.
- To recognize the different types of water efficiency processes and technologies.
- To analyse the water efficiency in green and non-green apparel buildings.
- To recommend good practices towards water efficient practices in the apparel industry.

2. BACKGROUND TO THE RESEARCH

Following sub section explores the relevant literature in the research arena where major focus is given to few areas; water consumption in apparel industry, green buildings, different types of water efficiency processes and technologies and finally Parameters to measure the water consumption in buildings.

2.1. WATER CONSUMPTION IN APPAREL INDUSTRY

Thiry (2011) argues that apparel industry is one of the largest industries in the world and apparel industry generally consumes huge amount of water which is resulting in increased of pressure on the available natural resources (Masupha, 2007). In addition to the water consuming production processes, apparel industry is also accountable for general water consuming activities such as drinking, cooking, sanitary use, cleaning, cooling, gardening, etc. (Volmajer *et al.,* 2012). Therefore, different manufacturing processes and activities effects in water consumption on apparel buildings which makes a significant impact on total water consumption in the world. As per Thiry (2011), scarcity of resources will make the apparel industry less feasible and more expensive to continue doing business as usual. Most of the apparel industries tend to conserve resources including water, more efficiently and effectively in order to mitigate their negative impacts (Thilakarathna and Silva, 2012).

However, apparel industries are now focusing on water efficiency systems and proper treatment applications, particularly with respect to environment legislations and international competition (Masupha, 2007). Therefore, most of the industries including apparel industry have now started to evaluate the water efficiency methods and also all over the industrial world enforce legislative measures to achieve sustainable water resource management (Masupha, 2007). According to Thilakarathna and Silva (2012), many apparel industries in Sri Lanka, renewed to ethical and sustainable factories. Few of leading apparel manufacturers in Sri Lanka already obtained green building certifications and identified water as a key resource to be concerned (Sri Lanka Apparel, 2009). Thus, next section discusses about the term “Green Building” concept.

2.2. GREEN BUILDINGS

The term sustainability ensures that it meets the present needs without compromising the ability of future generations to meet their own needs (Kates *et al.*, 2005). Then, green building has become a flagship under the sustainable development (Ali and Nsairat, 2009) and the water efficiency is one of the key objectives addressed by the “Green Building” concept (Nelson, 2007).

Waidyasekara *et al.* (2013) have done a comparative study of green building rating systems of eleven countries. The study identifies 10-15 range of credits is being allocated for water section. Figure 1 illustrates, weightage allocated for the water category by each rating system. When it comes to Sri Lankan context, the Sri Lankan Green Rating System allocates 14 points for water section out of total 100 points. This proves that water efficiency is an inherited feature in green building concept which is mostly addressed in the building’s design stage. However, unlike old days, most buildings exercise the energy efficiency and water efficiency practices without compromising as green buildings and non-green buildings (Singapore's National Water Agency, 2008).

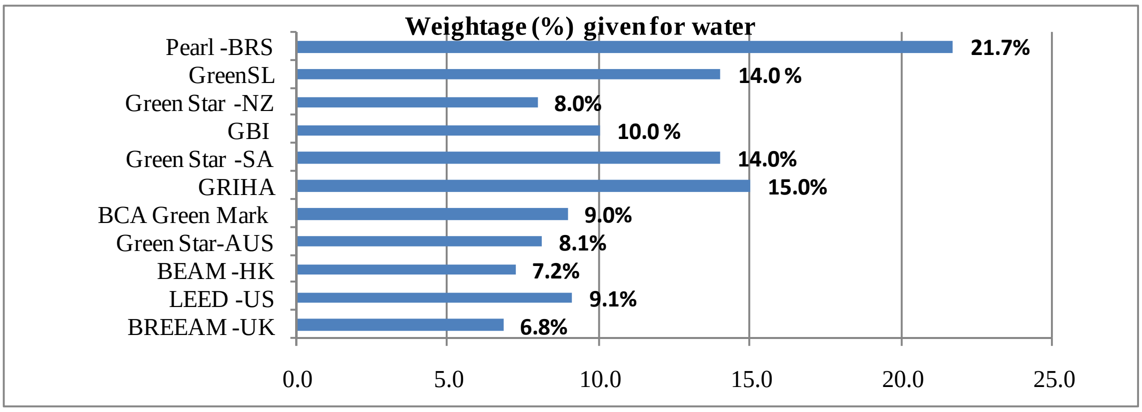

Figure 1: Weightage Given for Water Category by GBRS
Source: Adapted from Waidyasekara *et al.*, (2013)

2.3. DIFFERENT TYPES OF WATER EFFICIENCY PROCESSES AND TECHNOLOGIES

The different types of water efficiency processes and technologies describe under two sub-headings as Water efficiency processes to conserve water and different types of technologies to conserve water.

2.3.1. WATER EFFICIENCY PROCESSES TO CONSERVE WATER

Even traditionally, water efficiency received little or no attention in building design and operation, now there is a wide range of processes for improving the water efficiency in buildings (Mirata and Emtairah, 2011). Most scholars identified water hierarchy as the best process for efficient water usage in buildings, which is discussed in this section.

Mirata and Emtairah (2011) identify a ranking improvement option called "Waste Minimization Hierarchy" (see Figure 2) which is integrated with avoid, reduce, reuse, recycle and treat as major water efficiency methods in buildings. The priority order is decreasing along the triangle. Thus, according to the priority order, it is needed to implement the particular process or if not move to the next alternative along the priority order in order to address the different types of water efficiency processes in an optimum manner. Next Section describes some of the common water efficiency technologies can be used to conserve water in buildings.

Figure 2: Hierarchy of Proffered Efficiency Process
Source: Mirata and Emtairah (2011)

2.3.2. DIFFERENT TYPES OF WATER EFFICIENCY TECHNOLOGIES TO CONSERVE WATER

According to various scholars, the term water efficiency almost always engaged with the technology. Table 1 shows available technologies that can be applied to any type of building to achieve efficient water management system.

Table 1: Water Efficiency Technologies

Water Efficiency Technology	Source
Water audits	Department of the Environment and Heritage, 2006; North Carolina Department of Environment and Natural Resources, 2004
Metering	
Rectifying leakages	
Retrofitting and replacing inefficient fixtures	North Carolina Department of Environment and Natural Resources, 2004
Water saving taps	Liu and Ping, 2012
Faucet aerators	Arab Forum for Environment and Development, 2010
Faucets with on-demand sensors	Environment Agency, 2007; Arab Forum for Environment and Development, 2010
Faucets with automatic shut-off systems	Arab Forum for Environment and Development, 2010; United State Department of Energy, 2002
Dual flush low flushing cistern	Arab Forum for Environment and Development, 2010; Singapore's National Water Agency, 2008; United State Department of Energy, 2002
Effective flushing volumes	Environment Agency, 2007
Low-flush and waterless (water-free) urinals	Singapore's National Water Agency, 2008; Environment Agency, 2007
Urinals with on-demand sensors	Arab Forum for Environment and Development, 2010
Waterless Urinal (Liquid Sealant Cartridge Type)	Singapore's National Water Agency, 2008
Urinal controls	Environment Agency, 2007
Use of grey water in flushing	Arab Forum for Environment and Development, 2010
Using pressure-reducing valves	United State Department of Energy, 2002; North Carolina Department of Environment and Natural Resources, 2004
Irrigation efficiency	North Carolina Department of Environment and Natural Resources, 2004
Reusing grey water	Environment Agency, 2007
Rain water harvesting	Environment Agency, 2007

2.4. PARAMETERS TO MEASURE THE WATER CONSUMPTION IN BUILDINGS

According to Tate (2000), water efficiency performance is affected by five basic parameters including gross water use, intake, recirculation, discharge and consumptive use (refer Table 2).

Table 2: Water Efficiency Parameters

Parameter	Description	Water Efficiency Requirement
Gross water use	the total amount of water used to carry out an activity	Low
Intake	the amount of "new" water taken into the operation	High
Recirculation	the amount of previously used water employed in the activity	High
Discharge	the amount of water exit from the activity or process	Low
Consumptive use	the amount of water used up during the process	Low

Source: Tate (2000)

Furthermore, Arab Forum for Environment and Development (2010), identifies that water efficiency technological features applied in buildings is also a common parameter that can be used to measure the water efficiency performance in buildings. Thus, above parameters are identified as the basic parameters to measure the water efficiency performance in buildings.

3. Research Methodology

Research methodology for the study followed several steps. As the first step, a background study was carried out to make clear the subject area and to develop the research problem statement by following a reference study on journal articles, online journals, e-books, web sites, electronic library data base and other publications. As the second step, case study interview guideline was developed with the purpose of investigating the research question of how green buildings are water efficient compared to non-green buildings.

Buildings which are maintained and operated in a same management were considered during the cases selection. Therefore, the research will not be affected by different organisational backgrounds and aspirations among the facilities. Thus, one case from each apparel building was selected for the study, based on access, availability and time limitations. Semi-structured interviews were used as the main data collection technique. The interviews were conducted with three key participants of each organisation. Finally, collected data were analysed using cross case analysis. The QSR.NVivo version 10.0 produced by QSR (Qualitative Solutions and Research Private Limited); computer software was used.

4. Research Findings and Analysis

The findings from two case studies were discussed under several sub-headings as shown in Figure 3. Those will be the basis for following discussion. There are six headings. Contribution towards the water efficiency in general, Water efficient practices, Water consumption in green and non-green building in general and according to the process, driving factors for water efficiency on green and non-green buildings, and finally perceptions towards the green and non-green building will discuss in subsequent sections.

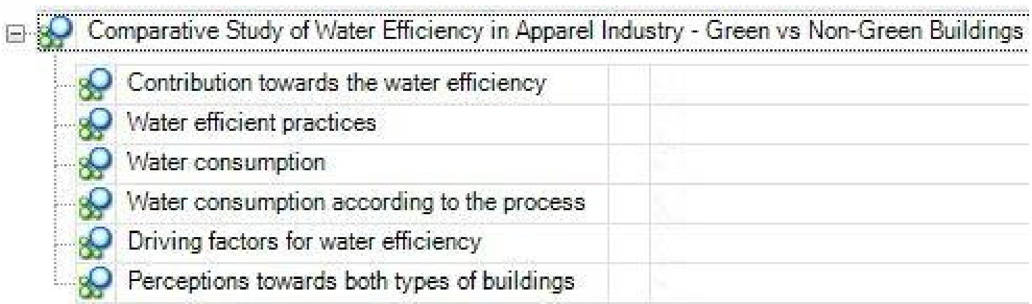

Figure 3: Coding Structure of the Research Findings and Analysis

4.1. *CONTRIBUTION TOWARDS THE WATER EFFICIENCY*

According to the empirical findings, Table 3 summarised the findings of general considerations towards the water efficiency in both organisations. It shows same purviews on establishing and maintaining sound water efficient systems on each building. The green building had claimed 12 points out of 14 point and was certified by the Green Gold Label in January, 2014. Thus, the green building received a sound attention on the water efficiency due to the concept of 'green' and 'the company sustainability policy'. Similarly, non-green building was also upgrading building's water efficiency performance based on the third party (sustainability division) evaluation, feedback and advises. However, at this point, it was observed that self-motivation of the internal management team of the green building was at a higher rate than the non-green building, in order to comply with the requirement of the Leadership in Energy & Environmental Design (LEED) and the company sustainability policy.

Thus, it shows both green building and non-green building had same purviews to uphold sound water efficient systems but, with the different attitudes towards water efficiency effort. The next section intends to identify existing water efficiency practices in buildings.

Table 3: Summary of the Consideration towards the Water Efficiency

	Green Building	Non-Green Building
Requirements	• LEED rating requirement • To reduce costs • To align with the company sustainability policy • To future water conservation • Uneven distribution of water throughout the year • To use as a marketing tool • To meet with the customer requirements • To meet with the local standards; EPL	• To reduce costs • To align with the company sustainability policy • To future water conservation • Uneven distribution of water throughout the year • To use as a marketing tool • To meet with the customer requirements • To meet with the local standards; EPL

4.2. *WATER EFFICIENT PRACTICES*

The below Table 4 summarises the findings of existing water efficient systems in both buildings.

Table 4: Summary of Existing Water Efficient Systems

	Green Building	Non-Green Building
Alternative Water Sources	tube wells, rain water harvesting, and grey water	tube wells, and grey water
Technological Applications	delay action push taps, water efficiency flush valves, dual flush cistern tanks, effective flushing volumes	delay action push taps, water efficiency flush valves, dual flush cistern tanks, effective flushing volumes, on-demand urinals
Metering And Sub-Metering	every possible point	only few points
Other	• Use only reused water for irrigation • Awareness programs	• Use only reused water for irrigation • Awareness programs

When it comes to water efficiency practices, as per empirical findings, both green building and non-green building contain similar water efficient practices such as use of alternative sources including well water and grey water, use of water efficient technologies including delay action push taps, water efficiency flush valves, dual flush cistern tanks and effective flushing volumes, use of reused water for irrigation and conduction of awareness programs as listed in Table 4. However, green building looks for more alternative water sources including well water, rainwater harvesting, and use of grey water than non-green building, where non-green building only rely upon the simply reachable and available water sources such as well water and grey water. Moreover, metering and sub-metering which is a primary criterion under the water efficiency and it is only regarded by the green building. As admitted in the LEED, the metering and sub-metering system was placed in recent years in the green building. However, for sub-metering, consideration was only given to possible water consuming points instead of all water consuming points.

When it comes to the non-green building, it was only weighted the total amount of water usage by the buildings. Therefore, both green building and non-green building contain similar water efficient practices except few differences such as; there were no on-demand urinals for green building and there were no rain water harvesting and metering and sub-metering system for non-green building. However, as per the theoretical findings, both buildings can enhance water efficiency systems by applying more technological applications which were discussed in the research background and most importantly, it is attentive to implement a sound metering and sub-metering system to uplift the efficiency of the water consuming systems. Thus, it will be enabled to have an overall view of the water consumption data in each and every water sensitive activity of the building. Because, even total amount of water usage is calculated, it is difficult to estimate water leakages, water losses and effects of the sub-water usage activities to the total water consumption of the building.

4.3. WATER CONSUMPTION IN GREEN BUILDING AND NON-GREEN BUILDING

Table 5 summarises the findings of water consumption of both buildings. As per empirical findings, both buildings were subjected to similar water consumption activities or processes including drinking, cooking, flushing, sanitary washing, cooling system, heating system and irrigation system. Well water is used as the primary fresh water source for both green and non-green buildings. Additionally, municipal water is used as fresh water source in the green building while non-green building utilizes bowser water. The activities which requires use of fresh water was same in green building and non-green building including; drinking, flushing, sanitary washing, cooling system and heating system. The average daily fresh water consumption of non-green building amounts to 95,000 L which is higher than the fresh water consumption of the green building. Since, both buildings are occupied by similar number of employees; this difference could be basically due to the rainwater harvesting system and high efficient technological applications included in the green building. The daily average total water consumption of the non-green building is 105,000 L which is again higher than the green building. Thus, it can be said that, level of water efficiency in the green building affects by efficient technological applications. Specially, compared to the non-green building, another advantage of the green building is the individual commitment on the efficient water usage.

Table 5: Water Consumption of the Green Building and Non-Green Building

	Green Building	Non-Green Building
Number of employees	2,200	2,200
Production area	6,428 m^2	6,689 m^2
Irrigation area	7,082 m^2	12,140 m^2
Building area	14,090 m^2	16,536 m^2
Fresh water consumption	90, 000 L per day	105,000 L per day
Rainwater consumption	5,000 L per day	-
Total water consumption	95,000 L per day	105,000 L per day
Reuse water consumption	40,000 L per day	30,000 L per day

4.4. WATER CONSUMPTION IN GREEN BUILDING AND NON-GREEN BUILDING ACCORDING TO THE PROCESS

Table 6 summarises the findings of water consumption in both buildings based on the process. According to the empirical findings, water consumption per person in green building is 31.82L per capita per day, while in non-green building it is 34.09 L per capita per day. Thus, compared to non-green building, green building water consumption per person is slighter by 2.27 L. Water saving due to the metering and sub-metering system, water efficient technological applications, and both individual commitment and third party commitment on the water efficiency of the green building were the reasons behind these results. When it comes to the irrigation system, water consumption in green building is 5.65L per m^2 per day while in the non-green building it amounts to 2.47 L per m^2 per day. Accordingly, when comparing to the non-green building, water consumption per square meter is 3.18L higher in the green building. During the analysis of research findings, it was found that both buildings have not given concern on the sub-metering of the irrigation water consumption. If sub metering systems could be introduced to irrigation systems, accurate and the real values on the irrigation system water consumption can be realized. Thus, this will make the buildings to gain optimum benefit from the reused water by implementing strategies such as water recycling etc. However, compared to the overall water efficiency performance of the non-green building, green building is efficient except in irrigation system water efficiency. Nevertheless, the water efficient practices of the non-green building are also at an identical level as the green building. Lack of concern on optimum usage of reused or grey water was identified as one of the drawbacks in water usage of the green building and there may be some other factors that affected for water efficiency which describes in next section.

Table 6: Summary of Water Consumption in Green Building and Non-Green Building According to the Process

	Green Building	Non-Green Building
Water consuming activities	General (Drinking, Cooking, Flushing, and Sanitary washing), Cooling system, Heating system and Irrigation system	General (Drinking, Cooking, Flushing, and Sanitary washing), Cooling system, Heating system and Irrigation system
General	70, 000 L per day	75,000 L per day
Cooling system	20,000 L per day	25,000 L per day
Heating system	5,000 L per day	5,000 L per day
Total water consumption	95,000 L per day	105,000 L per day
Reused water consumption	40,000 L per day	30,000 L per day
Water consumption per person	31.818 L per capita per day	34.091 L per capita per day
Water consumption per area	5.648 L per area per day	2.471per area per day

4.5. DRIVING FACTORS FOR WATER EFFICIENCY ON GREEN AND NON-GREEN BUILDINGS

During the data analysis of the two cases, it was identified driving factors for water efficiency of the selected green building and non-green building which discuses in this section.

As per empirical findings, building engineers have to upload the monthly water usage data to the 'sustainability division'. These data is evaluated by the sustainability division and monthly reviews were submitted to building management in order to maintain the water efficiency. As per the views given by the interviewees of the green building, it is evident that green building must be self-motivated in to providing these data to the sustainable division and to take corrective actions if necessary in order to maintain the water efficiency status and to comply with the green certification requirements.

In the non-green building, an individual effort is not required since those professionals do not have to maintain water efficiency standards enforced by a green certification requirement. Only requirement is to make excuses if there were any alarmed raise of water consumption level. Although that point was evident, as per the researcher, water efficiency improvements will only be resulted, if building management gives individual commitment in to continuous evaluation of water consumption levels together with considering evaluations given by the sustainability division. Therefore, individual commitment is one of the factors that effects on the level of water efficiency of green building and non-green building.

The theoretical findings of the study also identified that to enhance the water efficiency performance of the building, it should have a big picture of the building's water consumption data. It is clear, this opinion is not limited to only non-green building but for the green building as well. Because, even though in 2013 per capita per day usage was reduced to 31 L, in 2014, it has again increased between 32-33 L per capita per day. Thus, metering and sub-metering would be one of the primary water efficiency criterion for the buildings and at the same time, it should be received both individual and third party commitment for the continuous improvement of the water efficiency system.

Therefore, both individual commitment and third party evaluation by the sustainability division will drives green building and non-green building for effective water efficiency. Whether it is a green building or non-green building, if it will not align with any of this factor, it will be affected to the overall water efficiency performance of the building.

In the previous section, even it was identified that green building is more water efficient than non-green building in terms of water efficiency, however, both buildings were practised similar water efficiency practises, and yet water consumption performance of the green building is more efficient than non-green building. This may be due to the effect of the above mentioned driving factors for water efficiency.

4.6. PERCEPTIONS TOWARDS THE GREEN AND NON-GREEN BUILDING

The interviewees have different perception towards the green building and non-green building in terms of water efficiency. Both buildings are benefited by cost saving and resource saving resulted from water efficiency. The green building receives both international and local recognition by the Green Certification while non-green building only receives local recognition by certifications such as Environmental Protection Licence (EPL). The green building is further subjected to benefits such as use of green certification as a marketing tool and inspiration factor, updated with the new technologies, standards and receiving good reputation by the society, while same factors affected as demerits for the non-green building. On the other hand, demerits of the green building can be identified as use of a common LEED rating category to assess the building, excessive cost for acquiring the LEED Certification and lack of employee satisfaction due to the changes of the environment specially in water efficient technologies, while non-green building obtains the same level of economical benefits, resource conservation and local recognition without expending the additional high cost spent from the green building to receive the green certification. Table 7 summarise the merits and demerits of green and non-green building.

Table 7: Summary of Merits and Demerits

	Green Building	Non-Green Building
Merits	• Economical benefits by saving costs • Resource conservation • Local and international recognition • Use as a marketing tool • Use as a inspiration factor • Update with new technologies, and standards • Reputation	• Economical benefits by saving costs • Resource conservation • Only local recognition by the local standards (E.g. EPL) • No additional expenses to acquire the green certification
Demerits	• Use of a common LEED rating category • Cost of acquiring the LEED Certification • Lack of employee satisfaction	• No motivation/ inspiration factor • No international recognition • Difficult to market the building's water efficiency performance

5. CONCLUSIONS AND RECOMMENDATIONS

As the final conclusion, it can be said that, even the overall water efficiency performance of the green building is higher than the non-green building; still water efficiency performance of the non-green building is also at an identical level and there are more potentials to increase water efficiency performance in green building through use of modern technologies and good water efficient practices.

However, research findings and recommendations derived under this research is developed under a scenario where the cases managed and controlled under a same chain of management. Although, it is supported to minimize the different attitudes on the water efficiency, it resulted in similar perceptions on water efficiency. Therefore, it limits the application of research results only on apparel buildings of same management chain. The feasible recommendations on good practices towards water efficient buildings including green and non-green in the apparel industry are discussed in Table 8.

Table 8: Good Practices Toward Water Efficient Buildings

No.	Water Efficient Practice	Benefits	Description
1	Integration of Metering and Sub-metering System	• Facilitate to assess the real water requirements by the individual processes • Familiarize with the water consumption patterns by the each water consumption processes and activities	If there are any variations on the amount of water supplied and the actual amount of water requirement, then that indicates opportunities for water conservation and improvement of water efficiency.
2	Encourage for Alternative Water Sources	• Reduce the burden on the national water demand • Minimize the water utility bill • Contribution for the sustainability of the environment	Renewable alternative water can be supplied from using sources like well water and harvested rainwater.
3	Integration of Water Efficient Technologies	• Update with latest technological advancements that makes buildings more water efficient	Water efficient technologies were identified in the “Different types of Water Efficiency Processes and Technologies” Section of the Research Background
4	Encourage for Water Reusing and Recycling	• Utilize 100% grey water or reused water for irrigation systems instead of potable water • Reduce the burden on the national fresh water demand • Reduce or eliminate the discharge of waste water to the environment • Utilize the optimum water usage out of the building’s total fresh water demand	As the first steps, it is need to identify the possible areas that can apply water reusing and recycling. The grey water or reused water can be utilized for the irrigation and cultivation purposes. Excess supply can be further purified for the water recycling to get the optimum usage.
5	Encourage for Individual Commitment	• Improve the employees water use habits and behaviours • Enhance the management concern for the identification of water usage patterns, areas which need further improvements, requirement of the metering and sub-metering devices, meter reading errors, water leakages, and water losses • Derive individual responsibilities for both management and employees	Encourage both management and employee level to assist the enhancement of water consumption performances of the building. Employees can be educated by awareness programs, hand bills, and visual aids.
6	Third Party Commitment	• Assess the water efficient performances in an unbiased manner • Lead to be bench marked with the other water efficient buildings	Water efficient performances further evaluate and adjudicate by a third party.

Thus, whether it is a green building or non-green building, the above mentioned water efficient practices will facilitate to earn more economical benefits and to achieve more resource efficiency. Moreover, if it is a non-green building that is hoping to obtain green certification, these practices will help out to achieve water efficiency requirements of green building without an excessive effort.

6. REFERENCES

Ali, H. H. and Nsairat, S.F.A., 2009. Developing a Green Building Assessment Tool for Developing Countries: Case of Jordan. *Building and Environment*, (44), 1053-1064.

Arab Forum for Environment and Development, 2010. *Arab Environment: Water Sustainable Management of a Scarce Resource,* Beirut: Chemaly and Chemaly.

Environment Agency, 2007. *Conserving Water in Buildings,* Bristol, Rio House.

European Environment Agency, 2009. *Water Resources across Europe: Confronting Water Scarcity and Drought* [online]. Available from: http:file:///C:/Users/sud/Downloads/Water-resources-across-Europe (1).pdf. [Accessed 21 April 2013].

Kates, R.W., Parris, T.M. and Leiserowitz, A.A., 2005. What is Sustainable Development?. *Environment: Science and Policy for Sustainable Development*, 47(3), 8-21.

Liu, B. and Ping, Y., 2012. Water Saving Retrofitting and its Comprehensive Evaluation of Existing Residential Buildings. *Energy Procedia,* 14*,* 1780-1785.

Masupha, T.M., 2007. *Water Management at a Textile Industry: A Case Study in Lesotho*. Unpublished Doctoral Dissertation. University of Pretoria.

Mirata, M. and Emtairah, T., 2011. Generic Guidelines and Tools to Improve Water Efficiency. *Water Efficiency Handbook,* Arab: Al-BiaWalTanmia Magazine.

Nelson, P.A., 2007. Measuring from the High Watermark: Defining Baselines for Water Efficiency in Green Buildings. *New York University School of Law,* 11(1), 105-144.

North Carolina Department of Environment and Natural Resources, 2004. *Water Conservation and Water Use Efficiency Report* [online]. Available from: http://www.ncwater.org/Reports_and_Publications/hb1215/HB1215_Sec5_Report.pdf [Accessed 20 April 2013].

Roy, T. and Gupta, A.K., 2008. *Greenomics: Cost Efficiency of Green Buildings in India*. Hyderabad, India: Jones Lang LaSalle.

Singapore’s National Water Agency, 2008. *Water Efficient Building Design Guide Book* [online]. Available from Public Utilities Board online: http://tenpercent.com.sg/docs/WEBDgb web.pdf [Accessed 20 April 2013].

Smith, A., 2007. *To be Green or not to be Green? Why that is not the Question?*. United States of America: Pramerica Real Estate Investors

Sri Lanka Apparel, 2009. *Apparel Eco-Factory in Sri Lanka* [online]. Available from: http://gwg.garmentswithoutguilt.com/featured-in/48-apparel-eco-factory-in-sri-lanka [Accessed 21 April 2013].

Thilakarathna, T. and Silva, S.D., 2012. *Sustainability through Building of Green Factories* [online]. Available from http://www.civil.mrt.ac.lk/conference/ICSBE2012/SBE-12-109.pdf [Accessed 22 April 2013].

Thiry, M.C., 2011. *Staying Alive: Making Textiles Sustainable*. Research Triangle Park. USA: AATCC.

United State Department of Energy, 2002. *Domestic water conservation technologies.* Washington: New Technology Demonstration Program.

Vorosmarty, C.J., Green, P., Salisbury, J. and Lammers, R.B., 2000. Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science AAAS*, 289(284), 284-288.

Waidyasekara., K.G.A.S., De Silva., M.L. and Rameezdeen , R., 2013. Comparative Study of Green Building Rating Systems: Terms of Water Efficiency and Conservation. In*:* Sandanayake Y.G. and Fernando, N.G. ed *Socio-Economic Sustainability in Construction: Practice, Policy and Research*, Sri Lanka: Celon Institute of Builders, 108-117.

World Business Council for Sustainable Development, 2006. *Facts and Trends: Water Earthprint Limited* [online]. Available from: http://www.unwater.org/downloads/Water_facts_and_trends.pdf [Accessed 10 April 2013].

COMPREHENSIVE STUDY ABOUT SRI LANKAN CONTRACTORS' ESTIMATION PRACTICE

P. Ganeshu*, P.A.P.V.D.S. Disaratna and M. Francis
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The "estimating process" is a significant element within the circle of construction due to the lack of financial resources available. Tender cost estimating in Sri Lankan construction industry requires extensive knowledge and expertise. This research proposed a best estimation practice to the Sri Lankan construction industry. This study expects it will fulfil the research gap and uplift the Sri Lankan contractors' current estimation practice. The aim of this research is to suggest solutions to address the limitations of current estimating practice prevailing in the Sri Lankan construction industry comparing to the proposed best estimation practice. This research has been conducted through literature reviews, questionnaire survey and interviews. The questionnaire included sixteen steps identified as the best estimation practice through literature review and interviews, with a view to find out the current estimation practice of Sri Lankan contractors. The analysis of data revealed although they are following all sixteen steps, they couldn't able to gain the maximum benefit of those steps owing to some limitations. Therefore in order to find out the solutions for those limitations Seventeen interviews were carried out. Among those, nine interviews were from contractors and eight interviews were from consultants.

These conclude that limitations and solutions identified by the contractors were similar with those identified by the consultants. In the comparison of their opinions the degree of agreement on most of the factors between them is high. It shows consultants' understanding about contractors' works are quite high.

The study recommended that both contractors and consultants give more attention to the cost estimating process to manage the projects in a better way and to hire qualified technical staff in order to obtain an accurate estimate. Contractors were requested to keep databases and to make relevant changes and modifications in their existing estimating practices in their future projects.

Keywords: *Accuracy; Consultants; Contractor; Tender Cost Estimation.*

1. INTRODUCTION

The construction industry is usually considered to be the backbone in any economy, as it absorbs a relatively high percentage of the national workforce (Enshassi *et al.*,2010). Construction industry has its own characteristics that distinguish it from other sectors of the economy (Nega, 2008). Estimating is a technical process of predicting the cost of construction project (Chartered Institute of Building, 1997). Within the sphere of construction, the "estimating process" is a significant due to the lack of financial resources available (Britto, 2013). Comprehensiveness of the cost estimation process varies in terms of availability of information, nature of the project, available time duration for estimation and structural constituents (Shashand Ibrahim, 2005). Tender documentation includes drawings, specifications, conditions of contract, and bills of quantities which are used in preparation of cost estimate (Akintoye, 2000). Further, Akintoye (2000) stated that the estimating department undertakes various tasks in collaboration with other departments within the company to arrive at the consolidated net cost estimate for the project. Thus, contractors have to follow systematic process for performing cost estimation. The cost estimation process includes study the tender documents, prepare tender time table, visit to site and consultant, enquiries and quotations analysis, prepare the method statement and programme for the

* Corresponding Author: E-mail – sunganesh21@gmail.com

project, design temporary works, arrange mid tender review meeting, build up rates, price preliminaries, adjustments for price fluctuations, prepare cash flow, add overhead and profit and prepare bill of quantities (Chartered Institute of Building, 1997). The combination of mentioned process is named as estimation practice.

The best estimation practices are not only about predicting the cost of construction, but also it consist of several uses as control and monitor project execution, audit project success, preparation of tender, schedule of labour, material and plant, make decision to tender and select project to be tendered (Nagulan, 2001). Application of best estimation practices helps to ensure a high-quality estimate, certain best practices, should be followed if accurate and credible cost estimates are to be developed (Ahmad *et al.*,2012). These best practices represent an overall process of established and repeatable methods that result in high-quality cost estimates that are comprehensive and accurate and that can be easily and clearly traced, replicated, and updated (Brook, 2004). An understanding of cost estimating issues and considerations would make estimating an effective component of overall cost and project management (Michael, 2003). Therefore, implementing good estimating practices make it possible to improve planning and budgeting accuracy, resulting in the delivery of quality projects within shorter time frames.

Britto (2013) discovered that the existing estimating practices in Sri Lanka are not effective for the future, as the Sri Lankan construction industry isn't practicing the best practices as well as they are following the traditional practices. Further, accuracy of the estimate via these practices is not highly satisfactory. Therefore, previous studies signposted the indispensable need for the best estimating practices for the cost estimating in Sri Lanka. Abeysinghe (2006) recommended that it will be enormously benefited to have a review on cost estimating practice in terms of education and training. According to existing literature related to this research area, Sri Lankan construction industry operates without a proper and systematic estimation practice.

Sri Lankan contractors believe that ensuring accuracy of cost estimating does not much influence the probability of winning the job compared with determining the suitable markup. The decision level management takes greater care in markup decisions rather than the other cost estimation (Nagulan, 2001). This seems that the estimators are not encouraged to follow best estimation practices in proper manner by management. Thus, there is a necessity for establishing the best estimation practice in Sri Lankan construction industry.

In the Sri Lankan context many researches have been conducted on "Construction Estimates" as a whole (Sumanasingha, 2010). A few researches have been carried out to investigate regarding the estimation practices of Sri Lankan contractors and construction industry but they were unable to find out the current contractor estimation practices of the Sri Lankan contactors and its limitations. Thus, there is a necessity to fill this potential research gap. Hence, this study is focused to identify the solutions to address the limitations of current estimation practice used by Sri Lankan contractors.

Therefore this research aimed to suggest solutions to address the limitations of current estimating practice prevailing in the Sri Lankan construction industry comparing to the best estimation practice. Fulfilling the above research aim was done by achieving four research objectives. These objectives are; (1) Propose the best contractors' estimation practice (2) Identify the current estimation practice used by the contractors in Sri Lanka, (3) Find out the limitations of current estimation practices of Sri Lankan contractors by comparing with the proposed best estimation practice, (4) Propose the enhancement solutions for the identified limitations of the current estimation practices used by contractors in Sri Lanka.

2. LITERATURE REVIEW

2.1. IMPORTANCE AND PURPOSE OF PROPER ESTIMATING PRACTICE

It is found that uniform guidance on cost estimating practices and procedures that would be the basis for formulating valid, consistent, and comparable estimates was lacking within the Sri Lankan construction Industry (Britto, 2013). 'Best Practice' in cost estimation from project identification phase through to project delivery and implementation leads to efficient use of scarce public resources and mitigates the risk of cost overruns. Better cost estimation also provides higher levels of certainty for public sector organisations, governments and the public to whom government agencies are accountable (Department of Infrastructure, Transport, Regional Development and Local Government of Australia, 2008). Cost overrun is a chronic problem across most projects. While a significant research have been published on this topic, the understanding of the root causes and a clear direction towards improvement remained unexplored. The focus of the past research is mainly on the factors directly or indirectly associated with the project environment and their relative impact on overall cost performance in projects. The resulting concept model on cost overrun was unable to fill a significant knowledge gap in cost estimation practice across all industry sectors (Doloi, 2011). While numerous models and methodologies have been developed over past years on dealing with the cost estimation and managing escalations in projects, there is still a significant knowledge gap emerging in establishing a reference or base model for improving the estimating practices across the industry (Ahmad *et al.*, 2012).

Basic characteristics of credible cost estimates through the proper cost estimation practices are defined as; Clear identification of task, Broad participation in preparing estimates, Availability of valid data, Standardised structure for the estimate, Provision for programme uncertainties. The existing literature revealed that there is a need for developing the best practice cost estimation standard as a document that could be a benchmark for contractors to measure themselves against (Department of Energy, 2011).

The estimating department, while preparing the cost estimate takes an overall view of the project and considers factors that may have an impact on estimating and pricing for the project, including production performance anticipated during the construction stage (Chartered Institute of Building, 1997). In the study of Akintoye (2000) the initial analysis of the 24 factors were considered and the study shows that the main factors relevant to cost estimating practice are complexity of the project, scale and scope of construction, market conditions, method of construction, site constraints, client' s financial position, buildability and location of the project. The practice of cost estimating does not differ from conventional techniques based on the use of labour and material constants to obtain prices for bills of quantities items on an item by item basis (Akintoyeand Fitzgerald, 2000). Further the study shows that the major causes of poor practice and inaccuracy in cost estimating continue to be the lack of practical knowledge of the construction process by those responsible for the estimating function, insufficient time to prepare cost estimates, poor tender documentation and the wide variability of subcontractors' prices.

2.2. VIEW OF EXISTING BEST ESTIMATION PRACTICES THROUGH PREVIOUS STUDIES

Standard guides are identified as cost estimate guides and those are available from other government and nongovernment agencies that were relied on to determine the processes, practices, and procedures most commonly recommended in the cost estimating community. There are number of practices that have been developed as the estimation practices for different kind of construction works. The research therefore explored the estimation practices from five different sources. Table 1 shows the summary of estimation practices.

Table 1: Analysis of Steps of Estimating Practices

Steps of New Estimation Practices Proposal for Sri Lankan Contractors	**Practice01 (Chartered Institute of Building, 1997)**	**Practice02 (Department of Energy United States of America, 2011)**	**Practice 03 (Department of Infrastructure, Transport, Regional Development and Local Government of Australia, 2008)**	**Practice 04 (Pratt, 2011)**	**Practice 05 (Washington State Department of Transportation, 2008)**
Examine received tender documents and Project Information	X		X	X	X
Prepare tender time table, visit to site for Identify Ground Rules and Assumptions	X	X		X	X
Prepare the method and programme for the project	X	X		X	
Take off Quantities and obtain data	X			X	
Arrange mid tender review meetings	X			X	X
Build up rates and quotations analysis	X			X	
Prepare base estimate (Budget) and select the subcontractors	X	X	X	X	X
Price preliminaries, measured works and subcontractors work	X				X
Conduct Risk and sensitivity analysis		X	X	X	
Review and the approval of the budget from the management	X	X	X	X	X
Prepare and document the detail estimate	X			X	X
Adjustment for the price escalation and determine the markup decisions	X		X	X	X
Prepare cash flow and present BOQ/ Detail Estimate to management for Approval	X	X	X	X	X
Update the estimate to reflect the actual cost of changes		X	X		

Using Table 1, the estimation practice for Sri Lankan construction industry is proposed with sixteen steps.

Proposed Estimating Practice for Sri Lanka

1. Examine received tender documents and Project Information
2. Adjustment for the price escalation and determine the mark-up decisions
3. Build up rates
4. Prepare and document the detail estimate
5. Review and the approval of the budget from the management
6. Quotations analysis
7. Prepare tender time table, visit to site for Identify Ground Rules and Assumptions
8. Calling inquiries
9. Price preliminaries, measured works and subcontractors work

10. Update the estimate to reflect the actual cost of changes
11. Prepare the method and programme for the project
12. Prepare cash flow and present estimate to management for Approval
13. Conduct Risk and sensitivity analysis
14. Prepare (base estimate) net pricing and select the subcontractors
15. Arrange mid tender review meetings
16. Take off Quantities and obtain data

3. RESEARCH METHODOLOGY

3.1. RESEARCH APPROACH

The current study adopted survey approach to investigate the research phenomena. The questionnaires were issued to the professionals who involved in estimation and tendering of construction projects. The selected professionals: construction engineers, project managers and quantity surveyors are from both contracting and consultancy organisations. From the comprehensive literature survey, the Best estimation practice for Sri Lanka is proposed. Using the results of literature review, the questionnaire was prepared. A total of 100 questionnaires were distributed among randomly selected professionals. 75% of the questionnaires were returned. The questionnaire survey ranked the steps of proposed estimation practice under the perspectives of contractors and consultants separately.

In addition to questionnaire survey, semi structured face-to-face interviews were conducted with the experienced professionals to identify the limitation in practicing the proposed estimation practice and the suggestions to meet the best estimation practices in Sri Lanka. A total of seventeen participants were involved in semi structured interviews. Out of 17 interviewees, 9 represented contracting organisations and the remaining 8 are employed in consultant organisations. Thus, the study consists of both Qualitative and Quantitative approaches in order to achieve the desired objectives.

3.2. DATA ANALYSIS TECHNIQUE - RELATIVE IMPORTANCE INDEX (RII)

The results from questionnaire survey were analyzed using Relative Importance Index (RII). The RII technique has been widely used in construction research for measuring attitudes with respect to surveyed variables. Likert scaling was used for ranking questions that have an agreement level. The respondents were required to rate the importance of each factor on a 5-point Likert scale using 1 for not important, 2 for of little important, 3 for somewhat important, 4 for important and 5 for very important. Then, the relative importance index was computed using the following equation:

$$\text{Relative Importance Index} = \in W\frac{1}{AN} = \frac{5n1+4n2+3n3+2n4+1n5}{5N} \qquad \text{(Eq: 01)}$$

Where *W*, which is the weight given to each factor by the respondent, ranges from 1 to 5; *n5* = the number of respondents for very important; *n4* = the number of respondents for of important; *n3* = the number of respondents for somewhat important; *n2* = the number of respondents for little important; and *n1* = the number of respondents for not important. *A* is the highest weight (i.e., 5 in the study) and *N* is the total number of samples. The Relative Importance Index ranges from 0 to 1.

3.3. DATA ANALYSIS TECHNIQUE - CONTENT ANALYSIS

Fellows and Lui (2003) mentioned that in qualitative content analysis emphasis is on determining the meaning of the data and data are given coded allocation to categories and groups of ‘respondents’ from whom the data were obtained are fitted to these categories. Range of qualitative data analysis software are currently available to assist in content analysis process, including Ethnograph, ATLAS.ti, WinMAX, Hyper-RESEARCH and NVivo. This study selected content analysis using NVivo 7 to analyze the interview output.

4. Research Findings and Analysis

4.1. Current Estimation Practice of Contractors

This statistical analysis is carried out to identify the current estimating practices of Sri Lankan contractors, in order to fulfill the 2nd objective. The given best practice was proposed through the literature survey. The survey facilitates to obtain views of both contractors and consultants who are different in their interests. The contractors have been given the questionnaire to identify their current estimating practices against the best estimating practices. At the same time, the consultants have been given the questionnaire to identify level of importance of the steps which are expected to be performed by the contractors in estimation. 75 questionnaires were returned back from the professionals which including 35 consultants and 40 contractors. Table 2 indicated the steps of estimation practice and the respective RII values of consultants and contractors.

Table 2: Current Estimation Practice: Perspectives of Contractors and Consultants

	Estimating Practices Steps	Consultants' Perspective		Contractors' Perspective	
		RII	Rank	RII	Rank
1	Examine received tender documents and Project Information	0.971	01	0.935	01
2	Adjustment for the price escalation and determine the mark-up decisions	0.914	02	0.905	02
3	Build up rates	0.903	03	0.840	05
4	Prepare and document the detail estimate	0.903	03	0.855	03
5	Review and the approval of the budget from the management	0.897	05	0.760	13
6	Quotations analysis	0.891	06	0.830	07
7	Prepare tender time table, visit to site for Identify Ground Rules and Assumptions	0.886	07	0.845	04
8	Calling inquiries	0.886	07	0.790	10
9	Price preliminaries, measured works and subcontractors work	0.880	09	0.840	05
10	Update the estimate to reflect the actual cost of changes	0.874	10	0.795	09
11	Prepare the method and programme for the project	0.840	11	0.775	12
12	Prepare cash flow and present estimate to management for Approval	0.834	12	0.755	14
13	Conduct Risk and sensitivity analysis	0.829	13	0.785	11
14	Prepare (base estimate) net pricing and select the subcontractors	0.823	14	0.825	08
15	Arrange mid tender review meetings	0.800	15	0.715	16
16	Take off Quantities and obtain data	0.766	16	0.750	15

From Table 2, it is shown that from the consultants' perspective, out of sixteen steps fifteen steps have RII values more than (0.800), it shows that this practice has been exclusively recommended by the consultants as a good estimation practice for the Sri Lankan contractors. Therefore this confirms the proposed estimation practice from the existing literature suits to Sri Lanka. Furthermore, as per the ranking of RII "Examine received tender documents and Project Information" was ranked as the first most important step by the consultants with very high relative important index of (0.971). Similarly, according to contractors first most step is identified as "Examine received tender documents and Project Information" with the RII value of 0.935. This seems that the contractors and consultants are of the same opinion. The first and foremost thing for a contractor is to study and understand the information about the project and the important particulars attached thereof. It will enormously help the contractors to minimize their errors especially on scheduling, pricing and all other steps of estimation. The step: *Adjustment for the price escalation and determine the markup decisions*, is identify as the second important step in estimation by the contractors with RII value of 0.905 and the consultants with 0.914 RII value. *Prepare and document the detail estimate, Build up rates* are identified as the third important step by the contractors with the RII value of 0.903 while consultants identified *Prepare and document the detail estimate* (RII-0.855) , *Prepare tender time table, visit to site for Identify Ground Rules and Assumptions* (RII-0.845) as the third and fourth important steps.

Thus, the above Table 1 revealed that the contractor and consultant have identified that all sixteen steps are important by giving the RII value as above 0.80. (There are some items fall RII below 0.80). However, the priority order of the contractors and the consultants slightly differs in the identified steps. Further, the expectation of consultants' are always high compared to the contractors' current practices in estimation. Therefore, the research tends to investigate the limitations in following the proposed best estimation practice by the contractors.

4.2. LIMITATIONS IN PRACTICING THE PROPOSED BEST ESTIMATION PRACTICE

The semi structured interviews were carried out with the professionals who were experienced in estimation of projects. The participants were asked to indicate the limitations in following the proposed best estimation practices up to the expectation of consultants. The pool of interview participants included contracting organisation professionals: 6 chief estimators, and 3 senior quantity surveyors and consulting organisation professionals: 3 managing directors, 2 associate directors and 3 chief quantity surveyors.

The collected data through interviews were analyzed using content analysis. The result of content analysis is shown in the following Table 3.

Table 3: Limitations in Practicing the Proposed Best Estimation Practice

Limitations	Contractors		Consultants		Total	
	Frequency	%	Frequency	%	Frequency	%
Limited time to estimate	7	77.77	6	75.00	13	76.47
Lack of knowledge of employees	6	66.66	5	62.50	11	64.00
Inadequate employees	5	55.55	5	62.50	10	58.82
Improper documents	3	33.33	5	62.50	8	47.05
Work overload	2	22.22	6	75.00	8	12.50
Delay in quotations	3	33.33	2	25.00	5	29.41
Improper communication	1	11.11	3	37.50	4	23.52
Lack of experience of employees	1	11.11	2	25.00	3	17.64
Lack of resource	2	22.22	1	12.50	3	17.64
Changes through addendums	1	11.11	2	25.00	3	17.64
Improper record keeping	1	11.11	1	12.50	2	11.76

Limitations	Contractors		Consultants		Total	
	Frequency	%	Frequency	%	Frequency	%
High competition	1	11.11	1	12.50	2	11.76
Client unawareness	1	11.11	0	0.00	1	5.88
High estimator's risk	1	11.11	0	0.00	1	5.88
No standard to tenders	1	11.11	0	0.00	1	5.88
No standard document to refer	0	0.00	4	50.00	4	23.52
Unawareness of improper estimate	0	0.00	3	37.50	3	17.64
Poor management commitment	0	0.00	1	12.50	1	5.88

Table 3 listed the limitation in practicing the proposed best estimation practice with the respective frequencies of contractors' and consultants' opinion. There were a total of seventeen limitations found. The participants (7 contractors and 6 consultants) indicated that the 'limited time for estimation' as the most critical limitation. Even though a duration of two weeks is provided for estimation, the organisation is in a critical position to handle number of projects with the limited staffs. The research revealed that the limitations: 'Lack of knowledge of employees', 'Inadequate employees' are identified as 2nd and 3rd critical limitations respectively. The contractors agreed that the professionals employed in their firms are not with the expected knowledge level to perform estimation. Thus, the professionals pointed out the limitation in practicing the proposed estimation practice.

The research further investigated the solutions for the identified limitations. The next subsection illustrates the finding on the solutions for the identified limitations in practicing the proposed best estimation practice.

4.3. SOLUTIONS FOR THE IDENTIFIED LIMITATIONS IN PRACTICING THE PROPOSED BEST ESTIMATION PRACTICE

The research participants were asked to indicate the solutions for limitations in following the proposed best estimation practices up to the expectation of consultants. The result of content analysis is indicated in the following Table 4.

Table 4: Solution for the Identified Limitations in Practicing the Proposed Best Estimation Practice

Solutions	Contractor		Consultant		Total	
	Frequency	%	Frequency	%	Frequency	%
Prepare programme for estimation	4	44.44	2	25.00	6	35.29
Get extension of time	4	44.44	3	37.50	7	41.17
Provide training	4	44.44	3	37.50	7	41.17
Keep tender time table	3	33.33	1	12.50	4	23.52
Keep proper contacts	3	33.33	3	37.50	6	35.29
Make decision to tender	3	33.33	2	25.00	5	29.41
Recruit suitable person	2	22.22	5	62.50	7	41.17
Keep and update database	2	22.22	5	62.50	7	41.17
Conduct seminars	1	11.11	3	37.50	4	23.52

Maintain all records	1	11.11	2	25.00	3	17.64
Form high capacity tendering division	1	11.11	0	0.00	1	5.88
Use same standards	1	11.11	0	0.00	1	5.88
Provide standard to estimate	0	0.00	3	37.50	3	17.64
Consultant need to provide proper documents	0	0.00	3	37.50	3	17.64
Improve coordination among employees	0	0.00	2	25.00	2	11.76
Improve management concerns	0	0.00	2	25.00	2	11.76
Distribute works	0	0.00	1	12.50	1	5.88

The above table indicated that the most preferred solution is identified as 'Prepare programme for estimation' by the 4 contractors and 6 consultants. The participants further emphasised that the prepared programme of work should be strictly followed. The next best solutions identified by the interviews are 'get extension of time from the consultant' and 'provide training to the staffs'. Thus Table 4 furnished the opinion of contractors' and consultants' on solutions separately.

In addition to the above findings, the research compiles the limitations with the suitable solutions for each limitation in the following Table 5.

Table 5: Limitations and the Respective Solutions

Limitations	**Solutions**
Limited time to estimate	Get extension of time Keep tender time table Keep programme for estimation Keep proper contacts Recruit suitable persons Keep and update data base Maintain all details Form high capacity tendering division Improve management concerns Improve coordination among employees
Lack of knowledge of employees	Recruit suitable persons Conduct seminars Provide training
Inadequate employees	Recruit suitable persons
Improper document	Consultant need to provide proper documents Use same standards to tendering
Work overload	Form high capacity tendering division Improve coordination among employees Distribute works Improve management concerns
Delay in quotations	Keep proper contacts
Improper communication	Conduct seminars Provide training Improve coordination among employees
Lack of experience of employees	Conduct seminars Provide training

Limitations	Solutions
	Recruit suitable persons
Lack of resource	Improve management concerns
Changes through addendums	Consultant need to provide proper documents
Improper record keeping	Keep and update data base Maintain all details
High competition	Improve management concerns Recruit suitable persons
Client unawareness	Conduct seminars
High estimator's risk	Improve management concerns Recruit suitable persons
No standard to tenders	Use same standards Consultant need to provide proper documents
No standard document to refer	Provide standard to estimate
Unawareness of improper estimate	Conduct seminars Provide training
Poor management commitment	Improve management concerns

5. CONCLUSIONS AND RECOMMENDATIONS

A comprehensive study about Sri Lankan contractors' estimation practice was conducted to determine the current estimation practice and find out the solution for their limitations. For this research two types of sample groups were selected, which are namely contractors and consultants. The study was conducted through questionnaire survey and interviews. In order to achieve the objective, a mixed of qualitative and quantitative approaches was used.

The first objective "Propose the best contractors' estimation practice that can be used by the contractors", was achieved through the literature review. The second, third, and fourth objectives of this research were attained through the questionnaire survey and interviews.

The second objective was to "Identify the current estimation practice used by the contractors in Sri Lanka". Through issued questionnaire with proposed best estimating practice with 16 steps, current estimation practice level was identified. Even though Sri Lankan contractors are following all those steps they can't give equal important to each steps which are identified in best estimation practice as consultants' expectation due to some limitations. In addition, this study revealed the consultant expectation from the contractors related to each steps. As a conclude contractors did not provide their importance for each steps to fulfill consultants expectation.

Third objective of this study was to find out those limitations. Content analysis technique was used to achieve the third objective. Interviews were carried out to find the limitations which are considered by contractors and consultants as affecting the importance level of each step in proposed best estimation practice in Sri Lankan construction industry. Eighteen limitations were identified by both of them. The identified limitations are Limited time to estimate, lack of knowledge of employees, inadequate employees, improper document, work overload, delay in quotations, improper communication, lack experience of employees, lack of resource, changes through addendums, improper record keeping, high competition, client unawareness, high estimator's risk, no standard to tenders, no standard document to refer, unawareness of improper estimate and poor management commitment.

Identify the solutions for the identified limitations were objective number four. To fulfill the objective number four, the perspective of contractors and consultants of the essential solutions for the identified limitations in tender cost estimate in Sri Lanka was studied, these solutions were separately analyzed through content analysis using the obtained data from interviews, in the perspective of contractors and consultants. Seventeen solutions were identified such as Keep programme for estimation, get extension of time, provide training, keep tender time table, keep proper contacts, make decision to tender, recruit suitable person, keep and update database, conduct seminars, maintain all records, form high capacity tendering division, use same standards, provide standard to estimate, consultant need to provide proper document, improve coordination among employees, improve management concerns and distribute works.

According to the previous analysis both parties know and accept what are the limitations creating by themselves and recommend the solutions for those limitations. This research can be helpful to overcome those limitations and achieve the best estimation level by Sri Lankan contractors.

6. References

Abeysinghe, U.S., 2006. *Analysis of the reliability of consultant's estimate.* Unpublished dissertation (BSc). University of Moratuwa, Moratuwa, Sri Lanka.

Ahmad, N., Schlegal, O. and Elkadi, H., 2012. A review of the cost estimation issues in the tender preparation process in construction industry. In: Ahmed, S.M., Farooqui, R., Azhar, S., Shah, A., Lodi, S. H. and Smith, N. A., eds. *Construction in Developing Countries Conference* , Bangkok 4-6 July 2012. East Carolina University: Greenville, N. C., 154-160.

Akintoye, A., 2000. Analysis of factors influencing project cost estimating practice. *Construction Management and Economics,* 18(1), 77-89.

Akintoye, A. and Fitzgerald, E., 2000. A survey of current cost estimating practices in the UK. *Construction Management and Economics*, 18(2), 161-172.

Britto, A.D., Perera, S.K. and Illankoon, C.S., 2013. Factors affecting to the accuracy of pre-tender cost estimation of Road construction in Sri Lanka. *FARU Journal,* 5(1), 243-254.

Brook, M., 2004. *Estimating and tendering for construction work.* 3rd ed. London: Butterworth-Heinemann.

Chartered Institute of Building, 1997. *Code of estimating practice*. 6th ed. London: Longman.

Department of Energy United States of America, 2011. *Cost estimating guide* [online]. Available from: https://www.directives.doe.gov [Accessed 28 May 2014].

Department of Infrastructure, Transport, Regional Development and Local Government of Australia, 2008. *Best Practice Cost Estimation for Publicly Funded Road and Rail Construction* [online]. Available from: http://investment.infrastructure.gov.au/publications/administration/pdf/Best_Practice_Cost_Estimation.pdf [Accessed 28 May 2015].

Doloi, H.K., 2011. Understanding stakeholders' perspective of cost estimation in project management.*International Journal of Project Management*, 29(5), 622-636.

Enshassi, A., Sherif, M. and Karriri, A. E., 2010. Factors affecting the bid/no bid decision in the Palestinian construction industry. *Journal of Financial Management of Property and Construction*, 15(2), 118-142.

Fellows, R.F and Liu, A.M.M., 2003.*Research methods for construction.*2nd ed. United Kingdom: Blackwell's publishing.

Nagulan, S., 2001. *A survey of current contractors' cost estimating practices in Sri Lanka* Unpublished dessertation (BSc). University of Moratuwa, Moratuwa, Sri Lanka.

Nega, F., 2008. *Causes and effects of cost overrun on public building construction projects in Ethiopia*. Master's thesis. Addis Ababa University.

Pratt, D., 2011. *Fundamentals of construction estimating*. 3rd ed. United States of America: Delmar.

Shash, A.A. and Ibrahim, A.D., 2005. Survey of procedures adopted A/E firms in accounting for design variables in early cost estimates. *Journal of King Saud University,* 18(1), 1-17.

Sumanasingha, R.D., 2010. *Importance of pre- tender estimate and its influence on project success: consultant's perspective.* Unpublished dessertation (BSc). University of Moratuwa, Moratuwa, Sri Lanka.

Washington State Department of Transportation, 2008.*Cost estimating manual for WSDOT Projects* [online]. Available from: http://www.wsdot.wa.gov/ publications/fulltext/CEVP/EstimatingGuidelines.pdf [Accessed 28 May 2015].

CONCEPTUAL FRAMEWORK FOR SUSTAINABLE PUBLIC PROCUREMENT PROCESS IN CONSTRUCTION INDUSTRY

K.A.P. Gunawardhane* and Gayani Karunasena
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Public Procurement Process (Public PP) mainly focuses on the satisfaction of stakeholders in line with development objectives of the country. The importance of public expenditures within the world economy has stimulated and established interest in how public money is spent, with an emphasis on transparency and openness through the Public PP. This was identified as critical challenges with prevailing gaps of the Public PP when focuses on Sri Lankan construction industry. In this context Sustainable Public Procurement Process (SPPP) in construction industry emerge to Sri Lanka with numbers of benefits. Though it is a new concept to the developing countries, SPPP is not another type of procurement; it rather seeks to address the environmental, social and economic consequences of procurement actions. Moreover, the developed countries have implemented the SPPP successfully as a solution to challenges and gaps of existing Public PP. Hence, the SPPP has identified as one of most accepted alternative method to address the challenges and gaps of the Public PP in Sri Lankan construction industry.

Thus, this paper has proposed a conceptual framework for the SPPP based on secondary data. Further paper explored the framework in line with significant stages of Conceptual, Planning, Tendering/ Purchasing, Implementation, and Closeout with due consideration to the relationship of these all five stages of the Public PP. Relevant areas scrutinised through the comprehensive literature review to develop the proposed conceptual framework. Further, experts in the field of construction procurement also consulted to gather the opinions in order to evaluate the feasibility of conceptual framework.

Keywords: *Conceptual Framework; Construction Industry; Public Procurement Process; Sustainable Public Procurement Process.*

1. INTRODUCTION

Procurement process is adopted by not only the government entities but also the private organisations to obtain goods, works, and services by most appropriate manner Further, the World Bank (2010) described that public procurement is the process that use by the government entities to buy the inputs for vital public sector investments. Those investments both in physical infrastructure and strengthen institutional and human capacities lay foundations for national development. Accordingly, public procurement mainly consider the stakeholder satisfaction in line with the desired objectives of the country, where, the primary objective of the procurement process in private sector is optimum benefit to the organisation together with least cost and accepted quality in line with the desired objectives of the organisation. Hence, enhancement and improvement of the activities of Public Procurement Process (Public PP) directly benefitted to the nation in order to uplift the living standard of the community. Therefore, Public PP is examined as series of activities that significant to the sustainable development of the country. The activities of the Public PP identified as continues processes from risk assessment, selection of source, evaluation of alternative solutions, contract award, payment, and management of a contract up to the end of defect liability period (Murray, 2009; National Procurement Agency, 2006; Erridge, 2007; Larson, 2009; World Bank, 2010; Zheng *et al.*, 2010).

* Corresponding Author: E-mail - prasannakap@yahoo.com

Central Bank of Sri Lanka (2012) found that the Public PP in construction sector was the main driver of economic growth in Sri Lanka and it makes the most significant contribution, reflecting the massive public investment programmes and several private sector projects. Further, literature revealed that interest of the stakeholders in construction industry has growth to moderate the existing process in line with the global requirements. Moreover, the procurement process in construction industry was identified as very sensitive to change in line with the requirement of external environment of economic, political, financial, legal and technological (Williams *et al.*, 2007; World Bank, 2010).

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 organisation of the activities of the projects (Rameezdeen and Silva, 2002). Accordingly contemporary version of the existing procurement process that link with requirement of external environment as per the global needs has identified as sustainable procurement. Further, sustainable procurement process concluded as integral part to achieve the present global needs and uplift the economy of the country and living standards of the stakeholders in line with the triple bottom line indicators of economic, environmental and social (World Bank, 2010; Srivastava, 2007; Preuss, 2009; Walker and Brammer 2009; Williams *et al.*, 2007).

The aim of the paper is to propose conceptual framework for Sustainable Public Procurement Process (SPPP) to the Sri Lankan construction industry through the literature and opinions of the experts in the field of procurement. Hence scope of this paper includes introduction of Public PP, Remedies to the challenges and gaps of the existing Public PP, significant of the SPPP, and conceptual framework.

2. PUBLIC PROCUREMENT PROCESS (PUBLIC PP) OF CONSTRUCTION INDUSTRY IN SRI LANKA

The purchasing power of Sri Lankan public sector plays a significant role. Therefore, the Public PP has direct link with the economic development of the country. Hence, effective and efficient improvement of activities of the Public PP positively affected to uplift the economy of the country (Central Bank of Sri Lanka, 2012). Elaborating in this regard further emphasised that government is major client and regulator in the construction procurement in Sri Lanka. Furthermore, the Public PP in construction industry is identified as one of the backbones of the economy of Sri Lanka.

Therefore, the Public PP in construction industry should give equal weight age not only to the dimensions of time, cost and quality but also to the dimensions of social, environmental and economic when acquisition of goods, works and services with consideration of value for money in line with the requirements of the stakeholders and the global needs (Interagency Procurement Working Group, 2006; Mc Crudden 2004; Williams *et al.*, 2007).

The reigning political party took major steps to liberalize the economy in Sri Lanka in 1977. This involved several inter related initiatives to open up the economy to foreign trade and investment to deregulate domestic business in order to reduce the role of the state in economic affairs. At present, the economy of Sri Lanka has been shown transition features since end of the war in 2009. Therefore, the procurement systems are also in transition era (Central Bank of Sri Lanka, 2012). Further statistical figures of the Central Bank of Sri Lanka (2012) revealed that government of Sri Lanka spent on infrastructure development Rupees billion 310.3, 335 and 375.2 in the year of 2009, 2010 and 2011 respectively. Therefore Public PP in construction industry of the country is identified as integral part in order to achieve desired short term targets that to be an economic hub in the Asian region in line with the aim of sustainable development of the country. Hence, enhancement and improvement of the activities of Public PP in Sri Lankan construction industry will be directly benefitted to the nation in order to achieve the economic development of the country (World Bank, 2010; Murray, 1999; Larson, 2009; Erridge, 2007; Zheng *et al.*, 2010).

Central Bank of Sri Lanka (2012) found that the Public PP in construction sector was the main driver of economic growth in Sri Lanka. Further author mentioned that it makes the most significant contribution, reflecting the massive public investment programmes and several private sector projects. Furthermore, it was identified that Public PP of construction industry in Sri Lanka hold major share of the Gross Domestic Products (GDP) as developing country. Moreover, noted that interest of the stakeholders has grown to moderate the existing process. Hence, contemporary version of the Public PP of the construction industry should be substantiated and will have to be met by both the public and private sectors requirement to optimum alignment with the vision of the medium term development plan of the country in line with the global needs (Central Bank of Sri Lanka, 2012). Accordingly, improvement of existing Public PP in line with the global needs and requirements has positive impacts on the sustainable development of the country.

In line with the medium term development plan, the country vision of Sri Lanka is to become a global hub between the East and the West and become upper middle income country by 2016. Towards that vision, the government development policy framework expressed the areas that should be upgraded inter alia with improvement of competition in the field of infrastructure and environment sustainability (The Wold Bank, 2012). Thus the procurement process should upgrade to achieve the desired goals of the organisation or country by considering the requirement of stakeholders that link with the global needs and requirements (Srivastava, 2007; Preuss, 2009; Walker and Brammer 2009).

3. REMEDIES TO THE PREVAILING CHALLENGES AND GAPS OF THE "PUBLIC PP" IN SRI LANKAN CONSTRUCTION INDUSTRY

Liberalized economy of Sri Lanka has involved several inter related initiatives to open up the economy to foreign trade and investment to deregulate domestic business in order to reduce the role of the state in economic affairs. Further the country has taken several initiatives to enhance and upgrade the existing Public PP in line with the global needs (Central Bank of Sri Lanka, 2012). However, the initial cost has been found as the leading barrier to improve the procurement process. Further lack of support by the top management as leading facilitator also identified as obstacles. There are notable differences could be seen from developed countries to Sri Lanka on uses forms of capital efficiently to sustain economic growth and development in the medium and long term. Hence, the main challenge remains to Sri Lanka is high initial cost involvement to upgrade the system in line with the global need toward better infrastructure facilities to increase economic growth in the area of construction, services and manufacturing sectors (Biller and Nabi, 2013). However, the funding agencies has given consent to provide financial assistance to upgrade the existing procurement system together with the capacity development of the institutions.

Further Sri Lanka has no continuity in a national strategy on the procurement process unlike developed countries (Raymond, 2008). Moreover, the author pointed out that the existing Public PP in Sri Lanka not considers the global needs and requirements of sustainable development. In addition lack of knowledge and negative attitude of the officers and fraud and corruption involvement also negatively affect to the activities of procurement process. Therefore, present Public PP not compatible with the dimensions of sustainable development of the country. As such, government of Sri Lanka and the funding agencies have identified that the Public PP in Sri Lanka should be upgraded to expedite the future economic development to become a one of fastest growing economy in the Asian region. Hence, government of Sri Lanka takes preliminary actions to identify the remedial measures to bridge the gap with the financial facilities of the funding agencies (World Bank, 2010; Biller and Nabi, 2013; Murray, 1999).

However misunderstand and misidentification of the concept of the sustainable development by the stakeholders is the prevailing key dispute (Williams *et al.*, 2007; World Bank, 2012). Further, misidentification of procurement law and negative attitude of the procurement officers are also identified as major challenges and gaps (Williams *et al.*, 2007). Accordingly, administrative remedies have been identified by the funding agencies and government with consideration and awareness of environmental protection and social laws to address the existing challenges and gaps of the Public PP.

Hence literature revealed that number of challenges and gaps of the Public PP in construction industry as obstacles to provide the desired outcome of the stakeholders in Sri Lanka compatible with the global needs and requirements. Moreover, it was identified that the interest to upgrade the Public PP in construction industry has been increased by the stakeholders in line with the concept of sustainable development as per the global needs and requirements. Hence, majority of the literature found that sustainable development approach as one of the best remedial measure to bridge the challenges and gaps of the Public PP towards the development objectives of the country with the assistance of the funding agencies (Raymond, 2008; Williams *et al.*, 2007; World Bank, 2012).

4. SUSTAINABLE PUBLIC PROCUREMENT PROCESS (SPPP) IN CONSTRUCTION INDUSTRY

Sustainability means the capacity to maintain the entity, outcome, or process over the period of time. The concept of sustainability came to public attention after the 1972 based on the report of "Limits of Growth" that issued by the international think tank Club of Rome. In 1980 the world conservation strategy developed by the International Union for Conservation of Nature, in collaboration with United Nations Environmental Programme (UNEP) and World Wildlife Foundation, worked to make sustainability as a benchmark of international action. Accordingly, World Summit on Sustainable Development (2002) first time officially disclosed to the world the sustainable procurement as the process that promotes policies encouraging development and diffusion of environmentally sound goods and services. Further author recognised definition of sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Moreover, SPPP identified by Walker and Brammer (2009) acquire goods works and services for the organisation in line with the fulfilment of human needs with the protection of the natural environment so that these needs can be met not only in the present, but in the indefinite future. More broadly authors emphasised that the SPPP encompass triple bottom line policy areas of economic, environmental and social.

The procurement actions in order to achieve desired outcome of the organisation and country are the same on both sustainable and existing procurement process (Interagency Procurement Working Group, 2006). Mc Crudden (2004) argued that existing procurement process has drawn special attention on the dimensions of cost, quality and time than social, environmental and economic in order to achieve the value for money. However, Williams *et al.*, (2007) highlighted that the new trends to upgrade the Public PP in construction industry have been increased by the stakeholders as the global population is increasing and consequently the consumption rates per capita are also growing. Therefore, human consumption of resources significantly exceeds what the earth can provide. Further, essential services such as clean air and water, a stable climate and viable forests and fisheries are in long-term decline. The resources on which rely are being depleted at accelerating rates. Furthermore, authors stated that range of social, environmental and economic objectives can be delivered through the enhancement of the existing Public PP.

Clement *et al.* 2007 explained that the governments should take the full range of economic, social and environmental costs and benefits of public procurement into account for the sustainable improvement of the economy. Further authors emphasised that incorporation of sustainability concerns to the activities of the existing procurement system is one of the way to bridge the gap that identified by developed countries in line with the principles of sustainable development. The SPPP identified as most accepted method to address the issues and deficiencies in the existing Public PP (Interagency Procurement Working Group, 2006). Further, application of sustainability concerns to the current Public PP leverage the benefits for major regional and urban infrastructure projects.

Hence, the main benefits from sustainable procurement can be summarized as: controlling costs by adopting a wider approach to whole life costs, achieving internal and external standards complying with environmental and social legislation, managing risk and reputation of the organisation creating new, vibrant markets ensuring security of sustainable supply for the future ensuring maximum community and financial benefits (Interagency Procurement Working Group, 2006).

5. CONCEPTUAL FRAMEWORK TO THE SUSTAINABLE PUBLIC PROCUREMENT PROCESS IN CONSTRUCTION INDUSTRY

The SPPP identified as one of most accepted method to address the issues and deficiencies in existing Public PP of the developing countries (Interagency Procurement Working Group, 2006). Moreover the construction industry explored as an open system, hence, which is very sensitive to change with the needs and requirements of the stakeholders; further, its characterization throughout the world is determined by the operating external environment, which consists of subsystems such as economic, political, financial, legal and technological. This has leaded the industry to be in a challenging state in addressing the changes forced by the subsystems in an efficient and effective manner. Thus, the construction industry in Sri

Lanka is striving to tackle these changes through the new and innovative ways of construction, efficient resource utilization and better organisation of project activities. Consequently, activities of the Public PP in the construction industry are also subject to changes resulting in many newly innovated activities and systems in line with global requirements (Turin, 1973; Rameezdeen, 2002).

Development of the conceptual framework is a challenging roll with the identification of the previous research (McGaghie *et al.*, 2001). However, the author added that identification of the findings of the previous researches facilitate to understand the coherent set of ideas and opinions or main areas that to be considered for future studies. Accordingly the researcher found that the Office of Government Commerce (2007) defined the framework for sustainable construction procurement lifecycle since before identify the business needs up to construction management and disposals. Further the researcher explored that what should be considered in each and every stage of the procurement process of the SPPP as defined by the Office of Government Commerce (OGC). Furthermore, the author investigates that why should be considered those stages and areas in line with the framework of the OGC.

Accordingly, the researcher has opportunity to develop the study by focussing the subject areas and boundary (Miles and Huberman, 1994). Moreover, Rameezdeen (2002) described the framework for the construction procurement in line with the identified five (05) numbers of significant stages of Conceptual, Planning, Tendering/ Purchasing, Implementation, and Closeout. Further, the author added that each stage of the procurement process has significant value in order to achieve the desired outcome of the stakeholders. Hence, special attention has been drawn to the each and every stage of the procurement process with due consideration of the relationship of all the five stages. The Figure 1 illustrates the process adopted to develop the conceptual framework for this study.

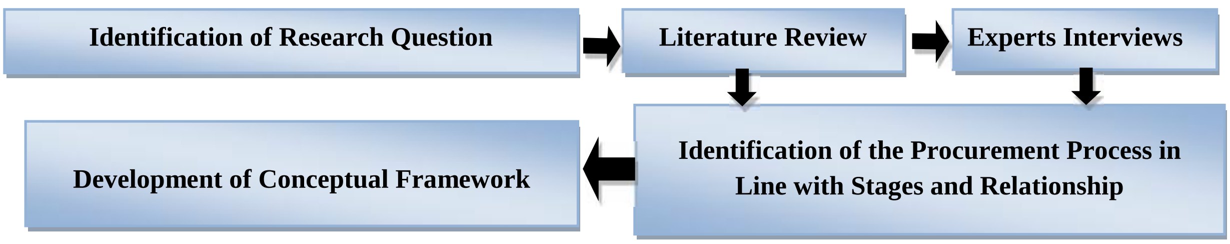

Figure 1: Procedure Followed to Develop the Conceptual Framework

Subsequently, through the critical literature and opinions of the experts identified that the SPPP as best remedial measures to the challenges and gaps to the Public PP and bridge the gaps in Sri Lankan construction industry as a developing country to achieve broader sustainable development objectives. The details of the experts who involved for the expert opinion survey are given in following Table 1.

Table 1: Selection of Experts

Field No	Selected Source of The Experts	Numbers of Experts
01	Funding Agencies (World Bank, Asian Development Bank, Japan International Cooperation Agency)	03
02	Government institutions (Ministries, Authorities, and Department)	03
03	Non-Governmental Organisation (NGO)	01
04	Private Organisations	03
	Total Numbers of Experts	**10**

Content analysis and cognitive mapping were used to analyse the data. Then integrate the sustainability concerns to the stages of the current Public PP in order to address the gaps identified in the selected areas through the findings and the experiences of the above experts in the field of the procurement. Consequently, the framework developed to integrate the sustainability concerns to the significant stages of the Public PP. Finally, further interviews with key experts in the field of procurement were conducted to analyse feasibility, applicability, potential benefits, main incentives, and key challenges and gaps of the conceptual framework in order to calibrate the framework to the Sri Lankan context.

5.1. *KEY FINDINGS OF THE LITERATURE AND EXPERTS INTERVIEWS*

5.1.1. CHALLENGES AND GAPS OF THE PUBLIC PP AND REMEDIAL MEASURES

As mentioned in previous section of the paper not only there are numbers of challenges and gaps to upgrade the existing Public PP, but also there are numbers of remedial measures available for those challenges and gaps. Further, integration of the sustainability concerns to the Public PP are identified as one of practicable remedial measure to bridge the gap of the existing Public PP.

Majority of the literature revealed the challenges and gaps to the procurement process. However, lake of information is available related to the significant stages of the Public PP in Sri Lankan construction industry. Thus, the expert interviews were conducted to gather the findings to identify the relationship and significant of the stages of the Public PP in Sri Lankan construction industry. Hence, in addition to the comprehensive literature review the unstructured expert interviews were conducted with the four numbers of selected experts in the field of public procurement to gather the data and information related to the procurement process with the special attention on the significant stages of the Public PP in Sri Lankan construction industry in order to identify the conceptual framework and feasibility of the framework with attention to the identified gaps of the significant stages of the Public PP. The findings are summarised in Table 2.

Table 2: Challenges and Gaps of the Public PP

Challenges and Gaps Identified Through the Literature	Challenges and Gaps Identified through the Opinions of the Experts
• High cost involvement.	• High cost involvement.
• Lack of support by the top management and policy makers. • Fraud and corruption involvement and negative attitude of the officers. • Misidentification of the concept of sustainable. development and relevant rules and regulations in Public PP.	• Lack of commitment of the stakeholders. • Lack of educational qualification and professional experience of the key players in the Public PP. • Fraud and corruption involvement and negative attitude of the officers.
• Not continuation of national strategy.	• Not continuation of national strategy. • National platform not exist to coordination and promote the Public PP. • Poor coordination between the organisations and government.

Further, through the interviews examined what is required as a prerequisite or enabling condition for sustainable public procurement in Sri Lanka as a developing country? Major emerging issues refer to the country context including the capacity needed to plan, manage, implement and account for the results of the sustainable procurement process policies and programs as well as linkages to development cooperation and generic principles of change management with due attention to the each and every stages of the Public PP. Further following remedial measures have been highlighted by the experts.

5.1.2. INFLUENCE OF THE PROCUREMENT GUIDELINES AND MANUALS, AND FINANCIAL RULES AND REGULATIONS AS REMEDIAL MEASURES TO THE CHALLENGES AND GAPS

The interviewees stated that at present, there is no regulatory body other than the Ministry of Public Finance for directly responsible to the procurement process of the country, procurement guidelines and manuals, and financial rules and regulations in Sri Lanka after the National Procurement Agency (NPA) had been dissolved and which absorbed to the Ministry of Public Finance. However, the procurement guidelines and manuals and financial rules and regulations of the donor funding agencies should be followed to disburse the foreign funds that granted for specific construction projects in Sri Lanka. Therefore, that will facilitate to integrate the vision and mission of the organisation in line with short term national targets. Hence, those could be considered as positive reactions towards the SPPP. In addition, experts added that the Institute of Construction Training and Development (ICTAD) and Institute of Engineer's in Sri Lanka (IESL) play assistance role in order to facilitate to streamline the procurement activities in construction industry. Specially, the ICTAD has concern to formulation and enhancement of the documents involved for the activities and actions on construction industry. Further, the IESL has given more weight age to the experts who involves to the procurement actions in construction industry establishing the code of ethics for the officers mentioning that the Engineers shall hold paramount the health, safety and welfare of the public and proper utilization of the funds and other resources in the performance of their professional duties.

5.1.3. Involvement of Short Term Target of the Government of Sri Lanka and Donor Funding Agencies as Remedial Measures to the Challenges and Gaps

As per the interviewees the main concern of the Ministry of Public Finance is monitor and administer the procurement activities in order to facilitate to achieve the sustainable economic development of the country in line with the short terms economic targets and to expedite the future economic development of the country to become an economic hub and one of fastest growing economy in the Asian region towards the target of US$ 7000 Per Capita income by 2020. Accordingly, procurement guidelines and manuals and financial rules and regulations of the developed countries and the donor funding agencies try to increase the sustainability concerns in each and every stages of the Public PP to the Sri Lankan construction industry in order to bridge the gaps and achieve the desired outcome of the stakeholders in line with the global needs.

Accordingly, through the expert interviews revealed that;

- Ministry of Public Finance is the authorised regulatory body in Sri Lanka which responsible for procurement activities in construction industry,
- The ICTAD and IESL provide assistance to streamline the procurement activities in Sri Lankan construction industry,
- Existing Public PP given more weight age to the dimensions of Time, Cost, and Quality than the dimensions of Social, Environmental, and Economic,
- Main Challenges and gaps to upgrade the procurement process are high cost involvement, lack of knowledge and experience, and not follow the national strategy,
- Donor funding agencies willing to grant technical and financial assistance to upgrade the existing Public PP in order to achieve the requirement of the stakeholders in line with the global needs.

5.2. Conceptual Method for Sustainable Public Procurement Process (SPPP)

Thus, as a revealed through the opinions of the experts, a generic model to mainstream the SPPP is presented. The model is based on a root cause analysis on identified challenges and gaps of the stages of Concept/ Initiation, Planning, Tendering (Purchasing), Implementation, and Closeout in the procurement process. Further, the experts pointed out that the assessment and prioritization of the suitability dimension shall be given in line with the identified challenges and gaps to achieve the stated objectives on each and every stage of the Public PP. The model focuses on mainstreaming issues at the national and the organisational level. Moreover the experts pointed out the major recommendation on the objectives and management approaches at the national level such as comprise awareness rising, the development of agreed set of sustainable procurement process benchmarks, strategic planning and implementation processes that are adapted to the country situation as well as global needs in line with the requirements of the stakeholders.

The recommended actions by the experts aiming at establishing a national SPPP framework are further broken down to the organisational level or the level of the individual procuring entity. The proposed actions at this level focus on the design and implementation of a strategy to embed sustainable public procurement in daily procurement practices. The SPPP is the core of this analysis as illustrate in Figure 2.

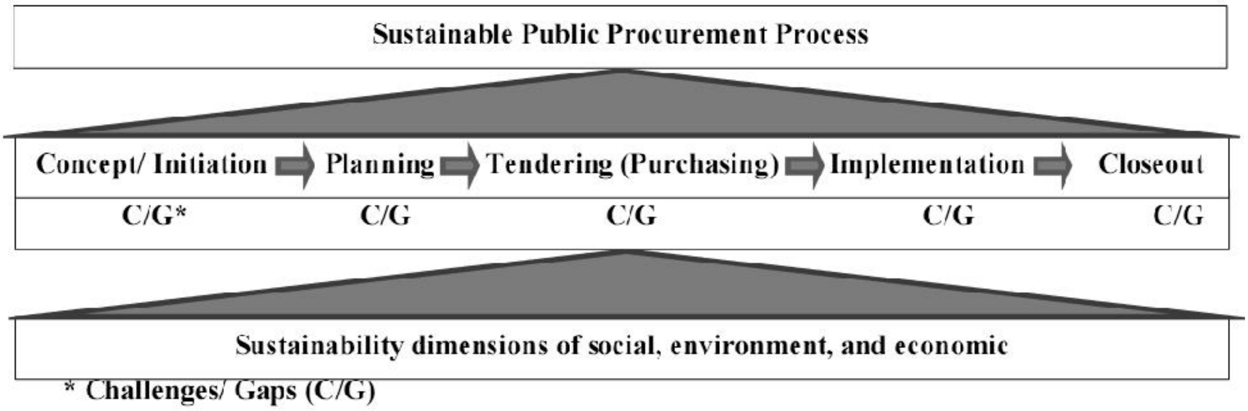

Figure 2: Sustainable Procurement Process to the Sri Lankan Construction Industry

5.2.1. CONCEPT STAGE

The activities of the procurement lifecycle are identified and initiated by the Procuring Entities (PE) in this stage. At this stage the PE is established and employed staff to carry out the procurement activities. Accordingly, the PE takes action to define objectives, scope, purpose and deliverables of the procurement process. However, the experts in the view that high cost involvement, lack of commitment of the stakeholders, lack of educational qualification and professional experience of the officers in the Public PP, and vision and mission of the organisation not link with the national strategy are the significant challenges and gaps available in this stage. Further, experts added that Sri Lankan national policy depends on short term political targets. Moreover experts noted that these challenges and gaps negatively affect to deliverables of the procurement process. Hence, at this stage the framework is focused to integrate sustainability concerns to these identified challenges and gaps of the activities of the initial stage of the procurement process. The remedial measures noted by the experts summarised as; formulate the independent national platform to streamline the activities in Public PP in line with the global needs to monitor and control the procurement activities, the vision and mission of the organisations shall be established in line with national strategy, establish International Organisation for Standardization (ISO) for the Sri Lankan context for the elements of social, environmental, and economic (ISO 14000 for Environment management system), change the mind-set of the stakeholders towards sustainable development, and design should be focused on principles of sustainable development.

5.2.2. PLANNING STAGE

This stage involves create set of plans to guide the procurement activities. The procurement plan will facilitate to the PE to ensure to procure the right quality products at the right time under the least cost. The procurement plan defines the requirement of the PE, identify all the items that need to be procured and create sound financial justification for financial allocation. Though, the experts identified that Sri Lanka doesn’t exists firm development plan in link with the sustainable development of the country in line with global needs. Further, vision and mission of the organisations link with short term political target and not link with sustainable development of the country are also identified as challenges and gaps in this stage. Moreover experts added that lack of educational and professional qualification and experience of the officers are also the prevailing challenges. Hence, in the planning stage attention is given to improve and enhance the sustainability concerns as remedial measures to these identified challenges and gaps of the activities of the procurement process by developing research and development in sustainable construction, enhancing education and awareness on sustainable development, and linking the vision and mission of the organisation towards national strategy.

5.2.3. TENDERING (PURCHASING) STAGE

All the procurement action leads to select the best supplier, contractor, and consultant at the right time with the optimum cost to the PE in this stage. Preparation of bidding/ tendering document, invitation of bids, evaluation of bids, selection of lowest evaluated substantial responsive bidder to award the contract are the main activities of the tendering stage. Further, the procurement officers try to identify, monitor and control the relationship with the supplier, contractor, and consultant as per the rules and regulation specified in the procurement guideline and manuals. However, the experts pointed out that lack of knowledge, negative attitude, and fraud and corruption involvement are the main challenges and gaps available in this stage in addition to the high cost involvement. Hence, main attention is given to build the knowledge of the officers and relationship with the stakeholders in line with the aspects of the sustainable development and build the continue relationship with the previous actions from the conceptual and planning stage as remedial measures to the challenges and gaps of this stage. Further, experts pointed out that ISO should be considered as evaluation criteria of the bids, more weight age shall be given to the sustainable construction methodology while changing attitude of the stakeholders.

5.2.4. IMPLEMENTATION STAGE

This stage identified as longest stage of the procurement lifecycle that deliver the physical output of the procurement process. The range of management and monitoring techniques are used in this stage to manage and control the time, cost, quality, change, risk, issues, and communications. The procurement management review is carried out at the end of the implementation stage in order to ensure the deliverables. Further the milestone indicators of goods, works, and services are identified as scheduled at the end of the stage to ensure the successfulness of next stage. However, the experts noted that misunderstand and misidentification of the concept of sustainable development and procurement law of the officers are the significant challenges and gaps available in this stage. Hence, the actions are taken to observe and monitor the activities of the procurement process to link the sustainable development in line with global needs and enhance the knowledge of the stakeholders as a remedy to the available challenges and gaps such as; delegate the responsibility to the independent national platform to monitor and control implementation activities and upgrade the law of the country and rules and regulation related to the Public PP in line with the requirements of SPPP.

5.2.5. CLOSEOUT STAGE

The procurement documents are prepared in this stage guide to close the activities of the procurement process. Further the procurement actions are described that the objectives have been met and the deliverable handed over to the end-user. Therefore, the officers of procurement should ensure the all the actions of the procurement process are completed as per the contract agreement. Accordingly in this stage the post implementation actions are implemented to determine the success of the procurement activities and identify the lessons learned after the procurement actions have been closed. Though, the experts added major gaps of lack of knowledge and negative attitude of the officers should be addressed. Hence the experts proposed awareness, inspection and evaluation of the procurement actions on the sustainable dimensions of social, environmental, economics have been carried out in order to ensure the targeted outcome achieve or not as a remedy to the prevailing challenges and gaps.

Accordingly, the above Figure 2 illustrates conceptual framework for the SPPP considering stages of the Public PP that associate with sustainability aspects. Further try to build up the relationship between the stages of Public PP and try to figure out the relationship between the relevant stages and sustainability aspects. However the output of sustainable products can be identified as a result of involvement of the dimensions of economic, social, and environmental to the procurement process.

Therefore, existing Public PP in construction industry in Sri Lanka should give equal weight age not only to the dimensions of time, cost and quality but also to the dimensions of social, environmental and economical when acquisition of goods, works and services with consideration of value for money in line with the requirements of the stakeholders and the global needs (Interagency Procurement Working Group, 2006; Mc Crudden 2004; Williams *et al.,* 2007). Further experts pointed out that this is not new concepts however given equal weight to the all the dimensions of the Public PP. Finally the opinions of the experts in the field of procurement established the feasibility of the conceptual framework of sustainable procurement for construction industry.

6. CONCLUSION AND WAY FORWARD

The aim of this paper was to propose conceptual framework for sustainable procurement process for the construction industry in order to bridge the gaps of the existing Public PP in line with requirement of the stakeholders and the global needs.

As mentioned previously findings revealed that the Public PP has number of challenges and gaps to improve the system. Further through the literature it was identified that the SPPP as one of practicable remedial measure to address the challenges and gaps of the existing Public PP in Sri Lanka as per the previous experience of developed countries in line with the requirement of the stakeholders and the present global needs (Raymond, 2008; Walker and Brammer, 2009). Hence through the literature and the opinions of the experts in the field of procurement identified the conceptual framework for sustainable procurement process for construction industry with consideration of the dimension of social, environmental, and economic while carrying out the public procurement activities as a best practice in order to enhance the standard of living and economy of Sri Lanka. Further sustainable actions assist to expedite the achievement of short terms targets of the organisation and country in order to facilitate to achieve the sustainable development in line with the global needs and requirements (World Bank, 2010; Biller and Nabi, 2013; Murray, 2009; Larson, 2009).

This study limited to develop the conceptual framework for the SPPP to the Sri Lankan context. Accordingly, following recommendations are offered to the academic researchers to carry out and prioritise further researches;

- Implementation of proposed framework in local and national level.
- Applying proposed framework for the different industries other than the construction.
- Conduct in-depth analysis on each and every action of the significant stages of the Public PP in order to deliver the optimum output.

7. REFERENCES

Biller, D. and Nabi, I., 2013. *Investing in Infrastructure - Harnessing its Potential for Growth in Sri Lanka*. International Bank for Reconstruction and Development / The World Bank 1818 H Street NW, Washington DC 20433.

Central Bank of Sri Lanka, 2012. *Annual Report 2012.* Colombo, Sri Lanka: Central Bank of Sri Lanka (ISBN 978-955-575-260-2).

Erridge, A., 2007. An Assessment of Competitive Tendering using Transaction Cost Analysis. *Public Money and Management,* 1(3), 122-36.

Interagency Procurement Working Group, 2006. *UN Procurement Practitioner's Handbook*. Jiniva: Common Procurement Certification Scheme for the United Nations (UN).

Larson, P.D., 2009. Public vs Private Sector Perspectives on Supply Chain Management. *Journal of Public Procurement,* 9(2), 222-47.

McGaghie, W.C., Bordage G. and Shea, J.A., 2001. Manuscript Introduction: Problem Statement, Conceptual Framework, and Research Question. *Academic Medicine*, 76, 923- 924.

Miles, M.B. and Huberman, A.M., 1994. *Qualitative Data Analysis,* 2nd ed. London: Sage.

Murray, J. G., 2009. Improving the Validity of Public Procurement Research. *International Journal of Public Sector Management,* 22(2), 91-103.

National Procurement Agency, 2006a. *Procurement Guideline 2006 Goods and Works.* Level 22, West Tower, World Trade Center, Colombo 1, Sri Lanka: National Procurement Agency.

National Procurement Agency, 2006b. *Procurement Manual 2006 Goods and Works.* Level 22, West Tower, World Trade Center, Colombo 1, Sri Lanka: National Procurement Agency.

Office of Government Commerce (OGC), 2007. *Sustainability*, *Achieving Excellence in Construction Procurement Guide* [online]. Available from: http//:www.ogc.gov.uk/documents/CP0016AEGuide11.pdf [Accessed 10 May 2014].

Preuss, L., 2009. Addressing Sustainable Development through Public Procurement: The Case of Local Government. *Supply Chain Management*, 14(3), 213.

Rameezdeen, 2002. *Ethic Culture and its Impact on Construction*. In: Proceedings of Conference on Sri Lanka: Challenges Offer Society in Transition, Colombo: 16-18.

Rameezdeen, R. and Silva S.D., 2002. Trends in Construction Procurement Systems in Sri Lanka. *Built Environment, Sri Lanka*, 2(2), 2-9.

Raymond, J., 2008. Benchmarking In Public Procurement [online]. *An International Journal*. 15(6), 782-793. Available from: http//:www.emeraldinsight.com/1463-5771.htm [Accessed 10 May 2015].

Srivastava, S.K., 2007. Green Supply- Chain Management: A State-of-the-Art Literature Review. *International Journal of Management Review*s, 9(1), 53-80.

Turin, D.A., 1973. *The Construction Industry: Its Economic Significance and Its Role in Development*. 2nd Ed. London: University College Environmental Group.

Walker, H. and Brammer S., 2009. *Sustainable Procurement in the Public Sector: An International Comparative Study* [online]. Available from*:* http//: www.emeraldinsight.com/0144-3577.htm [Accessed 10 May 2014].

Williams, S., Chambers, T., Hills S. and Dowson F., 2007. *Buying a Better World: Sustainable Public Procurement* [online]. Available from: www.forumforthefuture.org/sites/default/files/.../buying-better-world.pdf [Accessed 10 May 2014].

Wold Bank, 2012. *Turning Sri Lanka's Urban Vision into Policy and Action*. Sri Lanka: The World Bank Colombo office, 73/5, Galle Road, Colombo 03.

World Bank, 2010. *Guide Lines Procurement under IBRD Loans and IDA Credits* [online]. Procurement Policy and Services Group. Available from: http://siteresources.worldbank.org/INTPROCUREMENT/Resources/e-GP.ppt. [Accessed 10 May 2014].

World Summit on Sustainable Development, 2002. *Plan of Implementation of the World Summit on Sustainable Development*, New York, NY: United Nations.

Zheng, J., Knight, L., Harland, C., Humby, S. and James, K., 2010. An Analysis of Research in to the Future of Purchasing and Supply Management. *Journal of Purchasing and Supply Management*, 13(1), 69-83.

CONSTRUCTION AND DEMOLITION WASTE RECYCLING: THE CASE OF CONSTRUCTION WASTE MANAGEMENT (COWAM) PROJECT

I.G.T. Samarasingha* and Gayani Karunasena
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction waste in general consists of both waste generated by construction as well as demolition. Disposal of demolition waste is becoming a growing problem which became evident after the Indian Ocean Tsunami in 2004, particularly in Sri Lanka. Management of these wastes came into picture with the establishment of a C&D waste recycling plant by the Construction Waste Management (COWAM) Project. With the development of construction industry, the question arises whether COWAM plant alone is capable of managing such waste. Thus, this paper presents recommendations to further improve the COWAM plant by expanding the same into other local areas. COWAM plant was selected as a single case study and data were gathered through semi-structured interviews. It revealed lack of funds to establish recycling plants and infrastructure and unavailability of a proper C&D waste management policy in Sri Lanka as major problems. Taking contracts to demolish buildings and increasing the number of productions are the most important recommendations to improve the COWAM plant. Further, allocation of requisite budget for infrastructure and public awareness is recommended to enhance the COWAM concept in Sri Lanka.

Keywords: *Construction & Demolition Waste; COWAM Plant; Waste Management; Waste Recycling.*

1. INTRODUCTION

When considering construction and demolition (C&D) waste, generally it is defined as solid waste that arises from construction, renovation and demolition activities (Lu *et al.*, 2011). Hiete *et al.* (2011) added that C&D waste also includes by-products generated during reconstruction activities of structures such as buildings, roads and bridges. With reference to those major activities, different authors have classified C&D wastes into categories associated with the stages of construction projects such as contracting, design, procurement, transportation, material handling, on-site management and operations, and residuals or demolitions (Kulatunga *et al.*, 2006; Osmani *et al.*, 2008). Among them, when considering the amount, demolition waste takes the first place since it removes a whole structure. Thus, disposal of demolition waste is becoming a rising problem around the world and similarly in Sri Lanka (Senaratne and Wijesiri, 2008 cited Nagapan *et al.*, 2012).

Further, this became noticeable when Sri Lanka suffered from the Indian Ocean Tsunami in 2004, when disposing huge amounts of generated demolition waste became a major issue (Karunasena *et al.*, 2012; Interim Report of COWAM Project: Vision for 2018, 2008). Therefore, with the crisis at the aftermath of the Tsunami 2004, finding a method for sustainably managing C&D waste become critical in Galle, which was a severely affected city in Sri Lanka by the Tsunami, destroying more than 15000 houses. Thus, during the period of 2005-09, the Construction and Waste Management (COWAM) project, which was funded by the European Union (EU), came into picture as the most sustainable way to deal with C&D waste generated (Karunasena *et al.*, 2012). The project consisted of a C&D recycling plant called the 'COWAM Centre' to recycle most of such wastes (Interim Report of COWAM Project: Vision for 2018, 2008). However, with the development of construction industry, as more demolition wastes are generated, the question arises whether COWAM alone is capable to manage all such waste. Thus, it creates a need to realize the ways and means of improving COWAM project for the betterment of Sri

* Corresponding Author: E-mail - thisaraqsqs@gmail.com

Lankan construction industry. Therefore, aim of this study is to explore suggestions for further improvement of COWAM plant to expand it into other local areas, through four objectives, namely, (1) reviewing current C&D waste recycling practices (2) identifying strategies and practices of recycling C&D waste materials and their reuse in COWAM project (3) determining barriers to expand COWAM plant and (4) determining probable suggestions to extend the COWAM concept into other local areas of Sri Lanka.

Accordingly, research was confined to C&D waste management strategies applied in other countries with special emphasis on current situation in Sri Lanka. COWAM plant was selected as the case of the study to reveal issues of C&D waste management, since it is the only recorded C&D waste recycling plant in Sri Lanka. Further, probable suggestions were identified through literature and expert opinion to enhance the COWAM concept into other local areas. Forthcoming section illustrates findings of literature regarding C&D waste management practices in the world with special emphasis on Sri Lanka.

2. LITERATURE REVIEW

2.1. CONSTRUCTION AND DEMOLITION WASTE RECYCLING: GLOBAL PERSPECTIVE

Construction industry is identified as not environmentally friendly, since construction activities not only consume a large amount of natural resources, materials and energy, but also generate unacceptable level of solid wastes (Yuan *et al.*, 2011; Rameezdeen, 2009). Thus, it is recognized worldwide that construction activities have an effect on environment; where nowadays, C&D waste management is an emerging discipline that has attracted extensive attention of the world (Yu *et al.*, 2012; Lu *et al.*, 2011). Waste management is identified as any technique or procedure which avoids, eliminates or reduces waste or allows reuse or recycling for benign purposes (Sustainable Construction, 1994 as cited in Tam, 2010). Although C&D waste management process can be categorized into several stages, Teo and Loosemore (2010) argued to divide the total C&D waste management process in to two as; (1) reducing wastes and (2) managing unavoidable wastes. Reduction is considered as the most effective and efficient strategy, however, it is not fitted with unavoidable waste, such as demolition waste which needs to be managed through either 'reuse', 'recycling' or 'disposal' (3Rs principle) (Tam and Tam, 2008; Teo and Loosemore, 2010). Among them, since recycling has twin benefits of material/ energy conservation and reduced disposal efforts (Sushil,1990), many countries made great efforts to increase C&D waste recycling to reduce massive amounts of waste and conserve natural aggregate resources (Hiete *et al.*, 2011). Recycling generally refers to use of undesirable outputs or wastes as input in the same process or system, or from one process/ system as input to some other process/ system as a raw material or for generation of power or by-products (Sushil,1990).

The global contribution of C&D waste to total waste generation during the last decade differed considerably among countries, from Japan (36%) and Germany (19%) to the United States (29%), Hong Kong (38%), Australia (42%), the UK (50%) and Spain (70%) (Tam, 2010; Tam*et al.*, 2007; Fischer and Werge, 2009 cited Hiete *et al.*, 2011). Further, it was about 15% in Brazil, 20-50% in Denmark and 25% in France (Yu *et al.*, 2012). Among them the majority ends up in landfills, in uncontrolled sites or in other inappropriate places around the world (Llatas, 2011). Due to this common practice, number of impacts on environment, including pollution of air, surface water and underground water, risks to public health and loss of natural resources were identified within last decades, thus disposing of construction waste in landfills is identified as both economically and environmentally costly, wasting both natural resources and valuable landfill spaces (Llatas, 2011; Rameezdeen, 2009). Meanwhile, in some countries there is considerable pressure to encourage recycling due to their own factors, such as in Taiwan due to shortage of raw materials and in Hong Kong due to limited landfill areas (Huang *et al.*, 2002; Tam and Tam, 2007 cited Hiete *et al.*, 2011). Further, as European Parliament (2008 cited Llatas, 2011) stated, the new European challenge is to achieve a minimum of 70% reuse, recycling or other material recovery by weight of C&D waste by 2020 in EU member states. Because, it is estimated that about 20 % of the total material requirement for construction industry could be met by reuse/ recycling of materials, although this percentage will vary from industry to industry (Sushil, 1990). As identified by Franklin Associates (1998 cited Llatas, 2011), one of the main barriers to achieve such objectives is that, in spite of C&D waste having long been a worldwide priority, there is still insufficient knowledge about this waste stream. It was known that a major part of C&D waste is generally inert, and therefore, may not pose an environmental threat as great as hazardous waste or typical municipal solid waste (Wang *et al.*, 2004). This feature has precisely meant that they have not been controlled in many regions with respect to other waste streams, which has resulted in lack of data and statistics on this waste flow. In the US, for example, a recent study indicates that actual amount of C&D debris generated is unknown (Cochran and Townsend, 2010). In Europe, most data available today is extracted from a study undertaken by several European consultants for the European Commission in 1999 (Symonds, 1999 cited Llatas, 2011). In addition, in Spain the current National Plan of Construction Waste recognizes that it has not been possible to determine an exact figure for annual production of C&D waste due to lack of reliable statistics (Spanish Government-Ministry of the Environment, 2009).

2.2. CONSTRUCTION AND DEMOLITION WASTE RECYCLING: SRI LANKAN CONTEXT

After the Indian Ocean Tsunami of 2004, Sri Lanka faced issues such as high accident risks to pedestrians, traffic jams in already congested cities and obstructions to drainage systems, creating flash floods during monsoon and mosquito breeding grounds due to illegal dumping of C&D waste on vacant lands or road sides (Interim Report of COWAM Project: Vision for 2018, 2008). However, due to some factors such as arrival of many current landfills at full capacity, high costs to establish landfills with adequate environmental protection, public resistance to construction of local landfills, an increased interest in reducing demand for natural resources while creating a sustainable construction industry and hazardous materials contained, land filling is becoming less desirable in Sri Lanka (Jeffrey, 2011; Rameezdeen, 2009). Further, due to scarcity of vacant lands, collection and disposal issues, solid waste management became an environmental, social as well as political issue in Sri Lanka (Jayaratna, 1996; Anji, 2009 cited Karunasena and Amarathunga, 2010). However, as Nitivattananon and Borongan (2007) noted most Asian countries including Sri Lanka do not have specific goals or regulations designed for C&D waste management, although some countries include some sections in their solid waste management regulations and/ or related policies. Currently, existence of regional and national policies, laws, and regulations governing 3R principles (Reduce, Recycle, Reuse) for C&D waste is minimal in Asia. For instance, Nitivattananon and Borongan (2007) stated that, in Sri Lanka reuse and recycling such as door frames, cabok (laterite brick) is practiced up to some extent. In addition, Sri Lankan reuse and recycling industry is limited to demolition contracts only and no process wastes are being taken for reuse and recycling (Rameezdeen, 2009). Materials which are recycled in Sri Lanka and their reusable rates, according to a study done by Rameezdeen in 2009, is shown in Table 1.

In this case, development of COWAM Centre – for environmental education and information resource, awareness raising of construction waste, involvement and participation of citizens or Non-Governmental Organisations in the strategy building, dissemination of information to public tried to fill the gap of proper construction waste management procedure in Sri Lanka (Rameezedeen, 2009).

Table 1: Average Recovery Rates of Materials

Material	Reusable Rate After Recycling (%)
Door Frames	100
Window Frames	100
Brick	75
Cabok (Laterite brick)	95
Roof Timber	100
Asbestos Roofing Sheets	100
Zinc Alum Roofing Sheets	20
Cali cut Roof Tiles	85
Ceiling Panels	75
Rain Water Gutters	75
Rain Water Down Pipes	50

Material	Reusable Rate After Recycling (%)
Toilet Fittings	75
Ceiling Fans	25
Concrete Grills	40
Timber Stair case Handrails	50
Steel Gates	65
Stone Paving Blocks	55
Door sashes	100
Reinforcement Bars	11
Floor and Wall Tiles	5

Source: Rameezdeen (2009)

2.3. CONSTRUCTION WASTE RECYCLING PROJECT: COWAM CENTER, GALLE

Within this attempt, construction waste management is considered under the theme of Solid Waste Management (SWM) in Sri Lanka (Ogola *et al.*, 2011). As Karunasena and Amarathunga (2010) stated, basic legal framework required for solid waste management in Sri Lanka is provided under Government, Provincial Council and Local Authorities' regulations and legislations. Following the disastrous Indian Ocean Tsunami of 2004, disposing of C&D waste become a critical issue in the hard hit coastal belt of Sri Lanka (Rameezdeen, 2009). Within this background the COWAM project was initiated to manage C&D waste in Sri Lanka. The project was started as a pilot construction recycling plant (COWAM Newsletter, 2009). Started in January 2006, the project was due to end in June 2009. COWAM was funded through the EU-Asia Pro Eco II B - Post Tsunami Program and was led by the TuTech Innovations GmbH of Hamburg, Germany. The project partners in Sri Lanka were the Galle Municipal Council and University of Moratuwa (Interim Report of COWAM Project: Vision for 2018, 2008).

Basically, the idea of COWAM came up due to a wide range of environmental and economic problems in the Galle Municipality and its citizens, ranging from water pollution to dengue mosquito breeding to traffic accidents by inappropriate management of C&D waste (COWAM Newsletter, 2009). Therefore, with the experience of huge amount of C&D waste management, the COWAM project looked at most appropriate ways to deal with C&D waste within Galle Municipality (Karunasena *et al.*, 2012). Further, the COWAM center had a vision for 2018, which includes several goals such as increasing the number of recycling plants in Galle up to five (05), increasing the number of employees up to fifty (50) and the number of marketable recycled products from 10-15 (Rameezdeen, 2009). Moreover, there was an ultimate goal to make the Galle COWAM project a model for other local authorities. However, it can be observed that the idea of COWAM has not spread throughout Sri Lanka as expected at the beginning. Thus, the COWAM centre in Galle has become the only recorded C&D waste management plant in Sri Lanka.

3. RESEARCH METHODOLOGY

The aim of this study was to carry out an in depth investigation on C&D waste recycling strategies and practices in the COWAM project to recommend approaches to expand C&D waste recycling in Sri Lanka. Case study method was proved to be the most appropriate, as it provides access to real-life context of C&D waste generation, collection and handling (Yin, 2009). It provides a rich data set based on experiences and explanations of people and organisations involved. Further, it has the ability to test existing theories or concepts. Within this study, a single case study was selected namely, COWAM Center, as it is the only recorded C&D waste recycling plant in Sri Lanka. To collect data, interviews, documentation and direct observations were conducted. Altogether three interviews were conducted due to lack or personnel related to the COWAM Center Management Process. The three personnel were expertise respectively in Recycling process within the COWAM plant; Process management at COWAM Center; and Solid waste management at Galle Municipal area. Duration of these interviews varied from 30 to 45 minutes, conducted in Sinhala language, and recorded with the permission of interviewees.

Further, direct observations of COWAM plant site, recycling process and waste collection were conducted. Documentation was done using records and documents available at the plant to further verify the data collected through interviews and observations. Code-based content analysis technique was used to analyse the data using QSR. NVivo- version 7.0.281 (Copyright © 2007 QSR International Pvt Ltd.) software. In addition, cognitive mapping was used for proper data displaying, using the same computer software. Findings from the case study are discussed in the following section.

4. RESEARCH FINDINGS

Findings revealed that Sri Lanka is at a primary stage of C&D waste management approaches and there is no specific policy on C&D waste management. Thus, it is treated as a part of existing solid waste management policy. Ascertaining that, the interviewee 2 said "we have a general solid waste management policy, but not specifically for C&D waste. Therefore, there is no island wide accepted procedure to handle the C&D waste." C&D waste management signifies a new requirement in Sri Lanka with the development of construction industry and limitation of vacant lands.

Following sections discuss research findings of study on broad headings such as existing practices in C&D waste recycling in COWAM project, barriers to improving COWAM project and probable suggestions to enhance COWAM concept in Sri Lanka.

4.1. EXISTING PRACTICES IN C&D WASTE RECYCLING IN COWAM PROJECT

For recycling, only demolition wastes are considered at the COWAM plant. Although wastes are not collected according to types, mostly collected waste is concrete fragments while rubble is collected rarely. Among demolition wastes, ceramic products are not recycled at the plant due to handling difficulties of crushed output. An average amount of 1850 m^3 of demolition wastes are collected at the plant annually. C&D waste amounts taken to recycle by the COWAM plant within last six years are shown in Figure 1.

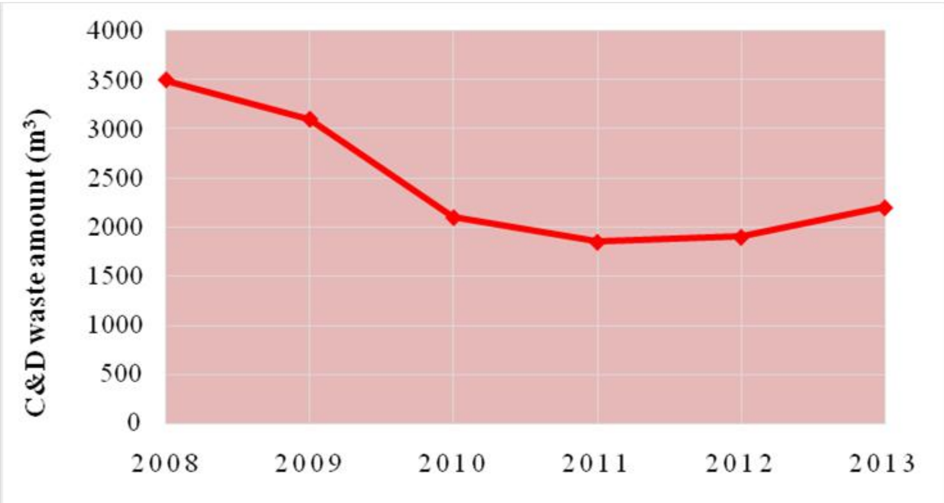

Figure 1: C&D Waste Amounts Taken to be Recycled at The COWAM Plant

Then, sorting of debris is done manually at demolition sites to separate bulk fragments and mixed waste. The wastes are transported to the plant and stored until recycled. There is adequate space for waste storing at the site of the plant. Recycling may or may not be done on the same day the waste is transported to the plant. Crushing waste materials and making entirely new items by those crushed output is the recycling process adopted within the COWAM plant. When there are larger sized waste fragments, those are needed to be made into 225x150mm size or smaller than that to feed the crushing plant as shown in Figure 2.

Figure 2: Concrete Fragments: Original Size and Hand Broken Fragments

According to direct observations, making large sized particles into smaller fragments is done manually. As the output of recycling process, it produces aggregate sizes 37.5 mm, 25mm, 19 mm, chips and sand within the plant. This output was observed as 1/3 of total waste collected. With the use of those, further they produce cement blocks and interlocking for pavements, from year 2010 onwards (See Figure 3: Productions of recycled aggregates: Interlocking and cement blocks).

Figure 3: Productions of Recycled Aggregates: Interlocking and Cement Blocks

When considering amounts of production, it was recorded that about 2000 m^3 of waste is adequate to produce 5500 cement blocks. Figure 4 illustrates the annual production of cement blocks and interlocking blocks against annual aggregate production and annual C&D waste collection.

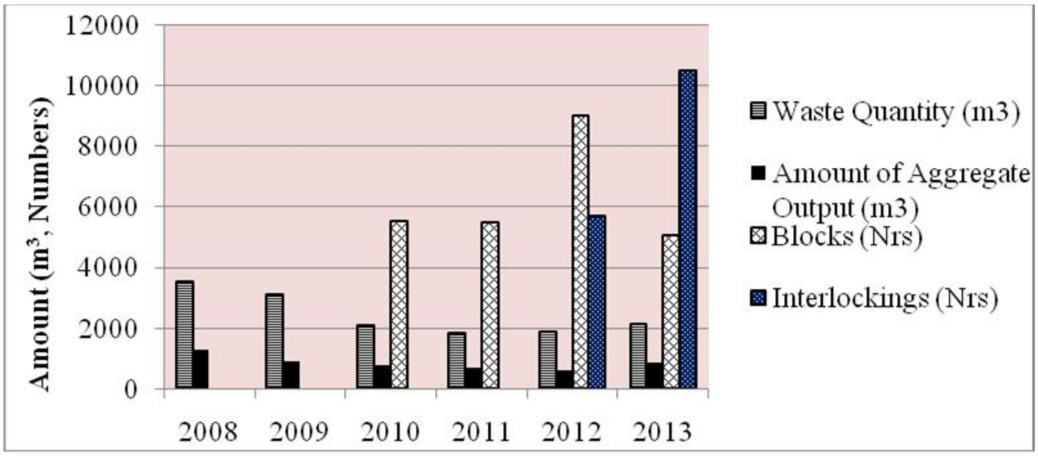

Figure 4: Annual Production against Annual Output of Aggregate and Collected Waste

The strength of those blocks have been measured through several experiments done by researchers and found that the compressive strength of blocks developed using crushed demolition waste is greater than that of conventional blocks.

4.2. PREVAILING BARRIERS TO IMPROVE THE COWAM PROJECT

Issues and barriers to improving the COWAM plant need to be better evaluated as it is more logical to consider those factors to enhance the COWAM plant to provide a better service to the country.

When considering the current situation of the COWAM plant, it was identified that there are no limitations regarding man power or skills required for the process of recycling. Meanwhile, according to empirical data, there are several issues exists such as insufficient amounts of waste received by the plant, difficulties of recycling waste in rainy days due to limited number of shelters, lack of public awareness on usability of demolition waste and lack of awareness on problems associated with illegal disposal of waste. There are further barriers related to existing practices that need be addressed through policy improvements and government support. In addition to lack of waste coming into the plant, there are some issues with financing the improvements needed at the COWAM plant. Thus, according to the interviewee 2, it is the basic reason for deviation of current situation of the plant from the objectives set in 2008. Ineffective government procedures, less government commitment, absence of a proper market identified for recycled products and absence of specific guidelines/ specifications or C&D waste management policy in Sri Lanka are further issues identified through the study.

Further, to overcome identified barriers and enhance the COWAM concept, recommendations were listed and they were discussed under two basic categories such as ‘Recommendations on improvements of the project’ and ‘Recommendations on enhancing the concept into local area of Sri Lanka’.

4.3. RECOMMENDATIONS ON THE ENHANCEMENT OF COWAM PROJECT

In order to mitigate issues identified in existing C&D waste management procedures, several attributes can be recommended.

- ***Taking Contracts of Demolition, in Addition to Recycling***

In addition to collecting demolished debris, interviewee 1 recommended to put an advance step and take contracts of demolition of buildings. Further, the same respondent stated that “if we can take contracts of demolition of buildings, we can ensure that total amount of debris of demolished buildings come to us. In addition, we can separate debris in a proper manner and, reusable materials can be removed separately.”

- ***Introducing a Movable Crusher***

Though existing procedures of recycling available at COWAM plant is sufficient for current C&D waste amount, as interviewee 1 recommended, it can be enhanced to a more effective way of recycling waste if a moveable crusher can be introduced. Interviewee 1 expressed that “if we have a moveable crusher, then we can move the crusher to a demolition site, do the crushing at the site and transport the crushed output to the COWAM plant.” As he pointed out, then the wastage of demolition waste can be put to a minimum, making an effective recycling procedure.

- ***Mechanical Sorting Process***

As observed, sorting method used by the COWAM plant is simple sorting of C&D waste by hand. However, according to Tansel *et al.* (1994 cited Huang *et al.*, 2002) one critical factor that the profitability of recycling C&D wastes depends on is selected technology for recycling. Thus, a mechanical sorting process, which consists of five operational units, is another recommendation for the improvement of COWAM plant by interviewee 2. As he described, mechanical sorting includes bar screening, disk screening, magnetic separation, air classification and final manual separation, as shown in Figure 5.

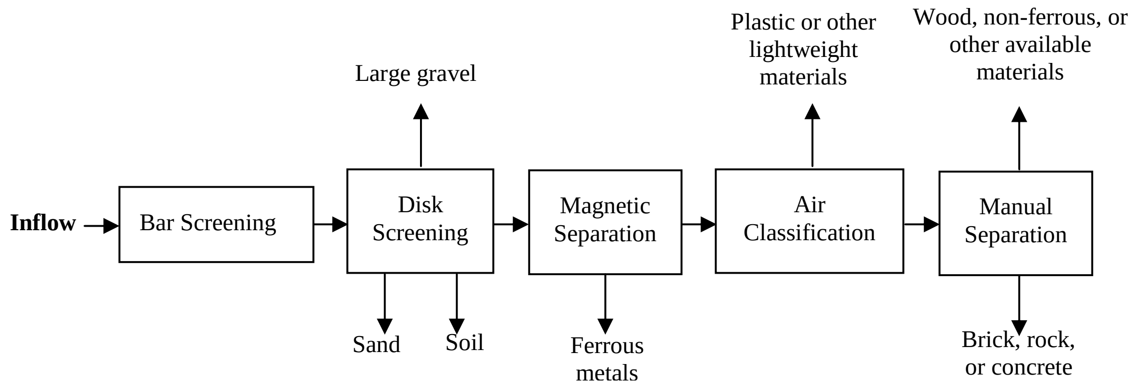

Figure 5: Mechanical Sorting Process of C&D Waste

Therefore, he further noted that if a mechanical separation method for sorting debris could be used, then the items of recycling outputs can be increased. As he mentioned, several countries in the world take advantage of such sorting processes of waste recycling, such as Taiwan, from the year 2000.

- ***Use Shadings for Storing the Collected Waste Until Recycling***

There are problems with waste recycling in rainy days. That is because in rainy days the efficiency of machine drops due to wetness of waste. Moreover, interviewee 3 indicated that in rainy seasons, the stored waste turned into a wet mixture making it difficult to be handled in a plant. Therefore, as recommended by all three interviewees, it is recommended to construct shades to cover waste piles.

- ***Increase the Number of Production Items***

According to interviewee 2 and interviewee 3, process can be expanded to produce decorative cement products such as garden furniture, concrete posts to strengthen fences, decorative load bearing concrete posts, etc. Then marketability may not be a problem, as such products have a good market demand being products that meet general requirements of people. Further, citing an example, interviewee 3 said "production at COWAM plant is also like clothing production by hand looms. If a place to sell the products of COWAM plant can be arranged, such as the "Laksala" for hand loom productions, then marketability can be achieved."

- ***Make Better Promotion of Productions Made out of Recycled Demolition Waste***

As described by interviewee 1, advertisements and other promotions can be used to inform people about products made by recycled materials.

4.4. RECOMMENDATIONS ON ENHANCING THE COWAM CONCEPT INTO LOCAL AREAS

- ***Legislation and Enforcement: Proper Waste Management Policy***

As described by interviewee 2, it is opportune to develop rules, regulations for C&D waste management and introduce a proper waste management policy in Sri Lanka, which will be helpful to spread the concept of COWAM into other local areas also. That is because, national legislation is essential for a C&D waste management system to function. It provides the legal framework to license land filling, impose a land filling levy, control handling of hazardous wastes and other activities related to C&D waste management, etc.

- ***Economic Incentives to Support the Market***

The most effective means to encourage reuse and recycling of C&D waste is to charge high taxes for land filling to discourage illegal waste disposal at landfills. Specially, this can be effective in urban and rapidly developing areas such as Colombo to reduce land filling.

- ***Information Exchange and Awareness Programs***

In order to improve the COWAM concept within other local areas, there is a need to exchange information and experiences, which takes place at workshops and seminars and through professional journals and newsletters of professional associations.

- ***Initiate Promotional Programs to Encourage Using Recycled Materials***

Government institutes such as ICTAD, SLS etc., should conduct promotional programs to encourage use of recycled materials for constructions and revise existing standards to facilitate such.

- ***Allocation of Requisite Budgets for Infrastructure***

Providing necessary capital and technologies by the government will be helpful to establish COWAM concept in other areas in the country.

5. CONCLUSIONS

This paper provides recommendations for further improvement of C&D waste recycling in Sri Lanka, based on the COWAM recycling project. Encountered main issues include limited finances available to the Galle Municipal Council to enhance this project and unavailability of proper C&D waste management policy in Sri Lanka. In order to overcome such issues, further recommendations were suggested, including; taking contracts to demolish buildings in addition to collecting debris, introduce a movable crusher to crush demolition waste at demolition sites, introducing products such as garden furniture, concrete posts to strengthen fences, decorative load bearing concrete posts etc. Allocation of requisite budget for infrastructure, which is required to implement a recycling plant and introduction of a proper C&D waste management policy were considered as recommendations to expand of the COWAM concept into other local areas.

5.1. CONTRIBUTIONS

This research unearthed a less considered side of construction industry; building demolition waste management. Although it is less considered by people involved in the construction industry, the researcher presented that there are opportunities to optimize sustainable use and management of demolition waste for an environmental friendly construction industry. Thus, the contribution of research to the construction industry can be listed as bellow.

- Construction industry generates an unacceptable level of solid waste, while consuming a large amount of natural resources, materials, and energy. In addition, most raw materials used in construction industry come from non-renewable resources. Therefore, for sustainable construction persistence, managing of waste generation must be considered.
- When considering the content of construction associated waste, demolition waste is at least double of it. Therefore, while considering construction waste management, demolition waste must be given the priority. Hence, implications of this research were mainly focused on identifying probability of managing demolition waste generation through waste recycling.
- Further, research findings revealed that recycling of demolition waste can generate entirely new products, which can be used for cost effective constructions. Therefore, improving the COWAM plant will be a vast saving of virgin materials in the country.

6. REFERENCES

Cochran, K.M. and Townsend, T.G., 2010.Estimating Construction and Demolition Debris Generation Using a Materials Flow Analysis Approach. *Waste Management*, 30(1), 2247–2254.

Galle Municipal Council, 2008. *Interim Report of COWAM Project: Vision for 2018*. Galle: Galle Municipal Council.

Galle Municipal Council, 2009. Optimizing the Sustainable Use and Management of Construction Waste in Sri Lanka.*COWAM-Newsletter* [online]. Available from: http://cowam.tec-hh.net/CowamNewsletter_5_internet.pdf [Accessed 26 May 2015]

Hiete, M., Stengel, J., Ludwig, J. and Schultmann, F., 2011. Matching Construction and Demolition Waste Supply to Recycling Demand: a Regional Management Chain Model. *Building Research & Information*, 39(4), 333-351.

Jayaratne, K.A., 1996. *Community Participation in Urban Solid Waste Management Case Study of Siddharthapura Low Income Settlement, Colombo, Sri Lanka* [online]. Available from: http://www.globenet.org/preceup/pages/fr/chapitre/partenai/h/wast.htm [Accessed 12 September 2013].

Jeffrey, C., 2011.*Construction and Demolition Waste Recycling: A Literature Review* [online]. Available from: http://inhabitat.com/a-craigslist-for-materials-helps-recycle-construction-waste [Accessed 15 September 2013].

Karunasena, G. and Amarathunga, D., 2010. Waste Management Strategies: Municipal Waste vs. Disaster Waste. In: *The Conference on Sustainable Built Environment*, Kandy 13-14 December 2010. 173-180.

Karunasena, G., Rameezdeen, R. and Amarathunga, D., 2012. Post-Disaster C&D Waste Management: The Case of COWAM Project in Sri Lanka. *Australasian Journal of Construction Economics and Building, Conference Series*, 1(2), 60-71.

Kulatunga, U., Amaratunga, D., Haigh, R. and Rameezdeen, R., 2006.Attitudes and Perceptions of Construction Workforce on Construction Waste in Sri Lanka. *Management of Environmental Quality – An International Journal*, 17(1), 57-72.

Llatas, C., 2011. A Model for Quantifying Construction Waste in Projects According to the European Waste List. *Waste Management*, 31, 1261–1276.

Lu, W., Yuan, H., Li, J., Hao, J.J.L., Mi, X. and Ding, Z., 2011.An Empirical Investigation of Construction and Demolition Waste Generation Rates in Shenzhen City, South China.*Waste Management*, 31, 680–687.

Ministry of the Environment, 2009.*Construction waste statistics*. Madrid: Spanish Government.

Nagapan, S., Rahman, A.I. andAsmi, A., 2012. Factors Contributing to Physical and Non-Physical Waste Generation in Construction Industry.*International Journal of Advances in Applied Sciences*, 1(1), 1-10.

Nitivattananon, V. and Borongan, G., 2007. Construction and Demolition Waste Management: Current Practices in Asia. In: *International Conference on Sustainable Solid Waste Management*, Mumbai 5-7 September 2007. National Solid Waste Association of India, 97–104.

Ogola, J.S., Chimuka, L. and Tshivhase, S., 2011. Management of Municipal Solid Wastes: A Case Study in Limpopo Province. *Integrated Waste Management* [online]. Available from: http://www.intechopen.com/books/integrated-waste-managementvolume-i/management-of-municipal-solid-wastes-a-case-study-in-limpopo-province-south-africa [Accessed 12 September 2013].

Osmani, M., Glass, J. and Price, A.D.F., 2008.Architects' Perspectives on Construction Waste Reduction by Design. *Waste Management*, 28(7), 1147-58.

Rameezdeen, R., 2009.*Construction Waste Management: Current Status and Challenges in Sri Lanka*. 1sted. Galle: COWAM project publication, Galle Europe Aid co-operation office.

Sushil, 1990. Waste management: A Systems Perspective. *Industrial Management & Data Systems*, 90(5), 1-67.

Tam, V.W.Y., 2011.Rate of Reusable and Recyclable Waste in Construction. *The Open Waste Management Journal*, 4, 28-32.

Tam, V.W.Y., Shen, L.Y. and Tam, C.M., 2007. Assessing the Levels of Material Wastage affected by Sub-Contracting Relationships and Projects Types with their Correlations. *Building and Environment*, 42(3), 1471-1477.

Tam, V.W.Y. and Tam, C.M., 2008. Waste Reduction through Incentives: ACase Study.*Building Research and Information*, 36(1), 37-43.

Teo, M.M.M. and Loosemore, M., 2010.A Theory of Waste Behaviour in the Construction Industry.*Construction Management and Economics*, 19(7), 741–751.

Yin, R.K., 2009. *Case Study Research: Design and Method.* 4th ed. New York: SAGE Publications.

Yu, A.T.W., Poon C.S., Wong, A., Yip, R. and Jaillon, L., 2012.Impact of Construction Waste Disposal Charging Scheme on Work Practices at Construction Sites in Hong Kong. *Waste Management*, 33, 138–146.

Yuan, H., Chini, A.R., Lu, Y. and Shen, L., 2011.A Dynamic Model for Assessing the Effects of Management Strategies on the Reduction of Construction and Demolition Waste.*Waste Management*, 32, 521–531.

Wang, J.Y., Touran, A., Christoforou, C. andFadlalla, H., 2004.A Systems Analysis Tool for Construction and Demolition Wastes Management. *Waste Management*, 24, 989–997.

DEVELOPMENT OF A CUSTOMER SATISFACTION ASSESSMENT MODEL FOR THE IMMIGRATION AND EMIGRATION SERVICE IN SRI LANKA

H.W.N. Madhusanka* and Nayanthara De Silva
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Immigration and Emigration Service (IES) is among the most vital set of state services of a country. In Sri Lanka it has played a great role with the augmented rates of immigrants and emigrants during past few years. The efficiency of this service relies on its customers' satisfaction. Thus the focus of the research was to identify the level of satisfaction of customers regarding the quality of services, and to suggest appropriate further improvement strategies to maximize its efficiency.

Quantitative approach was used for the effective fulfilment of desired objectives. During the first phase of data collection, two preliminary surveys were carried out to filter and specifically identify the factors to be included in the satisfaction assessment. Subsequently, the customer satisfaction assessment was completed focusing on 125 customers. In the second phase, semi-structured interviews were carried out with 4 experts, aiming to identify possible improvement strategies for further enhancements in the service quality.

Twenty eight factors were established to appraise the immigration and emigration service quality. The service quality assessment using IPA matrix revealed that the customers were satisfied with 15 factors and dissatisfied with 13 factors. Thus, several improvement strategies were proposed to improve the current service quality.

Keywords: *Customer Satisfaction; Customer Service; Satisfaction Assessment; Service Quality.*

1. INTRODUCTION

Customers are the most valuable assets in an organisation (Besterfield *et al.*, 2004). Accordingly, many researchers conceptualised customer satisfaction in different dimensions. In one of the most common definition, customer satisfaction is expressed as an individual's sensation of pleasure or displeasure resulting from comparing a product's or service's apparent performance in relation to customer's expectations. Furthermore, Pollack (2009) highlighted that customer satisfaction is deemed to be listed at the top in attaining stated organisational goals and objectives. Therefore, organisations tend to measure the level of customer satisfaction and re-engineer their processes accordingly to improve the level of satisfaction of customers (Yasin *et al.*, 2004; Rodie and Martin, 2001; Tan *et al.*, 2010). In addition, Karatepe *et al.* (2005) revealed that organisations consider customers' perceptions to determine their strengths and weaknesses to improve customer satisfaction strategies.

Several researches on customer satisfaction in service providing organisations; both in government and private sector have been studied to identify satisfaction measurement criteria (Mwita, 2000; Yusoff *et al.*, 2008; Yeon *et al*, 2006). Adapting customer satisfaction tools for these organisations in Sri Lanka has become essential with the rapid developments in the country, especially after ending the country's 30 years long civil war. Consequently, a significant improvement in the quality of services in tourism sector has been identified with the increased rates of immigrants and emigrants during past few years (Ministry of Economic Development, 2014). Thus, the Immigration and Emigration Service (IES) in Sri Lanka is considered as a major government customer service that requires a high attention regarding the satisfaction of customers since it provides services for more than 2500 local and foreign customers daily.

* Corresponding Author: Email - nandun.madhusanka@hotmail.com

2. CUSTOMER SATISFACTION ASSESSMENT DIMENSIONS AND FACTORS

A large number of studies have been conducted to identify satisfaction dimensions for service quality measurement to assess the customer satisfaction. Among those, the most widely used and most practical method is the SERVQUAL model (Zeithaml *et al.*, 2006). In the formation of this model, Parasuraman *et al.* (1988) initially presented 97 factors under 10 major dimensions (Zeithaml *et al.*, 1996). Later many authors identified that some of those dimensions were inter-related and hence SERVQUAL factors are restructured as 22 service quality measurement factors (Zeithaml *et al.*, 2006). They are grouped under following five dimensions.

- Reliability
- Responsiveness
- Assurance
- Empathy
- Tangibles

Furthermore, 5 factors by Yusoff *et al.* (2008), 1 factor by Bailey (1996), 2 factors by Brysland and Curry (2001), 1 factor by Kang and James (2004), 3 factors by Mersha and Adlakha (1992) and 1 factor by Rust and Oliver (1994) have been identified, other than in SERVQUAL model. Thus, these all factors can be summarised into 35 factors under five satisfaction dimensions (Table 1).

Table 1: Satisfaction Dimensions and Factors

No	Factors to Measure the Service Quality
Reliability	
1	Acts according to the promises
2	Sincere interest in solving problems
3	Performs the services right at the first time
4	Provides services at the time promised
5	Insists on error free records
6	Non disclosure of information to non entitled parties
7	Keeping records of past transactions
8	Coordination across departments
9	Works according to predefined schedules
Responsiveness	
10	Informs the exact time the services will be provided
11	Provides adequate explanations for delays
12	Employees' willingness to explain alternative solutions for issues/ concerns.
13	Provides prompt service
14	employees willingness to help
15	Attractive and up to date web site
16	Convenience of online services
17	Usage of latest technology
18	Responds to service requests quickly
19	Staff attentiveness to customer requests
Assurance	
20	Employee behaviour instils confidence
21	Security of transactions
22	Consistently courteous employees
23	Ability to provide accurate information.
24	Employees' knowledge to answer the questions

No	Factors to Measure the Service Quality
Empathy	
25	Kindness of employees
26	Provides individual attention for employees
27	Customers treated with dignity and respect
28	Convenience in operating hours and days
29	Understanding customer needs quickly and effectively
30	Friendliness and politeness of employees
Tangibles	
31	Visually appealing office equipments
32	Visually appealing physical facilities
33	Professional appearance of employees
34	Visually appealing building structure and materials
35	Presentation of associated materials

3. CUSTOMER SATISFACTION ASSESSMENT TOOLS

Various methods and models were developed by number of researchers to measure the level of customer satisfaction. Among those, the QIS model (Beach and Burns, 1995), Kano's model (Cheng and Chuang, 2008), American Customer Satisfaction Index (American Customer Satisfaction Index, 2014) and Importance Performance Analysis (IPA) matrix (Martilla and James, 1977) can be highlighted. In this research, IPA matrix was adapted to achieve the desired objectives due to its two dimensional nature which can be best fit to represent the level of satisfaction and the degree of their importance in providing IES.

3.1. THE IPA MATRIX

IPA was initially introduced by Martilla and James (1977). The matrix specifically identifies the low service quality areas that an organisation should primarily consider to enhance the level of customer satisfaction (Hung *et al.*, 2003). The two dimensional matrix can be constructed by using the results from service quality measurement surveys and customer satisfaction assessment surveys. The perceptions should be obtained under two criteria namely: the level of importance and the level of performance. The level of importance is depicted in the "X" axis while the level of performance is depicted in the "Y" axis. Obtained mean values for the level of importance and performance, for each factor categorises the matrix in to four major quadrants.

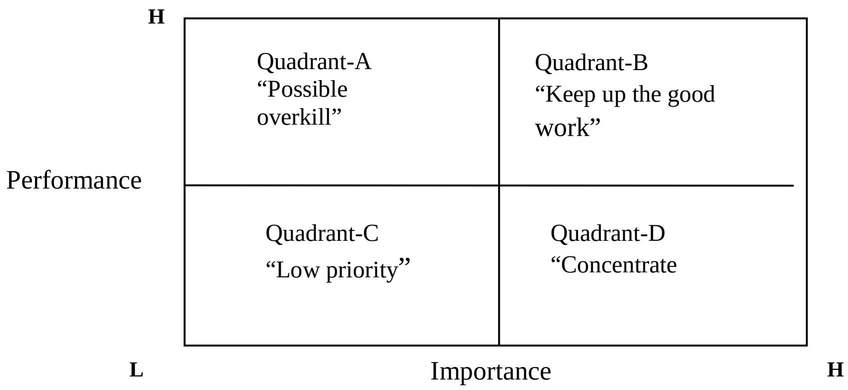

Figure 1: The IPA Matrix
Source: Martilla and James (1977)

The dimensions fallen under these four quadrants of the IPA matrix can be defined as follows;

Quadrant "A" - factors are considered as over performance areas in an organisation due to excessive resources utilization. Thus excessive resources can be utilised somewhere else to avoid possible overkills.

Quadrant B - factors are considered as major strengths of an organisation. Thus, these factors can be used to gain the competitive advantage to keep up the good work.

Quadrant C - factors in quadrant "C" are identified as minor weaknesses of the organisation. These factors can be identified as low priority areas and a significant concern is not required regarding the factors in this quadrant.

Quadrant D - factors in quadrant "D" are considered as low performing factors. Thus they are the major weaknesses and the organisation should concentrate more on those factors and should take immediate attempts to enhance the performance of these areas.

Therefore, based on the location in the IPA matrix, required improvement priorities of the satisfaction factors can be determined (Lambert and Sharma, 1990).

4. RESEARCH METHODOLOGY

The data collection was conducted into three phases. Further, the customer satisfaction was analysed by using the modified IPA matrix (refer section 4.2).

4.1. PHASE- I

Two preliminary surveys (preliminary survey I and II) were conducted focusing experts and customers of the IES.

Preliminary survey I - Thirty five factors under 5 dimensions (refer Table 1), were presented for the preliminary survey I to five experts to seek expert opinion on the suitability of each factor to be used in the customer satisfaction assessment of immigration and emigration service sector. A five point likert scale was used to obtain the level of suitability of each factor. Further, the respondents were requested to recommend any other suitable factors that are required to assess the customer satisfaction in IES.

Preliminary survey II - Customers' views also was seek to finalize the satisfaction dimensions. Customers were selected based on non-probability haphazard sampling method for better accuracy. Thus, the sample size was not predetermined. Customers were inquired individually, one after the other until the desired requirement is fulfilled. During this survey, each individual was given a list of factors identified by previous respondents and was asked to indicate the additional requirements and satisfaction factors other than the factors which were mentioned in the given list.

4.2. PHASE- II

The level of customer satisfaction was assessed through a questionnaire survey. Final questionnaire was developed with the findings of literature review, preliminary survey I and preliminary survey II. The questionnaire was consisted with 5 major dimensions and 31 factors. Customers were requested to state the level of "Expectation" and "Satisfaction" according to the given five point likert scale for each factor. Questionnaires were prepared in both "Sinhala" and "English" languages to effectively communicate with customers. Accordingly, 125 questionnaires were distributed among the customers.

Customer responds were analysed using the modified IPA matrix where some studies have customised and altered IPA to suit perfectly for the research purposes. However, the fundamental structure has remained as the same (Sampson and Showalter, 1999). Accordingly, Deng (2007) highlighted that the matrix can be further divided into more quadrants as required to specifically identify the strengths and weaknesses. Hence, with reference to the findings of the author, "D" quadrant was further divided into 4 quadrants (see Figure 2). As described in the section 3.1, "D" quadrant contains under performance areas. Hence this categorisation enables the effective identification of critical factors. This modified IPA matrix was adapted to analyse the findings of customer satisfaction assessment survey.

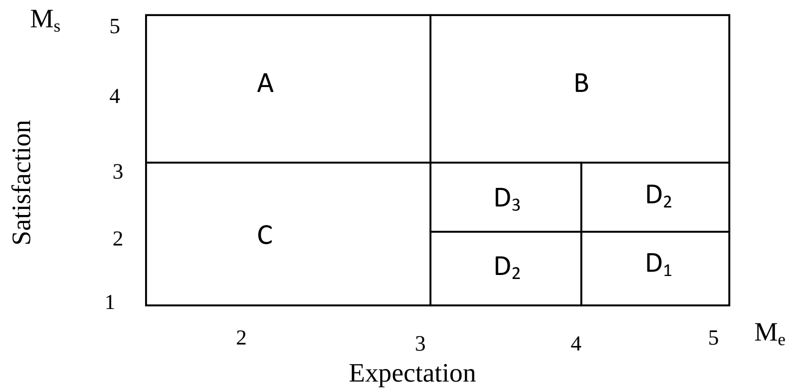

Figure 2: Modified IPA Matrix

M_e- Mean value of "Expectation" ratings, M_s- Mean value of "Satisfaction" ratings

- A -quadrant- the mean value of "Expectation" rating is less than 3 and the mean value of "Satisfaction" rating is higher than 3.

  $$M_e<3 \wedge M_s>3$$

- B- quadrant- The mean value of "Expectation" rating is higher than 3 and the mean value of "Satisfaction" rating is higher than 3.

  $$M_e>3 \wedge M_s>3$$

- C -quadrant- The mean value of "Expectation" rating is less than 3 and the mean value of "Satisfaction" rating is less than 3.

  $$M_e<3 \wedge M_s<3$$

- D- quadrant- The mean value of "Expectation" rating is higher than 3 and the mean value of "Satisfaction" rating is less than 3.

  $$M_e>3 \wedge M_s<3$$

  D1- Most critical factors (Mean value of "Expectation" rating is higher than 4 and the mean value of "Satisfaction" rating is less than 2)

  $$M_e>4 \wedge M_s<2$$

  D2- Moderately critical factors (Mean value of "Expectation" rating is between 3 and 4 and the mean value of "Satisfaction" rating is less than 2 or mean value of "Expectation" rating is higher than 4 and the mean value of "Satisfaction" rating is between 2 and 3)

  $$(3<M_e<4 \wedge M_s<2) \vee (M_e>4 \wedge 2<M_s<3)$$

  D3- less critical factors (Mean value of "Expectation" rating is between 3 and 4 and the mean value of "Satisfaction" rating is between 2 and 3)

  $$3<M_e<4 \wedge 2<M_s<3$$

4.3. PHASE-III

Consisted with a semi structured interview round which was used to interpret the results of customer satisfaction assessment survey and to determine possible improvement priorities. Four experts were interviewed during this phase.

5. RESEARCH ANALYSIS AND FINDINGS

5.1. SUITABLE SATISFACTION FACTORS

Nine factors from the above identified 35 factors were removed and another new 8 factors were added (Table 2) through the preliminary surveys I and II.

Table 2: Deleted and Added Factors

Satisfaction Dimensions	Deleted Factors from the Initially Identified List	Newly Added Factors
1.Reliability	1. Acts according to the promises 2.Insists on error free records 3.Non disclosure of information to non entitled parties 4.Works according to pre-defined schedules	
2.Responsiveness	5.Attractive and up to date web site 6.Convenience of online services 7.Responds to service requests quickly	1.Minimum waiting time to obtain services 2.5.Language translation services are provided when required 3.Proper sequencing and numbering of counters 4.Support and assistance provided at the inquiries table
3.Assurance	8.Employees knowledge to answer the questions related to the service procedures	5.Clarity of information provided in forms and other documents 6.Documents and forms can be easily understood and filled
4.Empathy		7. Priority is given for Elders, Disabled people, and Pregnant Mothers.
5.Tangibles	9.Visually appealing physical facilities	8.Providing a leaflet of information regarding the offered services

However, (1) Keeping of past transaction records of the customers, (2) Coordination across the service and (3) Priority given for elders, differently able people, and pregnant mothers, factors were significantly less in respond rates (less than 25 responses) and thus only 28 factors were used for the analysis.

5.2. SATISFACTION OF IES

Table 3 indicates the mean weighted ratings of expectations (M_e and M_s) and the standard deviations (SD_e and SD_s) of these factors.

Table 3: Level of Customer Satisfaction for Service Quality

Satisfaction Factors for Service Quality		Quadrant	M_e	SD_e	M_s	SD_s
Reliability						
R1	Employees are sincerely interested in solving problems	D-2	4.32	0.66	2.71	0.55
R2	Services performed right at the first time	B	4.13	0.68	3.76	0.60
R3	Services provided at the time promised	D-1	4.87	0.34	1.97	0.53
Responsiveness						
RE1	Informs the exact time the services will be provided	B	4.22	0.68	3.93	0.67
RE2	Minimum waiting time to obtain services	D-1	4.88	0.31	1.83	0.50
RE3	Sequence in counters and operations	B	4.53	0.59	4.43	0.60
RE4	Adequate explanations provided for delays	D-2	4.14	0.74	2.92	0.65

Satisfaction Factors for Service Quality		Quadrant	M_e	SD_e	M_s	SD_s
RE5	Employees' willingness to explain alternative solutions for issues/ concerns.	B	3.97	0.72	3.04	0.64
RE6	Language translation services are provided when required	C	2.98	0.85	2.91	0.74
RE7	Employees willingness to help customers to clarify their issues	D-1	4.06	0.67	1.92	0.53
RE8	Support provided at the front desk and inquiries table	B	4.74	0.46	3.12	0.67
RE9	Latest technology is used for the operations of department	B	3.78	0.50	3.22	0.59
RE10	Staff attentiveness to customer requests	B	4.94	0.23	3.22	0.67
Assurance						
A1	Confidential behaviour of employees	B	3.44	0.55	3.26	0.48
A2	Security of transactions	C	2.84	0.74	2.9	0.62
A3	Employees are consistently courteous	D-2	4.22	0.70	2.43	0.62
A4	Accurate information are provided at the department.	B	4.14	0.56	3.58	0.62
A5	Clarity of information provided in forms and other documents	B	4.66	0.51	4.17	0.53
A6	Documents and forms can be easily understood and filled	B	4.68	0.53	4.3	0.65
Empathy						
E1	Individual attention is provided for customers	B	3.26	0.61	3.47	0.65
E2	Customers treated with dignity and respect	D-2	3.58	0.66	1.78	0.52
E3	Kindness of employees	B	3.14	0.58	3.26	0.68
E4	Customer needs are understood quickly and effectively	D-2	4.54	0.65	2.92	0.63
E5	Friendliness and politeness of employees	D-3	3.34	0.63	2.89	0.56
Tangibles						
T1	Visually appealing office equipment	C	2.46	0.54	2.81	0.64
T2	Associated materials are provided by the department (information leaflets, stationary,	C	2.74	0.62	1.68	0.64
T3	Professional appearance of employees	B	3.16	0.76	3.32	0.56
T4	Visually appealing building structure and materials	B	3.75	0.59	4.08	0.53

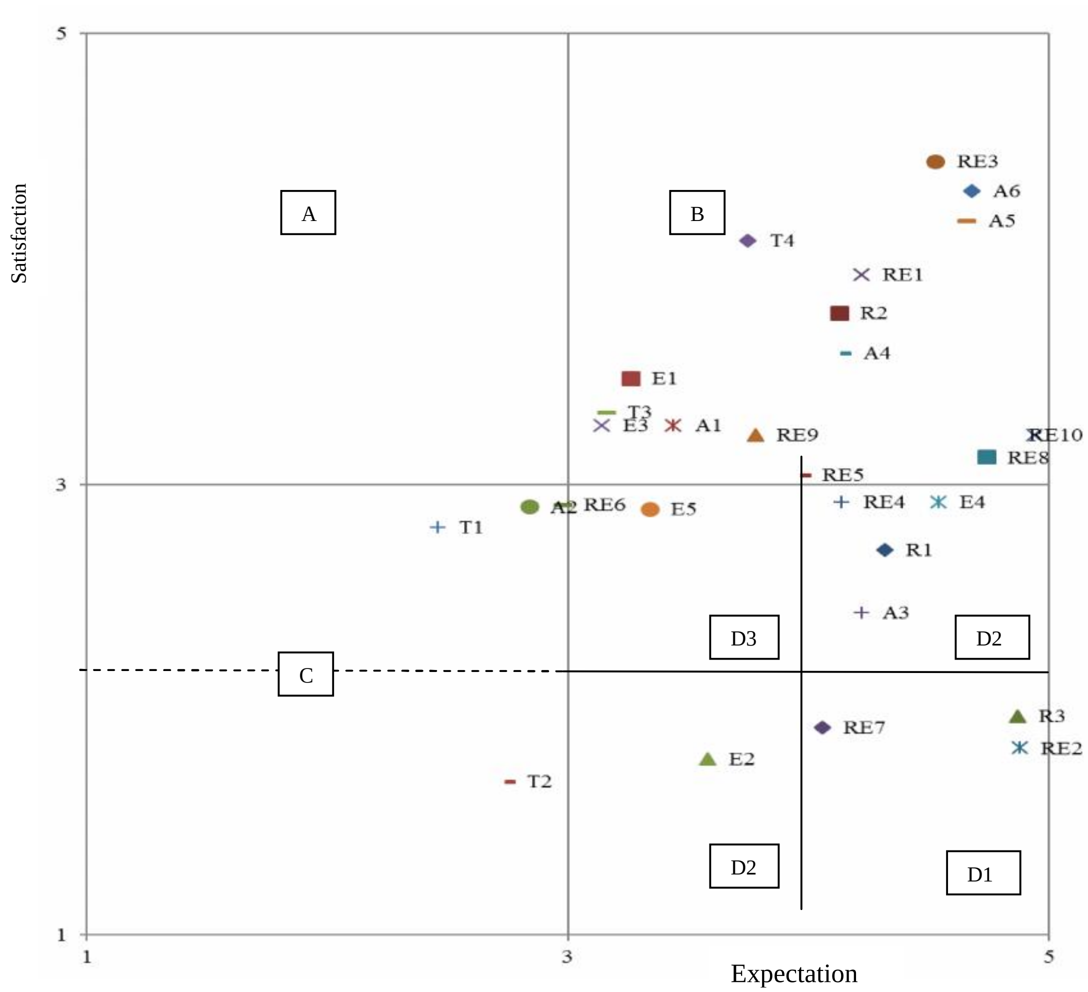

Figure 3: Results of the Customer Satisfaction Assessment Survey

Interestingly, none of the factors were identified under the quadrant "A" and thus IES has not over utilized its resources. The performances of those factors were up to a level that could satisfy the customers. Fifteen factors were fallen into the quadrant "B" which is rated as "Expected and Satisfied". The quadrant "C", that reveals the factors which have a lesser expectation level and lesser satisfaction level, has 4 factors. Immediate concern is not required to address these 4 factors since the level of expectation is less. However, they should be addressed in the long run. Quadrant "D" consists with less performance factors. As described in the "Research methodology" the highest critical quadrant in D is "D1" where the level of expectation is very high and the level of satisfaction is very low. Three factors were identified in "D1" and thus highest attention is required when identifying strategies to enhance the service quality. Similarly "D2" quadrant reveals moderately critical areas which include 5 factors. Further, "D3" quadrant was included with 1 factor which has a relatively low criticality than "D1" and "D2".

5.3. *IMPROVING THE SERVICE QUALITY*

IES has taken several improvements (refer Table 5) and thus customers are satisfied with 15 satisfaction factors. However, several other improvements can be suggested to remove all inefficient factors fallen in quadrant "D" in the matrix. These further improvements are established by eliciting expert knowledge. According to the experts who engaged in this service suggested to conduct continuous training programs to improve knowledge of the staff and further out sourced employees should have an opportunity to participate these programmes. Additional self-guidance is required for customers with more clear information boards and other visual aids. Accessibility for differently able people was identified as another area to be improved. Further space utilization within the service area can be optimized for better circulation and usage. For example, number of counters can be increased to enhance the convenience for customers.

Table 4: Improvement for Customer Satisfaction

Improvements Taken
▪ ISO 9001 quality management system was taken
▪ Public Relation officers were employed
▪ A productivity improvement team has been established
▪ Training and induction sessions for employees have been conducted
▪ Information centre was initiated to assist customers in all 3 languages
▪ Dining areas, Banking facilities, and other required support services have been provided within the service area
▪ Priority has been given for clergy, disabled people and pregnant mothers
▪ An incident investigation mechanism was established
▪ Monthly progress meetings have been arranged

6. CONCLUSIONS

During the past 5 years, Sri Lanka has experienced a significant growth in tourism industry. Subsequently, assessing the current level of customer satisfaction was identified as a valuable baseline to determine improvement priorities for IES to cater for the increased requirements.

The well known SERVQUAL model was the most feasible framework to identify the factors of its service quality. Twenty eight satisfaction factors were established for customer satisfaction assessment. Further, the modified IPA matrix was adopted as the suitable analysis tool for assessment. Fifteen 15 factors were rated as satisfied by customers. Only, 4 factors were rated as unexpected and unsatisfied whereas none of the factors were identified as satisfied for unexpected attributes. Most prominently, 9 factors were classified as dissatisfied by the customers although they expected them to be well performed.

Most of the customer satisfaction assessment surveys were done by considering only the level of “satisfaction”. This study provides a comprehensive approach to develop the satisfaction assessment questionnaire and assess the customer satisfaction with relation to their expectations. Further, the practical applicability of the “modified IPA matrix” was highlighted during the research. Hence, this piece of work would be an elementary guide to the future researchers to determine suitable dimensions and a satisfaction assessment tool for their customer satisfaction assessment survey. The adoption of above concept in service sector will also enhance the quality of its services and especially, it will positively influence towards the good productivity.

7. REFERENCES

American Customer Satisfaction Index, 2014. *The American Customer Satisfaction Index* [online]. Available from: http://www.theacsi.org/ [Accessed 24 March 2014].

Bailey, G., 1996. Customer care - making it work. *Managing Service Quality*, 6(3), 36-38.

Besterfield, D., Besterfield, G. and Besterfield, M., 2004. *Total quality management.* 3rd ed. India: Pearson Education.

Beach, L. and Burns, L., 1995. The service quality improvement strategy: identifying priorities for change. *International Journal of Service Industry Management,* 6(5), 5-15.

Brysland, A. and Curry, A., 2001. Service improvements in public services using SERVQUAL. *Managing Service Quality*, 11(6), 389-401.

Chen, C. and Chuang, M., 2008. Integrating the Kano’s model into a robust design approach to enhance customer satisfaction with product design. *International Journal of Production Economics*, 114(2), 667-681.

Deng, W., 2007. Using a revised importance-performance analysis approach – The case of Taiwanese hot springs tourism. *Tourism Management*, 28(5), 1274-1284.

Hung, Y.H., Huang, M.L. and Chen, K.S., 2003. Service quality evaluation by service quality performance matrix. *Total Quality Management and Business Excellence,*14(1), 79-89.

Kang, G. and James, J., 2004. Service quality dimensions: an examination of Grönroos's service quality model. *Managing Service Quality*, 14(1), 266-277.

Karatepe, O.M., Yavas, U. and Babakus, E., 2005. Measuring service quality of banks: scaledevelopment and validation. *Journal of Retailing and Consumer Services* [online], 12(5), 373-83. Available from: http://www.sciencedirect.com /science/article/pii/S0969698905000020 [Accessed 24 May 2014].

Lambert, D.M. and Sharma, A., 1990. A customer-based competitive analysis for logistics decisions. *International Journal of Physical Distribution and Logistics Management*, 20(1), 20-23.

Martilla, J.A.and James, J. C. (1977). Importance-performance analysis. *Journal of Marketing* [online], 41(1), 77-79. Available from: http://www.emeraldinsight.com/doi/pdfplus/ 10.1108/03090569310026402 [Accessed 26 March 2014].

Mersha, T.andAdlakha, V., 1992. Attributes of service quality: The consumers andapos; perspective. *International Journal of Service Industry Management*. 3(3), 56-72.

Ministry of Economic Development, 2014. *Rapid growth of tourism in Sri Lanka* [online]. Available from: http://med.gov.lk/english/?p=14618 [Accessed 26 March 2014].

Mwita, J., 2000. Performance management model: A system-based approach to public service quality. *International Journal of Public Sector Management*, 13(1), 19–37.

Parasuraman, A., Zeithaml, V.A. and Berry, L.L., 1988. SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing* [online], 64*(*1), 12-40. Available from: www.journals.elsevier.com /journal-of-retailing/ [Accessed 18 February 2014].

Pollack, B.L., 2009. Linking the hierarchical service quality model to customer satisfaction and loyalty. *Journal of Services Marketing*, *23*(1), 42-50.

Rodie, A.R. and Martin, C.L., 2001. Competing in the service sector: The entrepreneurial challenge. *International Journal of Entrepreneurial Behaviour*, 7(1), 5-21.

Rust, R. and Oliver, R., 1994. *Service quality*. Thousand Oaks. Calif: Sage Publications.

Sampson, S. E. and Showalter, M.J., 1999. The performance-importance response function: Observations and implications. *The Service Industries Journal*, 19(3), 1-25.

Tan, W.G., Cater, A.andToleman, M. (2010). Service management: a case study focusing on critical success factors. *Journal of Computer Information Systems* [online], 50(2), 1-12. Available from: http://www.iacis.org/jcis/jcis.php 38[Accessed 18 March 2014].

Yasin, M.M., Kunt, F.A.M. and Zimmerer, T.W., 2004. TQM practices in service organisations: an exploratory study into the implementation, outcome and effectiveness. *Managing Service Quality*, *14*(5), 377-89.

Yeon, S., Park, S. and Kim, S., 2006. A dynamic diffusion model for managing customer's expectation and satisfaction. *Technological Forecasting and Social Change* [online], 73(6), 648-665. Available from http://www.sciencedirect. com /science/article/pii/S0040162505000697 [Accessed 18 March 2014].

Yusoff, W., Ismail, M. and Newell, G., 2008. FM-SERVQUAL: A new approach of service quality measurement framework in local authorities. *Journal of Corporate Real Estate*, 10(2), 130-144.

Zeithaml, V.A., Berry, L.L. and Parasuraman, A., 1996. The behavioral consequences of service quality. 60(2), 31-46. Available from: http://areas.kenan-flagler.unc.edu/marketing/ facultystaff/zeithaml/selected%20publications/the%20behavioral%20consequences%20of%20service%20quality.pdf[Accessed 12 February 2014].

Zeithaml, V. A., Bitner, M. J. and Gremler, D. D., 2006. *Service marketing: Integrating customer focus across the firm.* 4th ed. New York: McGraw-Hill.

DIMENSIONS OF SUSTAINABLE CONSTRUCTION: THE PERSPECTIVES OF CONSTRUCTION STAKEHOLDERS

Cheng Siew Goh* and Steve Rowlinson
Department of Real Estate and Construction, The University of Hong Kong, Hong Kong

ABSTRACT

The recent trend of sustainable development in the Hong Kong construction industry has drawn construction organisations' attention to sustainability issues. However, the fragmented nature of construction industry has led to divergence in stakeholders' understanding of sustainable construction, in addition to the traditionally debatable concepts of sustainable development. This paper explores and examines how different stakeholders perceive and treat sustainable construction. Twenty two interviews were carried out with stakeholders from various backgrounds including architects, engineers, surveyors, contractors, developers, facilities managers, environmentalists, suppliers, and sustainability consultants. The results show that there is still a disagreement on embracing the economic and social pillars in sustainable construction, whilst the environmental pillar is acknowledged by the majority. In addition to the triple bottom line, sustainable construction is also linked to culture and health and safety. Interestingly, this study found that construction stakeholders perceive sustainable construction as an ideal situation in which it is very hard to attain zero carbon and complete sustainability in real life development. In view of the absence of a clear definition and direction in applying sustainable construction, a gap can form in sustainable practices when incompatible goals are set by various parties due to their different interests. As a result, more effort should be made by providing a platform for the diverse interest groups of construction stakeholders to share ideas, communicate and distribute sustainability information.

Keywords: *Dimensions; Stakeholder; Sustainable Construction.*

1. INTRODUCTION

Global issues such as climate change, exponential population growth, and finite natural resources have caused people to pay more attention to sustainable development. The wave of sustainable development has also brought a revolutionary movement to the construction industry and community. To remain competitive in the market, leading construction organisations react to the sustainability phenomenon by integrating sustainability practices into operations and projects. However, construction stakeholders face challenges to implement sustainability in practice due to the lack of a common definition and principle of sustainable construction.

This paper will recall the ongoing debate about the meaning and dimensions of sustainable construction from literature. Hence, it conceptualises the interpretation of sustainable construction from the viewpoint of various construction stakeholders to examine how well has sustainable construction been captured by stakeholders in the industry.

2. UNDERSTANDING SUSTAINABILITY FROM THE LITERATURE / THEORY

Despite the high popularity of the sustainable development, there is no standardized definition for sustainability or sustainable related terms to date. The interpretation of sustainability concept is still open and a number of new thoughts and ideas have evolved over time. Oxford Advanced Learners' Dictionary defined "sustainable" as one "involving the use of natural products and energy in a way that does not harm the environment" or one that "can continue or be continued for a long time". In the Brundtland

* Corresponding Author: E-mail - goh11@connect.hku.hk

Report, World Commission on Environment and Development (WCED) (1987) proposed sustainability as "the ability to meet the present needs without compromising the ability to meet the needs of future generations". The interpretation of WCED has been widely accepted by recognising the interfaces of environmental, economic and social development in the commitment of sustainable development. Balancing the eternal trade off between people, planet and profit is proposed to be the central concept of sustainable development in order to maximise the absolute value of an undertaking (Beheiry *et al.*, 2006; Opoku and Ahmed, 2013; Talbot and Venkarataman, 2011). Apart from the balance, Said *et al.* (2008) and Talbot and Venkarataman (2011) also suggested sustainability as a long term exercise carried out by various parties for attaining a sustainable condition within the parameters of social, environmental, and economic cornerstones.

3. SUSTAINABILITY AND THE CONSTRUCTION INDUSTRY

Although sustainability practices are evolving in the construction industry, it seems that the philosophy of sustainability cannot give practical guidance to construction players attempting to integrate it into their businesses or operations. Sustainability is an overarching concept which can impact and be impacted by every aspect of development. Development implies changes and it often involves the transformation of natural resources into desired outputs. Construction is one of the industries that undergoes massive transformation to introduce changes and development to the people, society and country. As highlighted by Du Plessis (2007), placing the terms of "sustainability" and "construction" together would further magnify the interpretive dilemma since these two terms are both highly complex ideas.

Viewing the broad coverage of sustainability, it deems that sustainable construction (SC) should address wider concerns on the comprehensive construction cycle from material extraction, planning, design, implementation, deconstruction and management of resultant waste, instead of a site activity or a particular stage of the project life cycle (Goh and Rowlinson, 2013). As indicated by Hill and Bowen (1997), sustainable construction was initially proposed to describe the responsibility and role of the construction industry in achieving sustainability, where the construction industry is deemed to include civil engineering and building construction. Kibert (2007) advanced his definition proposed in a 1994 conference by defining sustainable construction as "how the construction industry together with its product, the 'built environment' can contribute to the sustainability of the earth including its human and non-human inhabitants". In the meantime, Said *et al.* (2008) proposed to adhere the definition of sustainable development to the principles of sustainable construction by protecting the environment and enabling all people to improve their life through the pursuit of economic and social objectives. Du Plesis (2007) emphasised the use of a broad interpretation of construction as a cradle to grave process embracing environmental protection, value addition to the quality of life, and both technological and non-technical aspects of social and economic sustainability.

Hill and Bowen (1997) divided the principles of sustainable construction into four pillars, i.e. social, economic, biophysical and technical aspects, while Conseil International de Batiment (CIB) (cited Kibert 2008) articulated seven principles to ideally inform decision making of sustainable construction: 1) reduce resource consumption; 2) reuse resources; 3) use recyclable resources; 4) protect nature; 5) eliminate toxins; 6) apply life cycle costing; and 7) focus on quality. At the same time, Fellow and Liu (2008) suggested that four systems as sustainability indicators, i.e. economic, socio-economic, socio-environmental and legal systems. Pearce (2006) also employed a different approach - economist's approach to define sustainability in construction by measuring human well-being through assets.

Literature review implies that the interpretation of sustainable construction is still contentious and continues evolving. By and large, sustainable construction shall cover three key elements of sustainability in its concept and application, i.e. environment, economy and society. Although there is a growing body of literature and standards recognising the triple bottom line, construction stakeholders with varied interests may still hold different viewpoints in regard to sustainable construction.

Since the understanding of sustainable construction held by stakeholders at all levels of project delivery is key to its successful implementation, a lack of common understanding among construction stakeholders could impede the development towards the goal of sustainable construction. Therefore, it is important to examine what sustainable construction meant to stakeholders.

4. METHOD

This study used a qualitative approach to explore and examine the dimensions of sustainable construction. In-depth interviews were employed to obtain detailed information from various construction stakeholders who are engaged actively in sustainability practices during the delivery of construction projects. Unlike surveys, the approach of interview is more exploratory and open-ended in nature. Interviewees were asked about their understanding and perception about sustainable construction. Under the structure of interview, both interviewees' responses and feelings towards sustainable construction were also observed and examined. With participant permission, the interviews were recorded and the interview data were transcribed and coded in accordance to thematic analysis.

The interview participants were selected through purposeful sampling to ensure that the interviewees offer information-rich cases at interview. All interviewees were required to have direct exposure to sustainable construction projects or practices. A broad spectrum of professions and background, ranging from developers to academics, architects, engineers, surveyors, contractors, planners, supplier and facilities manager, were embraced in the sampling to avoid overlooking any interests of the related parties and also to ensure the comprehensiveness of the subject being studied.

Table 1 shows the profile of the interviewees. The interviewees possess with an average 22.5 years of working experience in the construction related field. All interviewees hold either executive position or managerial position in their organisations. They have played significant roles in either decision making or the implementation of sustainable construction in their respective organisations.

Table 1: Profile of Interviewees

No	Code	Experience (Years)	Job Position
1	C01	35	Engineering and Risk Manager
2	C02	>35	Chief Quantity Surveyor, Corporate Legal Consultant
3	A03	18.5	Chairman of HK Chapter of China Green Building Council
4	E01	>22	Project Director
5	D01	40	Director in Architectural Services
6	C03	12	Design Manager
7	C04	15	Design Manager
8	U01	>30	Director of Planning and Design
9	E02	8	Sustainability Officer
10	E03	16	Director in Building & Technology Division
11	D02	25	Assistant director
12	C05	37	Chief Sustainable Development Manager
13	E04	>25	Executive Director
14	R01	20	Associate Director & Director of Sustainable Development
15	E05	12	Director
16	S01	45	Director of project advisory
17	I01	9	Co-founder and Creative director
18	E06	7	Director of Sustainability
19	C06	26	Director
20	M01	> 20	Regional Head of Real Estate & Site Development
21	S02	31	Director
22	E07	28	Executive Director and Regional Manager

5. FINDINGS AND DISCUSSION

All the interviewees have a common understanding of the inclusion of the environmental pillar in their definitions of sustainable construction (SC). As reflected by interviewees, sustainability is always viewed relating to carbon footprint, pollution, green resources, material use, resources efficiency, energy consumption, water use and waste management.

A03 stressed four major savings in SC: material, water, energy and land resources while E03 proposed six factors in applying sustainable construction i.e. sustainable materials, ultimate energy use, water consumption, waste management, access to public transport, and life cycle cost. E02 argued that SC should contain the least environmental impact or pollution, minimum carbon emission, prolonged life cycle, renewable resources, less energy and material use, durable material, and recyclable and reusable materials. The interviewees highly acknowledge the environmental pillar since the focus of sustainable construction practices is mainly directed at environmental sustainability (Smitt and Pitt, 2011).

Regarding the economic pillar of sustainability, most interviewees share a common interest to embrace life cycle cost in the practice of SC. People should avoid from narrowing their focus to the cost incurred from a particular project stage; they should instead consider true cost, which involves the cost commencing from the supply, taking-off and bringing in to the site, until the disposal of materials. E01 supports the view and holds that life cycle costing is critical in improving sustainable performance; cost effectiveness and payback period should be often given a high priority in the pursuit of sustainability. She felt some sustainable features such as windmills often have low cost effectiveness due to their high initial cost and maintenance cost, considering their limited benefits generated. The inclusion of life cycle cost in SC practice is supported by E03 and D02 too. Rather than mere construction cost, E03 and D02 opined that SC should examine the whole life cycle cost of buildings, whereas life cycle entails the whole processes of design, construction, operation, demolition and maybe even the reuse of the buildings. E03 also asserted that "*achieving life cycle can drive the occurrence of other sustainable factors which can help to drive more sustainability into the buildings, while the emphasis on short term gains will always lead to wrong decisions*". As reflected by E03, operation cost is typically 80% of the total building life cycle cost, and if a building can be operated at lower cost, it can produce lower energy consumption, better water usage and lower waste outputs.

Meanwhile, the integration of the social pillar in SC does not gain much support from the interviewees, although some acknowledge the significance of social concerns in developing sustainability in construction. E02, for instance, embraces indoor environment quality, flexibility in building use, occupants' comfort and intelligent systems in the principles of SC. As an urban planner, U01 advocates placing a great emphasis on the development of urban landscape, culture, and human interaction in SC. He feels that current construction has induced a low town bearing and imposed lesser connectivity between people and the place. Therefore, more attention should be placed on the natural setting, cultural landscape and community in an effort to attain sustainability. A balance between culture and community identity also needs to be stressed. R02 indicated that adding value to the entire community and neighbourhood development is part of SC.

The embracement of economic and social development in SC is sometimes arguable. According to E04, it would be somewhat broad to include them, particularly the inclusion of social development depends very much on the types of site involved (e.g. heritage preservation site). As a policy maker, E09 also opined that SC should only deal with environmental perspective, although a project can also contribute to regional neighbourhood. In her views, the contribution of construction to economy is not on a macro scale with long term impacts to the overall industry development. From the perspective of C03, cost is a separated exercise in sustainable project operation, whereas the emphasis on sustainability tripod depends on the adopted procurement. Similarly, E07 also excludes social and economic development in the consideration of SC. The empirical findings concur with Abidin (2010), which also found that sustainable construction is viewed as a form of environmental protection and seldom to be related to social well-being and economic factors. The historical tendency to focus on environmental sustainability has over aligned sustainable development with green movement and alienated business executives (Beheiry *et al.*, 2006)

Meanwhile, health and safety are perceived as an important concept of SC. Rather than triple bottom line, C06 has employed a unique approach for sustainability by incorporating safety and health in SC to form a quadruple bottom line. As highlighted by E04, a better work environment and rest areas are often provided to labourers in order to achieve zero accident on site, since Labour Department in Hong Kong will suspend the work at site if any accident happens. F01 also supports the inclusion of safety by acknowledging the importance of safety towards sustainability.

Striking the balance between the three pillars is another emphasis placed by the interviewees in their pursuits of sustainability. The balance to achieve SC is another focus given by the interviewees in picturing SC. As revealed by D01, it is critical to strike a balance between cost, people and environment in a sensible way in implementing SC. The value of sustainable development would lose if the project fails to achieve one of the three pillars. Construction practices should examine the entire issues of people, cost and technology in the path towards sustainability. Exploring life cycle costing is important to determine the worthwhileness of sustainable efforts as it is impossible to introduce sustainable features which are unacceptable by the people, as stated by D01. Concurrently, A03 believes that three pillars of sustainable development have not been developed equally in construction, whereby environmental development receives comparatively less emphasis than the other two aspects in the past. He opined that more effort is currently invested in environmental improvement in order to retrieve the balance of SC.

To uphold the long term development, stakeholders also consider sustainable construction as an integrated and total approach that covers the entire life cycle - from cradle to grave. D02 regards SD as a total concept by covering all areas of property life cycles from design, construction, maintenance, renovation to demolition. Interviewee R01 also advocated SC as an integrated construction practice based on a closed-loop system of thought, which tracks the supply chain of materials sources from the extraction, production to waste generation and moves back to the production cycle. The integrated system promotes a close link and full cooperation between project parties such as developers, designers, contractors and facilities managers. Supporting to the idea of a closed loop system, E05 also felt that "*SC is to create building structure with resources and spaces available to (attain) a self-sufficient manner*". The self-sufficient manner refers to not only energy and water conservation but also the economic sufficiency.

Interestingly, the findings suggest that sustainable development in construction could be an ideal situation and maybe very hard to have zero carbon, or a complete sustainability in the construction development. The interviewees expressed the following comments for achieving sustainable construction:

> "*It is impossible to achieve zero waste with current technology and methods* [C05]"
>
> "*Sustainable interior design is ideal and cannot 100% achievable* [I01]".
>
> "*Self-sufficient is however an ideal situation and it is very difficult to achieve. Instead, we should strive to get as close as possible to this ideal situation in all aspects* [E05]".

Apart from the traditional triple bottom line, this study found that culture is another important issue for developing sustainable construction. The interviewees highlighted the importance of changing people's mindset to work towards sustainable development. As expressed by E03, although smart engineering solutions have been designed for the clients, end users and/or operators still need to know how to use them in their designed way. He shared his experiences, whereby the operators switched the building devices to automatic off, and did the operation manually, which is the way they are used to it. The case has proven how critical of the understanding and commitment of the end users and/or operators to successfully shift the whole construction society towards sustainable development. It is thus necessary to improve the knowledge and commitments of not only construction parties but also all involved interested stakeholders in the construction industry for attaining SC. The finding is consistent with the work by Ball (2002) which argues cultural sustainability to be one of the most important un-addressed issues.

C04 believed that the sustainable development trend will only be changed totally when private developers are willing to pursue sustainability and build good quality buildings without any enforcement of government policy. It is essential to pursue sustainability from a genuine heart but not from either the desire to secure advantage over other firms in the market or the desire to comply the legislation requirements. Meanwhile, interviewees also asserted that people should change their lifestyles by mapping their real needs to any decisions they made. Even though a smallest development, it would also lead to negative impacts on the environment, human and the planet by changing the original identity and ecology system surrounding of a place. As a result, Fellow and Liu (2008) suggested that only a real convergence value shift, supported by strong and enforced legislation to get to grips with the divergence in value judgement of various systems in completing sustainable development framework.

In the absence of a clear definition, concepts, principles and directions in applying sustainable construction, stakeholders tends to make SC suit their particular needs and fit their professions, in which they would be more familiar in their field of practice (Chong *et al.*, 2009). A gap would be formed in sustainable practices when incompatible goals are set by various parties due to their different interests. To achieve the wholesome sustainability in construction, the crossover and integration of knowledge between different fields is essential (Chong *et al.*, 2009).

6. CONCLUSION

A right context of knowledge and mindset about sustainable development is still questionable, particularly in light of the arguable definitions and principles of sustainable construction. There appears to be a need for construction stakeholders to acquire the right context of sustainability knowledge. The three fundamentals of sustainability should always be encompassed into the implementation framework by the construction stakeholders. Even if social and economic developments are sometimes taken into the considerations, it seems that sustainable construction is firmly entrenched within the environmental movement only. To avoid the knowledge gap of sustainable construction from continually expanding, a common definition and framework should be established to smoothen the transition towards sustainable construction. More effort could be done by providing a platform to the diverse interest groups of construction stakeholders to share ideas, communicate and distribute information to work towards a common goal in their sustainable construction practices.

7. REFERENCES

Abidin, N.Z., 2010. Investigating the Awareness and Application of Sustainable Construction Concept by Malaysian Developers. *Habitat International*, 34(4), 421-426.

Ball, J., 2002. Can ISO 14000 and Eco-Labelling Turn the Construction Industry Green? *Building and Environment*, 37(4), 421-428.

Beheiry, S., Chong, W. and Haas, C., 2006. Examining the Business Impact of Owner Commitment to Sustainability. *Journal of Construction Engineering and Management*, 132(4), 384-392.

Chong, W. K., Kumar, S., Haas, C.T., Beheiry, S.M.A., Coplen, L. and Oey, M., 2009. Understanding and Interpreting Baseline Perceptions of Sustainability in Construction among Civil Engineers in the United States. *Journal of Management in Engineering*, 25(3), 143-154.

Du Plessis, C., 2007. A Strategic Framework for Sustainable Construction in Developing Countries. *Construction Management and Economics*, 25(1), 67-76.

Fellows, R. and Liu, A., 2008. Impact of Participants' Values on Construction Sustainability. *Proceedings of the ICE - Engineering Sustainability*, 161(4), 219-227.

Goh, C. and Rowlinson, S., 2013. Conceptual Maturity Model for Sustainable Construction. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 5(4), 191-195.

Hill, R.C. and Bowen, P.A., 1997. Sustainable Construction: Principles and a Framework for Attainment. *Construction Management and Economics*, 15(3), 223-239.

Kibert, C.J., 2007. The Next Generation of Sustainable Construction. *Building Research and Information*, 35(6), 595-601.

Kibert, C.J., 2008. *Sustainable Construction: Green Building Design and Delivery*. New Jersey: John Wiley and Sons, Inc.

Myers, D., 2005. A Review of Construction Companies' Attitudes to Sustainability. *Construction Management and Economics*, 23(8), 781-785.

Opoku, A. and Ahmed, V., 2013. Understanding Sustainability: A View from Inta-Organisational Leadership within UK Construction Organisations. *International Journal of Architecture, Engineering and Construction*, 2(2), 120-130.

Pearce, D., 2006. Is the Construction Sector Sustainable? : Definitions and Reflections. *Building Research and Information*, 34 (3), 201-207.

Smith, A. and Pitt, M., 2011. Sustainable Workplaces and Building User Comfort and Satisfaction. *Journal of Corporate Real Estate*, 13(3), 144-156.

Said, I., Osman, O. Mohd Shafikei, M.W., Abdul Razak, R. and Abdo Rashideh, W.M., 2008. Identifying the Indicators for Sustainability in the Construction Industry. *The International Journal of Organisational Innovation*, 2(3), 336-350.

Talbot, J. and Venkataraman, R., 2011. Integration of Sustainability Principles into Project Baselines Using a Comprehensive Indicator Set. *International Business and Economic Research Journal*, 10(9), 29-40.

WCED, 1987. *Our Common Future*. Oxford: Oxford University Press.

DISPUTE ADJUDICATION BOARD AS AN ADR METHOD IN THE CONSTRUCTION INDUSTRY OF SRI LANKA

Mahesh Abeynayake*
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Unresolved disputes can lead to project delay, increased tension and can damage long term business relationship. As a result, Alternative Dispute Resolution (ADR) methods were evolved during the passage of time to resolve construction disputes. Dispute Avoidance Procedures, which include Dispute Review Boards (DRB) and Dispute Adjudication Boards (DAB) are used in the construction industry since those methods are encourage parties to resolve their disputes at site level. The DAB first started to use in Sri Lanka after the FIDIC (1999) red book was introduced to use and due to the insistence of the World Bank and Asian Development Bank as funding agencies for the mega development projects. Although many research papers of foreign countries stated that their success with the DAB, Sri Lankan construction industry mostly practiced adjudication in ad-hoc manner. This research was carried out to provide suggestions to overcome the barriers to implement the full term DAB method in Sri Lanka. Therefore, it is indeed necessary to find out the genuine reasons behind the reluctance of stakeholders in Sri Lankan construction industry towards ADR methods and why stakeholders even do not use adjudication which has been recognized as an effective and efficient ADR method, elsewhere in the world. Questionnaire survey was carried out among contractor and consultant organisations and semi structured interviews were carried to gather descriptive answers from them. The research revealed the barriers to implement the full term DAB in Sri Lanka and provides suggestions to overcome those barriers. The research would also be conducted based on the provisions in Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer (FIDIC 1999) first edition and Standard Bidding Document Procurement of Works Major Contracts (ICTAD/SBD/02) second edition. A pivotal conclusion of this research is that the stakeholders in the construction industry prefer "adjudication" as an effective ADR method.

Keywords: *ADR Methods; Disputes; Dispute Adjudication Board; FIDIC.*

1. INTRODUCTION

Ashworth and Hogg (2002) decades the perceived shortcomings of construction dispute litigation, with its attendant costs, delays, and adversarial relationship have led to the growing preference for Alternative Dispute Resolution (ADR) methods. Examination of the literature, some of the methods could be better defined as Dispute Avoidance Procedure (DAP) instead of ADR methods.

DAP may appear in the form of several identities and distinct approaches, namely, Dispute Review Board (DRB), Dispute Adjudication Board (DAB) and Dispute Resolution Adviser (DRA). A Dispute Board (DB) comprises a board of one or three persons, independent of the contracting parties, engaged to perform an overview role of the execution of the project and the contract. Its primary function is to assist the parties to avoid disputes if possible or if not, to assist them to a speedy, cost effective and acceptable resolution of disputes, and avoid the need for litigation. The FIDIC suite of contracts provides for two distinct types of DAB. The first type is the "full-term DAB", which comprises one or three members who are appointed before the contractor starts executing the works, and who typically visit the site on a regular basis thereafter. The second type is an "ad-hoc DAB". The mechanism of Dispute Boards achieved such prominence and success in a relatively short time because of the significant advantages they offer in comparison to more traditional forms of dispute resolution. Although the success rates of DBs are encouraging, the process is not a panacea. The benefits that can be derived from DBs are highly

* Corresponding Author: E-mail - abey92@hotmail.com

contingent on careful planning and implementation. The research findings revealed that a few of stakeholders knew the actual procedures in adjudication and the vast difference between adjudication and arbitration and ad-hoc DAB is the most common way in DAB practicing in Sri Lanka. In Sri Lanka full-term DAB is rarely practicing. Therefore the aim of this research was to provide suggestions to overcome barriers to implement full term DAB in Sri Lanka. Specific objectives have been set to identify the advantages, disadvantages , critical factors of DAB and identify the barriers to implement the Full-term DAB in Sri Lanka and suggestions to improve the full-term DAB practice in Sri Lanka.

The major criticism of ADR methods is waste of time. It would lead to further delay in the settlement of the dispute due to unequalled litigation process. Secondly ADR methods would reveal too much of one's case or strategy to the opposition; eg. for those seeking to obtain information on the other side tactics and weakness. Another criticism has been that no adequate time to assess the details of the dispute. Many researchers have stated that most of the ADR methods are non-binding and identify it as a weakness (Horman, 2003; Fullerton, 2005).Finally, some writers criticize the involvement of legal professionals in ADR practice. They argue that ADR methods may be hijacked by the legal professionals sometimes would lead to legalism and formalism of its procedures (Brooker, 1993).

2. DISPUTE ADJUDICATION BOARD (DAB)

Adjudication is a method that the disputes are referred to a neutral third party for a decision which is binding on the parties only until the dispute is finally resolved by arbitration or litigation. This was a principle developed in the English legal system and finally held in the case of Macoh Civil Engineering Ltd. vs. Morrisson Construction Limited. In this case the Court held that 'Adjudication process intended to be a speedy mechanism for settling disputes in construction contracts on a provisional interim basis and requiring the decisions of adjudicators pending the final determination of disputes by arbitration or litigation'. This method of dispute resolution was introduced in England by Housing Grants, Construction and Regeneration Act in 1996 and the concept behind adjudication was aided by recommendations of Sir Michael Latham's fundamental review of the construction industry published in the report '*Constructing the Team'* in 1994 (Planterose, 2003; Sims, 2003). The Housing Grants, Construction and Regeneration Act (HGCRA) enacted in 1996 and it includes an adjudication procedure (Coutts and Dann, 2009). HGCRA granted adjudication with a legal enforceability. The Act came into force on 1st May 1998 and applies to all construction contracts entered into after that date in UK. However the Act currently applies only to written contracts and Act says that every construction contract should enable the parties to it to refer their disputes to adjudication under a procedure that complies with the Act.

At the commencement of the contract, parties agree to the appointment of an adjudicator known as the Dispute Adjudication Board (DAB) or a sole adjudicator. Latham (1994) has recommended referring the disputes which cannot be resolved first by the parties themselves in good faith to the adjudicator for a decision. He recommends that the board should be independent, and panel of names should be in the contract to deal with all major disputes. Since the board being an independent it would definitely improve the effectiveness of the decision making process.

Dispute Boards (DB), sometimes referred to as Dispute Review Boards (DRB) or Dispute Adjudication Boards (DAB) were evolved from the role of the engineer as decision maker in the first instance under various standard forms of construction contracts. The International Federation of Civil Engineers (FIDIC), a prolific publisher of standard form contracts for international projects, introduced the DAB in response to the condemnation of the dual role performed by the engineer as both the client`s agent and independent decision maker. In FIDIC -1999 published there major sets of condition of contract (the red, yellow and silver books) all of which contained DAB provisions. FIDIC Conditions of Contracts (1999) has introduced the Dispute Adjudication Board (DAB) system as a pre arbitration requirement. However, Adjudication is not more popular in Sri Lanka, because of non-availability of governing international convention and non-availability of statute locally.

A decision that has a quasi-binding effect, where the decision is binding unless the dissatisfied party follows the appropriate procedural rules, will allow the parties to maintain a less adversarial and more amicable relationship on the construction site while giving the parties an opportunity to contest a DAB decision that they feel is particularly egregious, erroneous, or improper for a DAB to decide. The DAB has broad power to establish procedural rules, decide upon its own jurisdiction, and decide the scope of any dispute. The DAB has the power to take its own steps to ascertain facts required to make a decision, including employing the use of its own specialist.

3. FIDIC CONDITIONS OF CONTRACT AND DAB

In FIDIC suite of contracts provides for two distinct types of DAB.

- Full term DAB
- Ad-hoc DAB

Full term DAB comprises one or three members who are appointed before the contractor starts executing the works, and who typically visit the site on a regular basis thereafter. The main reason for a full term DAB is to deal with disputes on or related to the construction site. A standing panel may also be able, if desired by the parties, to act as an informal sounding board when issues first arise and before they are formally referred to dispute resolution. The second type of DAB is the ad-hoc board, which comprises one or three members who are only appointed if and when a particular dispute arises, and whose appointment typically expires when the DAB has issued its decision on that dispute. It loses the distinct advantage of having an on-call DAB to assist in making decisions.

The conditions provide for reference of any dispute arising between the parties to the Dispute Adjudication Board (DAB) comprising one or three persons for its decision to be given within 84 days or such other time as is proposed by the DAB and approved by the parties. The decision of the DAB is binding unless and until intervened by other methods of dispute resolution provided by the conditions of the contract. If either party is dissatisfied with the decision or the DAB does not deliver its decision within the specified time limit it may give notice of dissatisfaction to the other party within 28 days after the decision or after the specified time limit, and the dispute will be referred to the next stage which is called arbitration. According to the FIDIC conditions if either party does not refer the dispute to the arbitration within the specified time period, the Adjudicators' decision becomes final and binding upon the Employer and the Contractor.

The requirement of the qualities and the quantities of persons, who are participate in the DAB has defined here. FIDIC Red book stated (under clause 20.2) that provisions for appointment of Dispute Adjudication Board. Accordingly there should be three qualified persons requires to be appoint and out of those three, one person should be serve as a chairman and the termination of a member would be able to enforce by a mutual agreement of both parties. Under the clause 20.4 to the FIDIC conditions of contract (as an Obtaining dispute adjudication board's decision), if there has been arose a dispute in the contract, as according to the aforesaid condition that the matter has to be inform to the DAB in writing to their further examinations and decisions with copies to the other party and to the Engineer. Within 84 days after giving such kind of reference to the DAB or within acceptable time duration by the both parties, the DAB's final decision has been express.

In addition to that if either party has disagreed with the decision given by the DAB, then they have to state their disagreement to the other party within 28 days after the DAB's decision. Furthermore after giving the notice of dissatisfaction, then they can attempt to the amicable settlement of the dispute. If it is not successful then the arbitration process shall begin after the 50 – 60 day of the notice of dissatisfaction is given.

4. ICTAD CONDITIONS OF CONTRACT AND DAB

According to the ICTAD conditions 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 refer 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 to the dispute.

The clause 19.2 of the SBD No. 02 of ICTAD stated provisions for appointment of Dispute Adjudication Board (DAB). Accordingly it has given its' 1st priority for adjudication process as a method of dispute resolution for any kind of dispute arose in construction projects. Also parties should appoint an DAB within 28 days from the date of commencement of the project. The requirement of the qualities and the quantities of persons, who are participating in the DAB has defined here. (Under clause 19.2 as Appointment of Dispute Adjudication Board as same as per the FIDIC Redbook under clause 20.2 as Appointment of Dispute Adjudication Board). Accordingly there should be three qualified persons requires to be appoint and out of those three, one person should be serve as a chairman and the termination of a member would be able to enforce by a mutual agreement of both parties.

Under the clause 14.1 of the SBD 03 of ICTAD there is a provision for Dispute Resolution.That it says for any kind of dispute they should go to an adjudication process rather than going for any other ways of dispute resolution. In the case of adjudication each party should have to give 07 days' notice to the other party by initiating the reference of dispute. When appointing the Adjudicator, ICTAD shall be the adjudicator unless the bidder expresses his or her disagreement in bidding document. Within 14 days from the letter of acceptance, contractor and the employer should able to appoint an adjudicator by their mutual consents. If not then the ICTAD shall appoint the adjudicator by the request of contractor or employer after expire of 28 days. As the same way the professional fee of the adjudication process should have to bear equally by the both parties.

Within the period of 28 days the adjudicator should give his or her determination. And each party can give any information or documents with reference to the process. And all the reference information and the documents kept in confidential by the adjudicator or the parties. After examine all relevant information and the other evident documents with respect to the dispute, ultimately the adjudicator has to give his final decision for the considered matter. And the decision given from the process of adjudication, and it is final and binding, unless if neither party express their objection before 28 days from the Adjudicator's determination.

5. LEGAL ASPECTS OF THE CONSTRUCTION ADJUDICATION

As per the arguments of Gould (2003) the legal characteristics of the Adjudication can be surnmarised in to five groups.

- The Adjudicator is a neutral individual who is not involved in the day-to-day running of the contract. He or she is neither an arbitrator, nor a state appointed Judge
- The Adjudicator's decision is temporary binding on the parties, and therefore, unlike mediation, the process does not require the co-operation of both parties
- The adjudicators' decisions are usually expressed as being binding until the end of the contract when either party may seek a review of the decision, most commonly by arbitration
- The adjudication is not arbitration and is therefore it is not subject to the Arbitration Act

In the case of Discain Project Services Ltd vs. Opecprime Ltd (2000), BLR 402 courts observed as *the adjudicator is working under pressure of time and circumstance which makes it extremely difficult to comply with the rules of natural justice in the manner of a Court or an Arbitrator".*

Ling (2006) has been suggested that, while the manner by which the principles of natural justice apply to arbitration and court proceedings have been well established, it may be unrealistic to expect adjudicators acting under severe time constraints in the context of the legislation to comply with these principles to the same extent.

Humphrey Lloyd QC J in his judgment in the English case of Balfour Beatty Construction Ltd. vs Lambeth London Borough Council (2002) EWHC 597, concurred that, *"principles of natural justice applied to adjudication may not require a party to be aware of the case that it has to meet in the fullest sense since adjudication may be inquisitorial or investigative rather than adversarial"*

In Sri Lanka the DAB comes in to effect in most of contract only after completion of the project. That is the ad-hoc DAB procedure is mostly practiced and also sometimes a dispute board is selected on a stand by basis and parties are not inviting adjudicator to site visit and meetings.

6. RESEARCH METHODOLOGY

For this research preliminary survey, detailed questionnaire survey and semi structured interviews were carried out to collect data from the construction industry. Questionnaires were distributed among 30 professionals in the consultant and contracting organisations and semi structured interviews were carried out among 5 professionals in the dispute resolution field. The questionnaire requested the respondents indicate their degree of agreement, on a five point Likert scale ranging from very low degree of agreement to very high degree of agreement. Mean weighted rating was used to analysis of data collected from questionnaire survey and content analysis was used to analysis the data collected from semi structured interviews.

7. DATA ANALYSIS

Dispute Adjudication board achieved prominent success in the construction industry due to its significant advantages over other most traditional dispute resolution methods. The professionals in the construction industry identified following advantages which can be gain from the full- term DAB over arbitration. Advantages were ranked based on the mean weighed rating worked out by the questionnaire survey as shown in Table 1.

Table 1: Advantages of DAB

Statement	Rank
Reduce and shorten the dispute resolution process	1
Enhances of credibility of the decision	2
Provide a Dispute Avoidance mechanism	3
DAB is addressed the disagreements or dispute, without the need for the historical reconstruction of events as in arbitration	4
Better communication among parties	5

7.1. CRITICAL FACTORS OF DISPUTE ADJUDICATION BOARD

There are many advantages of DAB process. But the benefits that can be gained from the DAB depend on the careful implementation of the DAB process. Seven factors were identified which are affecting to a successful DAB by the researcher through literature review and preliminary survey. Critical success factors were ranked based on the mean weighed rating worked out by the questionnaire survey as shown in Table 2.

Table 2: Critical Factors of DAB

Statement	Rank
Expertise for DAB should be selected based on the nature of the project	1
The Dispute Board need to receive relevant documentation during the course of works and site visits should be maintained throughout	2
DAB members should be carefully selected to provide a balance of experience and technical expertise.	3
The selection of panel members respected by the parties for their neutrality, integrity and expertise is important for a successful DAB	4
The success of the DAB process depend largely on the owner and the contractor`s mutual trust and confidence in the board itself	5

The success of DAB process depends on contracting parties satisfaction with every member. Therefore both parties must carefully investigate nominees to ensure that each nominee is experienced and technically qualified. If either party is uncomfortable with a member of a DAB the DAB process become ineffective. The ability to analyze the technical matters is very essential characteristic of a DAB member. Otherwise there is a high risk of failing the disagreement addressed properly. Each member should also have a certain amount of knowledge of contract administration and the ability to interpret contractual provisions. Absence of these loses the parties confidence on the member, and the DAB process and it leads to DAB procedure ineffective. The type of disputes varies according to the nature of the project. And the technical expertise required for the project based on the nature of the project. Therefore expertise for the DAB should be selected based on the nature of the project. The nature of the project defines the areas which DAB members should be expertise. This is a process largely based on the attitudes of the parties, the mutual trust and confidence of the board is a major success factor. Also regular site visits, meetings and reports from the parties are important to make fair decisions. In addition to that DAB members need to keep updated relevant project correspondence, monthly and other periodic reports, modifications to contract documentation, and potential disputes. Site visits should be maintained in a frequency that DAB members can sufficiently informed about the working progress and the probable conflicts.

7.2. BARRIERS TO IMPLEMENT OF FULL - TERM DISPUTE ADJUDICATION BOARD IN SRI LANKA

Moreover in Sri Lankan context, although the DAB appointed at site level parties are not being invited the DAB members for the site visits. Maintaining site visits throughout the project and receiving relevant documentation is a critical factor of a DAB. Therefore, this situation directly affect to the success of the DAB. In Sri Lankan culture professionals tend to go for next solution even though they feel the decision given by the DAB is correct. Therefore absence of legal framework to enforce the decision is directly affected to the successful implementation of the DAB. Further very few construction industry professionals are acting as adjudicators in Sri Lanka. Due to this reason contracting parties may unable to select an adjudicator based on the nature of the project. But this is a major success factor of the DAB. Further it diminish the opportunity of selecting parties by balancing experience and technical expertise, selecting parties for their neutrality, integrity, and the parties confidence of the DAB. Therefore this barrier leads to diminish most of the critical success factors of DAB. If DAB decision cannot be enforced the cost of maintaining a DAB throughout the project is a waste. Most of the contracting parties believe that the cost of maintaining a DAB throughout the project is a waste. This perception of high cost is a major barrier to implement the Full- term DAB in Sri Lanka. Since most of the contracting parties use the Sri Lankan conditions of the contract for their projects familiarity with the full term DAB is very less. Although the FIDIC conditions of contract contains provisions for full term DAB, most of the contracting parties not use the FIDIC document for their contracts. This is a major barrier to implement Full-term DAB in Sri Lanka.

7.3. SUGGESTIONS TO IMPROVE FULL - TERM DISPUTE ADJUDICATION BOARD IN SRI LANKA

Suggestions were presented for the purpose of minimizing the barriers to implement the DAB practice in Sri Lanka and generate the critical success factors of DAB directly as follows.,

- Conducting awareness programmes
- Develop a mechanism to directly enforce the decisions of DAB
- Incorporate a full-term DAB provision to the domestic (ICTAD) standard conditions of contracts

Further the contracting parties to a construction project should educate themselves about how to properly use the DAB process. Moreover since this is a mechanism which is based on the mutual trust and confidence of the parties unlike the adversarial system, the attitudes of the parties directly affect to the success of the DAB. Therefore attitudes of the parties should be changed. The industry professionals should be encouraged to enter in to this field and work as adjudicators to develop this field. Since the technical competence and experience of the adjudicator is a main success factor of the DAB adjudicators should be borne by the construction industry itself. Therefore by giving necessary knowledge of the DAB process and its benefit to the industry and the professional should be welcome to this field. Since FIDIC clauses also not provide a direct way to enforce the DAB decision, developing a mechanism to enforce the decision is very important. Majority of the contracting parties are reluctant to use this mechanism since the decision of the DAB not enforceable. By developing a mechanism to directly enforce the DAB decision this barrier can be minimized. If DAB can get an institutional support the contracting parties' mutual trust on the DAB can be improved and the attention of the contracting parties can direct to the DAB process. Further the construction industry professionals who are involved in producing contract documents can take a step to incorporate the full term DAB to domestic contracts.

8. CONCLUSIONS

The DAB allows more experience and greater relevant expertise to be applied to construction disputes. The strength of the adjudication process is that it provides a rapid and cost effective mechanism for deciding a dispute, which can be undertaken during a project without major distraction from the overall project objectives. A major advantage of the DAB is that it can operate on site and resolve issues before leaving the site. The results showed that Sri Lankan construction industry can gain numerous advantages from the full-term Dispute Adjudication Board including shorten the dispute resolution process, dispute avoidance, better communication among parties. However, several barriers impeding to gain those advantages from full-term Dispute Adjudication Board. To gain the advantages from the full-term DAB in Sri Lanka critical factors should be generated and Barriers should be minimized. Drawing from the results of this study, it is recommended to implement institution for conduct DAB process in Sri Lanka and conduct awareness programmes for industry practitioners who are willing to become construction industry professionals in the future to improve the full-term DAB procedure in Sri Lanka. Adjudication was identified as the most effective mechanism for resolution of construction disputes while Arbitration is the most popular method for dispute resolution in Sri Lanka.

9. REFERENCES

Ashworth, A. and Hogg, K., 2002. *Willis`s practice and procedure for the quantity surveyor*. 11th ed. Blackwell Science Ltd.

Brooker, P. and Lavers, A., 1997. Perceptions of alternative dispute resolution as constraints upon its use in the UK construction industry. *Construction management and economics*, 15, 519-526.

Balfour Beatty Construction Ltd VsLambeth London Borough Council, 2002. EWHC 597.

Bunni, N.G., 2005. *The FIDIC forms of contract*.3rd ed. London: Blackwell Publications Ltd.

Cheung, S. and Suen, H.C.H., 2002. A multi attribute utility model for dispute resolution strategy selection. *Construction management and economics*, 20, 557-568.

De Zylva, E., 2007. Alternative dispute resolution systems for construction contracts.In:Kanag- Isvaran, K.and Wijeratne, S.S., ed.*Arbitration law in Sri Lanka*. Colombo: ICLP, 117-138.

Discain Project Services Ltd Vs. Opecprime Ltd, 2000. BLR 402.

FIDIC, 2000. *The FIDIC contractors guide*. Geneva: International Federation of Consultant Engineers

Gerber, P.A., 2001. Dispute avoidance procedures(DAP`s) the changing face of construction dispute management [Online] Available from:http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2270265 [Accessed 10 January 2015].

Marzouk, M. and Moamen, M., 2009. A framework for estimating negotiation amounts in construction projects. *Construction innovation*, 9(2), 133-148.

Murdoch, J. and Hughes, W., 2008.*Construction contract law and management*. 4th ed. Oxon: Taylor and Francis.

Macoh Civil Engineering Ltd. Vs. Morrisson Construction Limited, 1999. 18 BLR 174.

Oladapo, A. and Onabanjo, B., 2009. A study of the causes and resolution of disputes in the Nigerian construction industry [online]. In: RICS (Royal Institution of Charted Surveyors), *RICS construction and building research conference.* Cape Town 10-11 September.RICS. Available from:*http://www.bailii.org/ew/cases/EWHC/TCC/1999/254.html* [Accessed 10 January 2015].

Seifert, B.M., 2005. International construction dispute adjudication under international federation of consulting engineers conditions of contract and the dispute adjudication board. *Journal of professional issues in engineering education and practice,* 131(2), 149-157.

Silver, K., 1991. Electronic Mail: The New Way to Communicate. In: Raitt, D.I., ed. *9th International Online Information Meeting*, London 3-5 December 1990. Oxford: Learned Information, 323-330.

Stiponwich, T.J., 1997. At the cutting edge, conflict avoidance and resolution in the US construction industry.*Construction economics and management*, 15, 505-512.

EFFECT OF ACCURACY AND TIMELINESS OF INFORMATION ON PERFORMANCE OF CONTRACTORS

Jeyapalan Suventhiny* and Himal Suranga Jayasena
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Improper information flow within the construction parties are most frequently experienced in Sri Lankan construction industry. Due to this situation, contractors faced several difficulties on their performance in terms of cost, time, and quality. Therefore, this paper intends to identify the accuracy and timeliness of information on performance of contractors. The aim is to identify how deficiencies in accuracy and timeliness of information affect performance of contractors in terms of cost, time, and quality. The outcome of this study will be beneficial for practitioners in Sri Lankan construction industry to reduce practical issues related accuracy and timeliness of information. Detailed questionnaire survey was used to identify the significant factors relating to accuracy and timeliness of information. Findings revealed that 'mistakes in design' and 'incomplete drawings' as the most significant factors on cost performance of contractors; 'delay in design', and 'slow drawing revision and distribution' as the most significant factors on time performance of contractors and 'mistakes in design' and 'incomplete drawings' as the most significant factors on quality performance of contractors. Further, factors were categorized as agreed factors and disagreed factors based on contractors' and clients' and consultants' perspectives. Important finding of the study is that there are number of factors considered highly significant by contractors but clients and consultants do not assume them to be so. Furthermore, the study recommended clients, contractors and consultants to hold their responsibilities with regard to information related issues on performance of contractors. Findings will be further useful to build a good relationship between stakeholders and improve the performance of contractors.

Keywords: *Cost; Information; Performance of Contractors; Quality; Time.*

1. INTRODUCTION

The construction industry faces a number of problems and challenges related to the successful completion of projects (Ofori, 2000; Krima *et al.*, 2007). Further, construction industry largely depends on team work and every stakeholder have agreed goals with regard to cost, time and quality for achieving the project success (Leung *et al.*, 2004). Conventionally, client or consultant continually conveys the risks to the contractor (Acharya *et al.*, 2006). Therefore, performance of contractor is a critical component to the success of any construction project since it is the contractor who converts designs into practical actuality (Xiao and Proverbs, 2003; Wong *et al.*, 2008). Further, Xiao and Proverbs (2003) state that performance of the contractor has long been defined in terms of cost, time and quality.

Several studies have been conducted to examine factors impacting on performance of contractors in developing countries such as; planning and scheduling of work activities, errors in project design and documentation work, inaccurate estimating, inaccurate taking off, delays in approvals, delays in progress payments, slow decision making by client and information and communication between the parties (Assaf *et al.*, 1996; Alwi *et al.*, 2002; Nawaz *et al.*, 2013; González *et al.*, 2014). Therefore, effective management of information improves the performance of project and contractors (Davenport and Beers, 1995).

Information plays a significant role in modern construction industry. Further, information quality displays the degree of accuracy with which reality is represented and information should be available on time,

* Corresponding Author: E-mail - jjsuba1990@gmail.com

when required and accuracy is characterized by perfect conformity to fact or truth; strictly correct and timeliness is defined as being at the right time (Chitkara, 1998). Therefore, contractor using incomplete and inaccurate design information is one of the problems that cause delays in construction. Furthermore, inaccurate design information cause defects in construction works and increase the reworks (Abdul-Rahman *et al.*, 2006). In addition, Lingard and Rowlinson (2005) state that the less accurate information related in as built drawings have an adverse impact on project completion. According to Toor and Ogunlana (2008), contractor waiting for information is one of the top ten problems causing construction delays. Due to this delay in information hinders contractor in receiving interim payments from public agencies which in turn can affect his cash flow affecting directly to construction performance. Further, the delay in design information causes difficulties in obtaining work permits and can affect to the performance of contractors.

In construction industry, the more detailed the information, the more realistic it becomes to plan the project in detail and hence, the more realistic it is to include detailed programs (Mawdesley *et al.*, 1997). Production information is prepared at an early stage of the project in sufficient detail to work out a tender or tenders to be obtained (Royal Institute of British Architects, 2007). According to Fewings (2005), production information flow is traditionally controlled by an information required schedule. Furthermore, information required schedule delivers a database about the contractor's estimation for the lead time plus a contingency from winning a given tender up to completion of works.

Since the information is not properly dealt, the construction projects mostly end up with delay and cost overrun (Al-Momani, 2000). The significant cost and time overruns subsequently leads for the quality issues in those projects. Those issues in cost, time, and quality are commonly identified as the poor performance in construction projects (Lo *et al.*, 2006). This poor performance is very much concerned by both client and contractor. Thus, it is highlighted that the accuracy and timeliness of information directly effects on performance of contractors.

Drawings, specifications and other contract documents are mostly used and given high priority as the sources of information for entire construction of a project (Institute for Construction Training and Development [ICTAD], 2007). In Sri Lankan traditional construction projects, the detailed information of these documents were unavailable during the initial stage. Therefore, contractors suffer without a clear picture of the project. This situation and improper information flow within the construction parties are most frequently experienced in Sri Lankan construction industry. Due to this situation, contractors faced several difficulties on their performance in terms of cost, time, and quality. Hence, the research gap was found to understand this effect of accuracy and timeliness of information on performance of contractor from existing literature. This paper is structured in six sections including a literature review, research methodology, and research findings. Finally, the conclusions have been drawn presenting the how deficiencies in accuracy and timeliness of information affect performance of contractors in terms of cost, time, and quality.

2. LITERATURE REVIEW

Increasing competition and deep variations are imposing construction professionals to constantly improve the performance in the construction industry (Ali *et al.*, 2013). In addition, the successful completion of a project is usually operated in terms of cost, time and quality performance (Hatush and Skitmore, 1997). Thereby, poor performance condemns the construction industry (Lee *et al.*, 2000; Kogioglou *et al.*, 2001; Bassioni *et al.*, 2005).

These stakeholders are performing in different ways relating to their own views (Lai and Lam, 2010). Chan and Chan (2004) state that every stakeholder have specific objectives related their field and criteria for evaluating achievement. Wang and Huang (2006) prove that criteria of project success significantly interrelated to the performance of clients and contractors. There is, therefore, a definite requirement for the client to have better performance of contractors in the construction industry.

Contractors should continuously improve the construction process and operation, project quality, project management and administration (Luu *et al.*, 2008). In addition, contractor is a responsible person for managing the construction project on site to the definite quality and to the planned schedule. Degree of performance of contractor is gathered from many projects and contractors characteristics include; contract value, experience in construction industry, size of contractors, deviation between project value and second lowest bidder, homogeneity of manpower, deviation between contract value and estimated value, and the number of change orders (Assaf *et al.*, 1996). However, the performance of contractor is a controversial but significant issue in the construction industry. Furthermore, Xiao *et al.* (2000) emphasize many factors comprising, legal, technical, managerial, cultural, environmental, and economic issues impact on performance of contractors. Furthermore, information is one of the factor effect on the performance of contractors (Davenport and Beers, 1995).

Titus and Brochner (2005) elaborated that information plays a vital role in construction environment during all stages. Chitkara (1998) defines information as a collection of data which has been proven to be accurate and timely, reduces uncertainty and risks, must be reliable, comprehensive, error free, precise, clear, consistent and understandable by those who need it. Modern day construction industry is highly competitive and projects require teamwork and management with data and information exchange between whole parties that will be responsible for the conceptualization, design, construction, management, operation, and maintenance activities during all phases of the project life cycle (Soibelman and Caldas, 2000).

Viljamaa and Peltomaa (2014) discuss that combined information is required for efficient decision making in construction projects. Aouad *et al.* (1995) emphasized that every phase of a construction project involves a large amount of professionals who need lot of information at many times. Therefore, in the production of a large amount of complex information which is often managed uneconomically. Hence, Aouad *et al.* (1995) introduced the new idea to improve effectiveness and improve the combination of information within the construction industry, it is necessary to establish an appropriate information framework. It is also important to adopt and use a central database where information integrity and reliability can be maintained. The management of the construction network requires different information at different levels of decision making, such as planning, programming, to design and implementation (Prabodhani, 2012). Moreover, input of information is required at all stages of construction. Every party have some specific situation regarding the working conditions that affect needs for and use of information (Ambrose, 1997).

In accurate information describes error or omission or non-conformance or imperfection in information. It determines the quality of information (Jr *et al.*, 1992). Miscalculations, misinterpretations, and omissions are considered to erroneous acts. Although some actions are identifiable as being erroneous, defining the term “error” is an arduous task (Wantanakorn *et al.*, 1999; Lopez *et al.*, 2010).

Client or client’s representatives should issue the information and documents within a particular time to the contractor. If any delays occur in delivering documents or information, it should be occur many conflicts and disputes such as cost overrun, delays and scheduling conflicts. Moreover, International Council for Building Research Studies and Documentation (1993) reported that an error or an omission always leads to a defect. Thus, any inaccurate information are generate the problems in construction. Tan and Lu (1995) stated that cost, scheduling and performance problems can invariably be tracked back to the problem of the quality of design, such as error, incompleteness, and lack of constructability. Kululanga *et al.* (2001) highlighted that most of the claims were caused by contract documents owing to errors, defects, and omissions. Moreover, Royal Institution of Chartered Surveyors (2007) noted that inaccurate information issuing delays can mislead contractors, resulting in contract variations and potential time related or cost related claims. Furthermore, improper preparation of all documents may cause overruns, poor performance.

Many researchers have mentioned this factor which is affecting the performance (Ledbetter, 1994; Xiao and Proverbs, 2003; Acharya *et al.*, 2006; Enshassi *et al.*, 2009; Azis *et al.*, 2013; Memon *et al.*, 2014). Due to these causes, this paper had focused on accuracy and timeliness of information in construction industry. Summary of twenty previous researches on information related factors effect on performance of contractors during post construction stage were reviewed and categorized in Table 1. The review highlights many number of information related problems, considered by the authors.

Table 1: Impact on Information Related Factors on Performance of Contractors

Performance Criteria	Factors	Source
Cost	▪ Lack of quality and detail of drawings ▪ Delay in design and approvals ▪ Absence of construction cost data ▪ Inaccurate cost estimation ▪ Slow information flow between parties ▪ Waiting time for approval of tests ▪ Poor provision of information to project participants ▪ Incomplete drawings ▪ Slow drawing revision and distribution ▪ Slow information flow between project team members ▪ Deficient documentation (specification and design) ▪ Inaccurate quantity take-off ▪ Inadequacy of plans ▪ Unclear information	Sonmez *et al.* (2007); Azhar *et al.* (2008); Le-Hoai, Lee *et al.* (2008); Enshassi *et al.* (2009); Creedy *et al.* (2010); Baloyi and Bekker (2011); Arcila (2012); Azis *et al.* (2013); Hwang *et al.* (2013); González *et al.* (2014)
Time	▪ Inaccurate estimates ▪ Mistakes in design ▪ Waiting time for approval of tests ▪ Poor provision of information to project participants ▪ Low speed of decision making within each project team ▪ Incomplete drawings ▪ Delays in design work / Lack of design information ▪ Slow drawing revision and distribution ▪ Slow information flow between project team members ▪ Inaccurate quantity take-off ▪ Mistakes and discrepancies in contract documents ▪ Design error due to unfamiliarity with the local conditions o environment, and the materials ▪ Lack of data in estimating the activity duration and resources	Arditi *et al.* (1985); Sullivan and Harris (1986); Chan and Kumaraswamy (1996); Ogunlana *et al.* (1996); Odeh and Battaineh (2002); Aibinu and Odeyinka (2006); Faridi and El-Sayegh (2006); Sambasivan and Soon (2007); Le-Hoai *et al.* (2008); Enshassi *et al.* (2009); Baloyi and Bekker (2011); González *et al.* (2014)
Quality	▪ Error or omission made by designer of product or process ▪ Incomplete drawings	Ledbetter (1994); Acharya *et al.* (2006)

3. METHODOLOGY

The aim of this study was to identify how deficiencies in accuracy and timeliness of information affect the performance of contractors. Survey method proved to be the most appropriate. Hence, the study does not require the control of behavioural elements and focuses on contemporary events.

A detailed questionnaire survey was carried out to identify the deficiencies in accuracy and timeliness of information affect the performance of contractors in terms of cost, time, and quality in contractors', consultants' and clients' perspective. Information on a total of 113 construction professionals was obtained consisting of 43 contractors, 39 consultants and 31 clients. Median, 1st quartiles, 3rd quartiles, and percentiles was calculated to achieve the aim of identifying the significant factors that influence the accuracy and timeliness of information on performance of contractors in terms of cost, time, and quality. Furthermore, median and 3rd quartiles have been used to identify the factors, which have same opinion among contractors, and clients and consultants, and which have conflict opinions by contractors, and clients and consultants. Mann-Whitney U test was used to identify the disagreement level of factors, which have conflict opinions from both groups of respondents. The Mann-Whitney U test was used whether the medians of two sets of data are significantly different from one another. The ordinal scale was adopted and transformed to Mann Whitney U value as shown in the formula:

$$U_1 = (n_1 \times n_2) + (0.5n_1)(n_1 + 1) - \sum R$$

Where,

U = the test statistic

n_1 = number of samples in group 1

n_2 = number of samples in group 2

$\sum R$ = sum of ranks of group 1 or group 2 (If $\sum R_1 > \sum R_2$, $\sum R_1 = \sum R$) (Eq: 01)

4. FINDINGS

4.1. FACTORS IN AGREEMENT ON COST PERFORMANCE OF CONTRACTORS

Table 2 displays the factors in agreement for effect of accuracy and timeliness of information on cost performance of contractors based on overall rank derived from all the respondents viz. contractor, client and consultants organisations. It also shows the rank given by contractors for the same factors for comparison.

Table 2: Factors in Agreement on Cost Performance of Contractors

No	Factors	Contractors' Rank
D3	Mistakes in design	2
D2	Incomplete drawings	1
S1	Mistakes and discrepancies in specification	3
C3	Missing information	4
D1	Lack of quality and detail of drawings	5
S2	Multiple meanings and confusions in specifications	9
C1	Mistakes and discrepancies in contract documents	10
C2	Unclear information in contract documents	12
T2	Delay in design	6
T5	Waiting time for approval of tests	14

Most Significant

Least Significant

From the data in Table 2, all these factors were agreed on effect level of accuracy and timeliness of information on cost performance of contractors by contractors, clients and consultants unanimously. These agreed factors were arranged in descending order of significance based on calculations of 10th percentile, 90th percentile since, median, 1st quartile, and 3rd quartile were equivalent for both groups. Therefore, percentiles were selected and factors were ranked accordingly. According to Table 2, incomplete drawings, mistakes in design and mistakes and discrepancies in specifications were ranked 1st, 2nd and 3rd by contractors respectively.

4.2. FACTORS IN DISAGREEMENT ON COST PERFORMANCE OF CONTRACTORS

Table 3 displays the factors in disagreement for effect of accuracy and timeliness of information on cost performance of contractors among all the respondents from contractor, clients and consultants organisations.

Table 3: Factors in Disagreement on Cost Performance of Contractors

Most Disagreement

No	Factors in disagreement	Rank (Contractor)	Rank (Client and Consultant)	Test statistic
T3	Slow drawing revision and distribution	7	12	1734.5
T4	Delay in responding to request for information	8	13	1692
T1	Slow information flow between parties	13	9	1528.5
S3	Deficient documentation	11	8	1428.5

Least Disagreement

According to Table 3, slow drawing revision and distribution, delay in responding to request for information, slow information flow between parties, and deficient documentation have a conflict of opinion on cost performance from both parties. These factors were arranged based on disagreement level between both parties. Slow drawing revision and distribution had the most significant difference in opinion between both parties and deficient documentation had less significant difference in opinion between both parties.

4.3. Factors in Agreement on Time Performance of Contractors

Table 4 depicts the factors in agreement for effect of accuracy and timeliness of information on time performance of contractors based on overall rank among all the respondents viz. contractor organisations and clients and consultants organisations. It also shows the ranks given by contractors for the same factors for comparison.

As depicted in Table 4, delay in design, slow information flow between parties, delay in responding to request for information, waiting time for approval of tests, slow drawing revision and distribution, lack of quality and detail of drawings, deficient documentation, missing information, unclear information in contract documents, and mistakes and discrepancies in contract documents were discussed based on effect level of accuracy and timeliness of information on time performance of contractors. All these factors were agreed on effect level of accuracy and timeliness of information on time performance of contractors by contactors, and clients and consultants in the same manner. These agreed factors were arranged in descending order of significance based on calculations of 10^{th} percentile, 90^{th} percentile since, median, 1^{st} quartile, and 3^{rd} quartile were equivalent for both groups. Therefore, percentiles were selected and factors were ranked accordingly.

Table 4: Factors in Agreement on Time Performance of Contractors

Most Significant

No	Factors	Contractors' Rank
T2	Delay in design	1
T3	Slow drawing revision and distribution	3
T4	Delay in responding to request for information	4
T1	Slow information flow between parties	2
T5	Waiting time for approval of tests	5
D1	Lack of quality and detail of drawings	7
S3	Deficient documentation	10
C2	Unclear information in contract documents	13
C3	Missing information in contract documents	11
T5	Mistakes and discrepancies in contract documents	12

Least Significant

According to Table 4, delay in design, slow information flow between parties, and slow drawing revision and distribution were ranked 1st, 2nd, and 3rd by contractors respectively. Mostly, time related factors had significant effect on timeliness of information on time performance of contractors.

4.4. FACTORS IN DISAGREEMENT IN TIME PERFORMANCE OF CONTRACTORS

Table 5 displays the factors in disagreement for effect of accuracy and timeliness of information on time performance of contractors among all the respondents from the contractor organisations, and clients and consultants organisations.

Table 5: Factors in Disagreement on Time Performance of Contractors

No	Factors in disagreement	Rank (Contractor)	Rank (Client and Consultant)	Test statistic
D3	Mistakes in design	6	9	1775
S2	Multiple meanings and confusions	10	13	1748.5
S1	Mistakes and discrepancies in specifications	12	8	1675
D2	Incomplete drawings	8	6	1533

Most Disagreement → Least Disagreement

According to Table 5, mistakes in design, multiple meanings and confusions in specifications, mistakes and discrepancies in specifications, and incomplete drawings have conflict of opinion on time performance of contractors from both parties. These factors were arranged based on disagreement level of both parties. Mistakes in design had most significant difference in opinion between both parties and incomplete drawings had least significant difference in opinion between both parties.

4.5. FACTORS IN AGREEMENT ON QUALITY PERFORMANCE OF CONTRACTORS

Table 6 displays the factors in agreement for effect of accuracy and timeliness of information on quality performance of contractors based on overall rank derived viz. all the respondents from the contractor organisations and clients and consultants organisations. Furthermore, all these factors were ranked according to all respondents' point of view from Sri Lankan construction industry. It also shows the rank given by contractors for the same factors for comparison.

Table 6: Factors in Agreement on Quality Performance of Contractors

No	Factors	Contractors' Rank
D3	Mistakes in design	1
D2	Incomplete drawings	4
S1	Mistakes and discrepancies in specifications	2
D1	Lack of quality and detail of drawings	3
C2	Unclear information in contract documents	8
C1	Mistakes and discrepancies in contract documents	6
C3	Missing information in contract documents	9
T4	Delay in responding to request for information	10
T3	Slow drawing revision and distribution	12

Most Significant → Least Significant

From the data in Table 6, all these factors were agreed on effect level of accuracy and timeliness of information on quality performance of contractors by contactors, and clients and consultants in the same manner. These agreed factors were arranged in descending order of significance based on calculations of

10th percentile, 90th percentile since, median, 1st quartile, and 3rd quartile were equivalent for both groups. Therefore, percentiles were selected and factors were ranked accordingly.

According to Table 6, mistakes and discrepancies in contract documents, mistakes in design, mistakes and discrepancies in specifications were ranked 1st, 2nd, and 3rd by contractors. Mostly, time related factors had less significant effect of timeliness of information on time performance of contractors compared to other factors.

4.6. *FACTORS IN DISAGREEMENT ON QUALITY PERFORMANCE OF CONTRACTORS*

Table 7 displays the factors in disagreement for effect of accuracy and timeliness of information on quality performance of contractors among all the respondents from the contractor organisations, and clients and consultants organisations.

Table 7: Factors in Disagreement on Quality Performance of Contractors

No	Factors In Disagreement		Rank (Contractor)	Rank (Client And Consultant)	Test Statistic
S2	Multiple meanings and confusions	Most Disagreement	5	6	1652.5
T5	Waiting time for approval of tests		13	9	1523.5
T2	Delay in design		14	12	1364.5
T1	Slow information flow between parties		11	8	1321.5
S3	Deficient documentation	Least Disagreement	7	4	1215

According to Table 7, multiple meanings and confusions, waiting time for approval of tests, delay in design, slow information flow between parties, and deficient documentation have conflict of opinion on quality performance between both parties. These factors were arranged based on disagreement level of both parties. Multiple meanings and confusions in specifications had the most significant difference in opinion between both parties and deficient documentation had least significance difference in opinion from both parties.

4.7. *FACTORS CONSIDERED HIGHLY SIGNIFICANT BY CONTRACTORS ONLY*

Table 8 displays the factors in disagreement which are considered highly significant by contractors. However, clients and consultants do not assume them to be so.

Table 8: Factors Considered Highly Significant by Contractors Only

Cost	Time	Quality
Slow drawing revision and distribution	Mistakes in design	Multiple meanings and confusions
Delay in responding to request for information	Multiple meanings and confusions	

According to Table 8, slow drawing revision and distribution, delay in responding to request for information are considered highly significant factors by contractors on cost performance of contractors. Mistakes in design and multiple meanings and confusions are considered highly significant factors by contractors on time performance of contractors. Multiple meanings and confusions is considered highly significant factor by contractors on quality performance of contractors. However, Clients and consultants do not assume them to be so. Therefore, clients and consultants do not give more attention on these factors.

5. CONCLUSION

From the findings of the study, it can be concluded that accuracy and timeliness of information have very high significant effect on the performance of contractors in Sri Lankan construction industry. Moreover, drawings and specification related factors have significant effect on cost and quality performance of contractors. Time related factors have considerable effect on time performance of contractors. Contract documents related factors have moderate effect on performance of contractors. 'Slow drawing revision and distribution', 'delay in responding to request for information', 'slow information flow between parties', and 'deficient documentation are disagreement factors on cost performance of contractors. 'Mistakes in design', 'multiple meanings and confusions', 'mistakes and discrepancies in specifications', and 'incomplete drawings' are disagreement factors on time performance of contractors. 'Multiple meanings and confusions', 'waiting time for approval of tests', 'delay in design', 'slow information flow between parties', and 'deficient documentation' are disagreement factors on quality performance of contractors. However, the most important finding of the study is that there are number of factors considered highly significant by contractors but clients and consultants do not assume them to be so. These are 'slow drawing revision and distribution' and 'delay in responding to request for information' on cost performance of contractors, 'mistakes in design' and 'multiple meanings and confusions' on time performance of contractors, and 'multiple meanings and confusions' on quality performance of contractors. Clients and consultants do not give more attention on these factors. Therefore, contractors suffer with cost and time overrun and quality issues related these factors. Consultants and clients should realize the significant factors and decrease the errors and delays in information. It can be improve the performance of contractors.

Finally, this research gives rise to a further researches direction to study on design and build projects and contractors supplied documents. In addition, this study was limited to performance of contractors. Therefore, a similar type of research can be conducted to study the performance of project.

6. REFERENCES

Abdul-Rahman, H., Berawi, M.A., Berawi, A.R., Mohamed, O., Othman, M. and Yahya, I.A., 2006. Delay Mitigation in the Malaysian Construction Industry. *Journal of Construction Engineering and Management,* 132(2), 125-133.

Acharya, N.K., Lee, Y.D. and Im, H.M., 2006. Conflicting Factors in Construction Projects: Korean Perspective. *Engineeering, Construction and Architectural Management,* 13(6), 543-566.

Acharya, N.K., Lee, Y. and Kim, J., 2006. Design Errors: Inefficiency or Carelessness of Designer?. *Journal of Performance of Constructed Facilities,* 20(2), 192-195.

Aibinu, A. A. and Odeyinka, H. A., 2006. Construction Delays and Their Causative Factors in Nigeria. *Journal of Construction Engineering and Management,* 132(7), 667-677.

Ali, H.A.E.M., Al-Sulaihi, I. A. and Al-Gahtani, K..S., 2013. Indicators for Measuring Performance of Building Construction Companies in Kingdom of Saudi Arabia. *Journal of King Saud University – Engineering Sciences,* 25(2), 125-134.

Al-Momani, A.H., 2000. Construction Delay: A Quantitative Analysis. *International Journal of Project Management,* 18(1), 51-59.

Alwi, S., Hampson, K. and Mohamed, S., 2002. Factors Influencing Contractors' Performance in Indonesia: A Study of Non Value-Adding Activities. In: *Proceedings International Conference on Advancement in Design, Construction, Construction Management and Maintenance of Building Structure,* Bali 27-28 March 2002. 20-34.

Ambrose, J., 1997. *Building Construction.* India: Chapman & Hall, Inc.

Aouad, G., Kirkham, J., Brandon, P., Brown, F., Child, T., Cooper, G., Ford, S., Oxman, R. and Young, B. (1995). The Conceptual Modelling of Construction Management Information. *Automation in Construction,* 3(4), 267-282.

Arcila, S.G., 2012. *Avoiding Cost Overruns in Construction Projects in the United Kingdom.* Thesis (M.Sc.). The University of Warwick.

Arditi, D., Akan, G.T. and Gurdamar, S., 1985. Reasons for Delays in Public Projects in Turkey. *Construction Management and Economics*, 3(2), 171-181.

Assaf, S.A., Al-Hammad, A. and Ubaid, A., 1996. Factors Effecting Construction Contractors' Performance. *Building Research & Information*, 24(3), 159-163.

Azhar, N., Farooqui, R.U. and Ahmed, S. M., 2008. Cost Overrun Factors in Construction Industry of Pakistan. In: *First International Conference on Construction in Developing Countries*, Karachi 4-5 August 2013. 499-508.

Azis, A.A.A., Memon, A.H., Rahman, I.A. and Karim, A.T.A., 2013. Controlling Cost Overrun Factors in Construction Projects in Malaysia. *Research Journal of Applied Sciences, Engineering and Technology,* 5(8), 2621-2629.

Baloyi, L. and Bekker, M., 2011. Causes of Construction Cost and Time Overruns: The 2010 FIFA World Cup Stadia in South Africa. *Acta Structilia,* 18(1), 51-67.

Bassioni, H. A., Price, A. D. F. and Hassan, T. M., 2005. Building a Conceptual Framework for Measuring Business Performance in Construction: An Empirical Evaluation. *Construction Management and Economics,* 23(5), 495-507.

Chan, A. P. C. and Chan, A. P. L., 2004. Key Performance Indicators for Measuring Construction Success. *Benchmarking: An International Journal*, 11(2), 203-221.

Chan, D.W.M. and Kumaraswamy, M.M., 1996. An Evaluation of Construction Time Performance in the Construction Industry. *Building and Environment,* 31(6), 569-578.

Chitkara, K.K., 1998. *Construction Project Management Planning, Scheduling and Controlling.* Haryana: Tata McGraw-Hill Publishing Company Limited.

Creedy, G. D., Skitmore, M. and Wong, J. K. W., 2010. An Evaluation of the Risk Factors Leading to Cost Overrun in the Delivery of Highway Construction Projects. *Journal of Construction Engineering and Management,* 136(5), 528-536.

Davenport, T. and Beers, M., 1995. Managing Information about Processes. *Journal of Management Information Systems,* 12(1), 57-80.

Enshassi, A., Al-Najjar, J. and Kumarasamy, M., 2009. Delays and Cost Overruns in the Construction Projects in the Gaza Strip. *Journal of Financial Management of Property and Construction,* 14(2), 126-151.

Enshassi, A., Mohamed, S. and Abushaban, S., 2009. Factors Affecting the Performance of Construction Projects in the Gaza Strip. *Journal of Civil Engineering and Management,* 15(3), 269-280.

Faridi, A.S. and El-Sayegh, S.M., 2006. Significant Factors Causing Delay in the UAE Construction Industry. *Construction Management and Economics*, 24(11), 1167-1176.

Fewings, P., 2005. *Construction Project Management: An Integrated Approach*. USA: Taylor & Francis.

González, P., González, V., Molenaar, K. and Orozco, F., 2014. Analysis of Causes of Delay and Time Performance in Construction Projects. *Journal of Construction Engineering and Management,* 140(1), 1-9.

Hatush, Z. and Skitmore, M., 1997. Evaluating Contractor Pre Qualification Data: Selection Criteria and Project Success Factors. *Construction Management and Economics,* 15(2), 129-147.

Hwang, B., Zhao, X. and Ng, S.Y., 2013. Identifying the Critical Factors Affecting Schedule Performance of Public Housing Projects. *Habitat International,* 38, 214-221.

Institute for Construction Training and Development [ICTAD], 2007. *SBD 2.* 2nd ed. Colombo: Institute for Construction Training and Development (ICTAD).

International Council for Building Research Studies and Documentation , 1993. *Post-Construction Liability and Insurance.* London: E&FN Spon.

Jr, J.L.B., Farrington, J.J. and Ledbetter, W.B., 1992. Causes of Quality Deviations in Design and Construction. *Journal of Construction Engineering and Management,* 118(1), 34-49.

Kogioglou, M., Cooper, R. and Aouad, G., 2001. Performance Management in Construction: A Conceptual Framework. *Construction Management and Economics*, 19(1), 85-95.

Krima, N.A., Wood, G., Aouad, G.F. and Hatush, Z., 2007. Assessing the Performance of Libyan Supervising Engineers. *Construction Management and Economics,* 25(4-6), 509-518.

Kululanga, G.K., Kuotcha, W., McCaffer, R. and Edum-Fotwe, F., 2001. Construction Contractors' Claim Process Framework. *Journal of Construction Engineering and Management,* 127(4), 309-314.

Lai, I.K.W. and Lam, F.K.S., 2010. Perception of Various Performance Criteria by Stakeholders in the Construction Sector in Hong Kong. *Construction Management and Economics,* 28(4), 377-391.

Ledbetter, W.B., 1994. Quality Performance on Successful Project. *Journal of Construction Engineering and Management,* 120(1), 34-46.

Lee, A., Cooper, R. and Aouad, G., 2000. A Methodology for Designing Performance Measures for the UK Construction Industry. In: *Bizarre Fruit Postgraduate Research Conference on the Built and Human Environment,* 1-12.

Le-Hoai, L., Lee, Y.D. and Lee, J.Y., 2008. Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries. *KSCE Journal of Civil Engineering,* 12(6), 367-377.

Leung, M., Chong, A., Ng, S.T. and Cheung, M. K., 2004. Demystifying Stakeholders' Commitment and Impacts on Construction Projects. *Construction Management and Economics,* 22(7), 701-715.

Lingard, H. and Rowlinson, S., 2005. *Occupational Health and Safety in Construction Project Management. USA: Taylor & Francis.*

Lopez, R., Love, P.E.D., Edwards, D.J. and Davis, P.R., 2010. Design Error Classification, Causation, and Prevention in Construction Engineering. *Journal of Performance of Constructed Facilities,* 24(4), 399-408.

Lo, T. Y., Fung, I. W. and Tung, K. C., 2006. Construction Delays in Hong Kong Civil Engineering Projects. *Jouurnal of Construction Engineering and Management,* 132(6), 636-649.

Luu, V. T., Kim, S. and Huynh, T., 2008. Improving Project Management Performance of Large Contractors Using Benchmarking Approach. *International Journal of Project Management,* 26(7), 758-769.

Mawdesley, M., Askew, W. and O'reilly, M., 1997. *Planning and Controlling Construction Projects: The Best Laid Plans....* England: Chartered Institute of Building.

Memon, A.H., Rahman, I. A., Abdullah, M.R. and Azis, A.A.A., 2014. Factors Affecting Construction Cost Performance in Project Management Projects: Case of Mara Large Projects. *International Journal of Civil Engineering and Built Environment,* 1(1), 30-35.

Nawaz, T., Shareef, N.A. and Ikram, A.A., 2013. Cost Performance in Construction Industry of Pakistan. *Industrial Engineering Letters,* 3(2), 19-33.

Odeh, A.M. and Battaineh, H. T., 2002. Causes of Construction Delay : Traditional Contracts. *International Journal of Project Management,* 20(1), 67-73.

Ofori, G., 2000. *Challenges of Construction Industries in Developing Countries: Lessons from Various Countries.* Thesis. National University of Singapore.

Ogunlana, S.O., Promkuntong, K. and Jearkjirm, V., 1996. Construction Delays in a Fast-Growing Economy: Comparing Thailand with Other Economics. *International Journal of Project Management,* 14(1), 37-45.

Prabodhani, S. S., 2012. *Successful Information Flow of Road Construction Projects: Study of Time Perspective to Prevent the Delays and Claims.* Unpublished Dissertation (B.Sc). University of Moratuwa.

Royal Institute of British Architects, 2007. *RIBA Work Stages.* British: Royal Institute of British Architects.

Royal Institution of Chartered Surveyors, 2007. *RICS New Rules of Measurement.* UK: Royal Institutions of Chartered Surveyors.

Sambasivan, M. and Soon, Y. W., 2007. Causes and Effects of Delays in Malaysian Construction Industry. *International Journal of Project Management,* 25(5), 517-526.

Soibelman, L. and Caldas, C., 2000. Information Logistics for Construction Design Team Collaboration. *Computing in Civil and Building Engineering,* 341-348.

Sonmez, R., Ergin, A. and Birgonul, M.T., 2007. Quantitative Methodology for Determination of Cost Contingency in International Projects. *Journal of Management in Engineering,* 23(1), 35-39.

Sullivan, A. and Harris, F.C., 1986. Delays on Large Construction Projects. *International Journal of Operations & Production Management,* 6(1), 25-33.

Tan, R.R. and Lu, Y., 1995. On the Quality of Construction Engineering Design Projects: Criteria and Impacting Factors. *International Journal of Quality & Reliability Management,* 12(5), 18-37.

Titus, S. and Brochner, J., 2005. Managing Information Flow in Construction Supply Chains. *Construction Innovation: Information, Process, Management*, 5(2), 71-82.

Toor, S.R., and Ogunlana, S.O., 2008. Problems Causing Delays in Major Construction Projects in Thailand. *Construction Management and Economics*, 26(4), 395-408.

Viljamaa, E. and Peltomaa, I., 2014. Intensified Construction Process Control Using Information Integration. *Automation in Construction,* 39(1), 126-133.

Wang, X. and Huang, J., 2006. The Relationships between Key Stakeholders' Project Performance and Project Success: Performance of Chinese Construction Supervising Engineers. *International Journal of Project Management*, 24(3), 253-260.

Wantanakorn, D., Mawdesely, M.J. and Askew, W.H., 1999. Management Errors in Construction. *Engineering. Construction and Architectural Management,* 6(2), 112-120.

Wong, P.P., Cheung, S. and Chow, A.Y., 2008. The Effect of Contractors' Learning on Performance. CIB International Conference on Building Education and Research, Heritance Kandalama 11-15 February 2008. 36-37.

Xiao, H. and Proverbs, D., 2003. Factors Influencing Contractor Performance: An International Investigation. *Engineering, Construction and Architectural Management*, 10(5), 322-332.

Xiao, H., Proverbs, D. G., Shaw, T. and Holt, G.D., 2000. A New Approach to Comparing the Performance of Contractors Internationally. In: Akintoye, A., ed. *16th Annual ARCOM Conference,* 6-8 September 2000. 117-125.

EFFECTIVE LEADERSHIP BEHAVIOURS IN CONSTRUCTION SAFETY PRACTICES

Zakari Mustapha*, Clinton Aigbavboa and Wellington Didi Thwala
Department of Construction Management and Quantity Surveying,
Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

ABSTRACT

Effective leadership behaviours have been shown in literature to be a contributing factor to construction safety practices. However, researchers have neglected the leadership behaviours and have their focus on the construction projects features of management. The inclusion of leadership as a part of an organisation has been the subject of interest all over the world. This development has driven researchers' interest to come out in a holistic manner to give the clear understanding of leadership. The review of literature in the existing body of knowledge becomes paramount in order to continue with the research on the subject matter. The review will also enable the road map for the future to be drafted. This development has led to the review of empirical studies conducted by researchers on leadership in the construction industry. The research adopted literature study from various sources such as reviews of leadership behaviour in the construction safety practices. This review of literature led to the selection of appropriate literature for the study. A rigorous process was carried out in the selection of appropriate literature for the study, from a total number of fifty-two studies reviewed, out of which thirty-five empirical studies were selected. The findings from literature were summarised through coding, according to the publication outlet, authors, nature of the study, country of publication, target population, methodology and key findings. It was found out that most of the empirical studies have focussed on construction projects features management, while less attention has been given to several other equal dimensions, particularly leadership behaviours in the construction industry. This study focussed mainly on the effective leadership strategies in achieving organisational goals. Discussions also included the health and safety improvement in the construction industry and types of motivational measures for safety

Keywords: *Behaviours; Effective Leadership; Safety Practices.*

1. INTRODUCTION

The construction industry has the third highest fatality rate and the ninth highest permanent disability rate per 1000 00 as reported by the South African Construction Industry Development Board (CIDB) (in Smallwood, 2010). The high rate of mortality among construction firms has been attributed to the risk and problems they faced. The construction industry has also been known to be the most risky business arena (Ofori1 and Toor, 2012). Hosseinian and Torghabeh (2012) asserts that most of the delays in project completion and high rise of company's expenditure are due to accidents in the construction industry. The reputation and reliability of contractors are ruined due to the delay in the project. They further indicated that high rates of accidents and fatalities in the construction industry have placed it among hazardous industries. Construction Health and Safety (H&S) is not improving (CIDB, 2009) even though, significant efforts have been made by several agencies to improve H&S within the construction industry in South Africa. Report from the South African Construction Industry Development Board (CIDB, 2009) shows that construction continues to contribute a disproportionate number of fatalities and injuries. This has contributed to the continuous high level of non-compliance with the Health and Safety (H&S) regulations in South Africa. Michaels (2012) asserted that there is the need to implement safety and health management systems and develop a culture of safety at workplaces to assist in accident prevention. This

* Corresponding Author: E-mail - zakarimustapha1967@gmail.com

paper presents an exploratory study of effective leadership behaviours in construction safety practices. It began with leadership in the construction industry and strategies of an effective leader in achieving organisational goals. This is followed by effective leadership behaviours, leadership roles, personality, values and emotional commitment, safety practices and health and safety improvement in the construction industry.

2. RESEARCH OBJECTIVES

The study addresses the following questions: Leadership in the construction industry.

Who is an effective leader?

Which strategies will be effectives for achieving organisational goals?

Which type of safety practices will contribute to the safety of employees?

Which type of motivation will lead to safety improvement?

How can effective communication and training contribute to safety practices?

From a discussion based on the key works in the literature, effective leadership behaviour that will lead to safety practices is explained.

What it means to be an effective leader in construction, and what it takes to succeed as an effective leader in construction are discussed.

3. LEADERSHIP IN THE CONSTRUCTION INDUSTRY

The capacity to engage people and groups outside one's formal control and inspire them to work toward common goals. Despite differences in convictions, cultural values, and operating norms are termed as collaborative leadership (Ibarra and Hansen, 2011, cited in Ofori and Toor 2012). A wide range of reasons have been cited for the failures in the construction industries in developing countries (Enshassi *et al.*, 2006 cited Ofori and Toor, 2012). Koksal and Arditi (2004) cited Ofori and Toor, 2012) cited insufficient capital, lack of business knowledge, fraud, managerial experience, line experience, commitment, poor working habits and environmental problems. Such as weaknesses in the industry, the impact of various disasters, poor growth prospects as well as high interest rates as the reasons for organisational failures in the construction industry. Reports of severe deficiencies in project performance such as, cost and time overruns, poor quality, technical defects, poor durability, and inadequate attention to safety and environmental issues (Ofori, 2012). Poor performance has also been reported as one of the greater implications. Little knowledge of any of the aspects of construction by the clients, end purchasers, users and other stakeholders of the construction industry have also been mentioned. There is a lack of appreciation, among researchers of the dangers of ineffectiveness of leaders in the construction industry. This calls for a greater need for leadership in construction in the developing countries to be developed to achieve organisational goals. Many models of leadership have shown their importance. The current study was undertaken on effective leadership behaviours in the construction safety practices. Research has indicated that effectiveness is a fundamental to good leadership. Gandz (2005) defines an effective leader simply as someone with good knowledge of construction workplace and strategies to organisational safety practices.

4. STRATEGIES OF AN EFFECTIVE LEADER IN ACHIEVING ORGANISATIONAL GOALS

Any effective leader is required to have good knowledge of workplace to be able to sense what is coming up ahead. This will enable him to see opportunities that should be the target of action and to see threats before they materialize. He should be able to establish means of achieving the goals of the organisation in order to get results. The role of the leader is to develop the right strategies to get results-winning strategies. An effective leader must be able to lead his workers for a very long time. He should as well be able to carry-out the work at hand properly.

Strategies to be carried out should be very valuable and well executed. And execution of any plan is only valuable if the strategy is right. An effective leader should be able to take note of progress of work and make necessary changes at any stage of work. He should be able to recognize any task that is not well executed. So that, care will be taken to monitor the outcomes systematically and thoroughly. He should always be in the position to make some changes in the strategies to achieve the organisational goals. Assessment of the works carried out should be done to put him on alert and be able to take any necessary action. A highly effective leader should be able to raise the level of his sensitivity to different information when new strategies are being introduced. An effective leader should always look for information that will inform and improve his strategic decisions to benefit of the organisational safety practices. This will pave way for any changes whenever it deems fit to strengthen the effort of the organisation. A highly effective leader should be able to act for both the short and the long terms simultaneously. Surveying of the work the environment is a must to enable him develop winning strategies for the organisation. The execution of the task should be done perfectly and monitoring must be carried out systematically. The core competencies of the organisation, management and leadership talents are built on through the effort of an effective leader (Gandz, 2005). Figure 1 shows the strategies in achieving organisational goals.

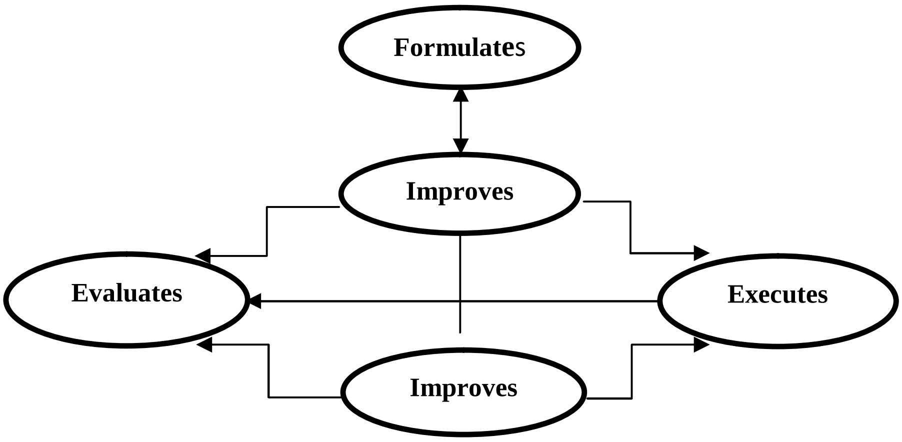

Figure 1: Strategies in Achieving Organisational Goals
Adapted from Gandz (2005)

There are three challenges of leadership namely: strategic, executional and developmental. Strategic involves both environmental surveillance and the formulation of winning strategies. While executional involves the implementation of those strategies, monitoring their impact and making adjustments as indicated. Developmental is based on building core competencies and cadres of leaders at all levels (Gandz, 2005).

5. EFFECTIVE LEADERSHIP BEHAVIOURS

A simple way of leadership practices or behaviour was developed by Kouzes and Posner (Business-Leadership-Quality (n. d.). Kouzes and Posner (1995) Model is made up of inspiration of the vision (IV), modelling of the way (MW), challenging the status quo (CS), encouraging the heart (EH) and enabling others to act (EO) as shown in Figure 2. These variables agree with the characteristics and traits of leadership.

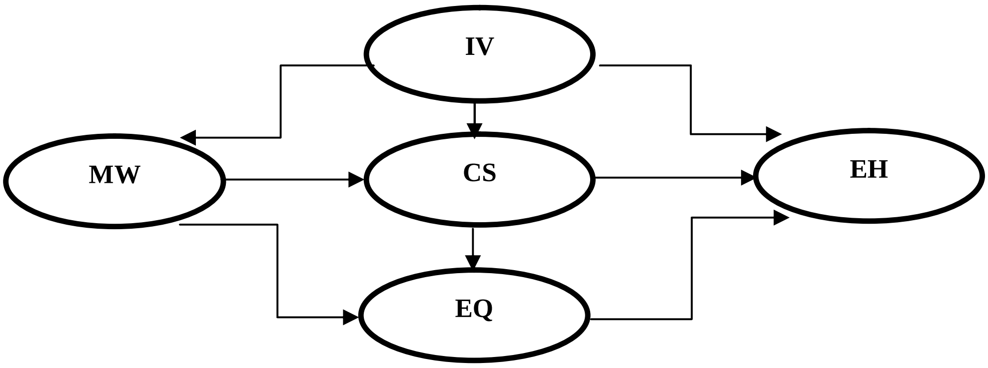

Figure 2: Kouzes and Posner (1995)
Source: Adapted from Business-Leadership-Quality (n.d.)

The strength and weaknesses of employees can be determined by the leader who works effectively in order to motivate them towards the achievement of the industry safety practices. Any leader expect good outcome from his employees works towards the achievement of the organisational goals by developing a strategy for his workers. The effective leader ensures that all employees receive appropriate training needed for their tasks. Give instructions and attach importance to employee's views to ensure smoothly running of the industry. Apart from these, the day to day activities of the industry is also managed. He provides report on the progress of any operation to be given to appropriate personnel the industry (Educational Portal, n.d.). The leader should be capable of developing and implementing a timeline for his workers to achieve the industry's goals. A leader should be able promote the principles of excellent teamwork among workers. This can be achieved by establishing values and goals to determine the activities before any action is taken (Tracy, 2008). Being an effective safety leader requires one to be aware of his responsibilities and commit himself to his work emotionally (Krause, 2007).

6. LEADERSHIP ROLES, PERSONALITY, VALUES AND EMOTIONAL COMMITMENT

The role of a leader becomes very important when an organisation focuses on safety improvement. Effective safety leadership has to do with several measurable and empirically-validated components. Figure 3 describes the personality (P), values (V) and emotional commitment (EC) of a leader and how he influences the safety practice in the construction industry (Krause, 2007).

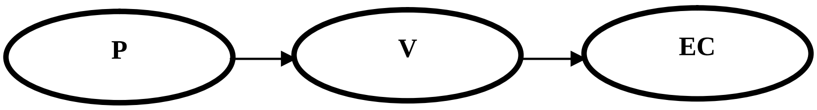

Figure 3: Effective Leadership
Source: Adapted from Krause (2007)

The core attributes that define personality in the "Big Five," are predictive of effective leadership. This has to do with change management, execution of organisational strategies, conflict handling and management of workers (Krause, 2007). The leadership personalities are in several form such: emotional resilience, extroversion, learning orientation, collegiality, and conscientiousness. A leader with emotional resilience can deal with stress and negative emotions when it comes to handling workers. An extroverted safety leader is always in contact with his workers about safety that helps to improve the safety practices of the construction industry. The aspect of learning orientation by the leader needs to be put under control even his creativity and new ideas that need. A highly collegial safety leader has his way of proving safety motivation to enable the workers put in their best at any assigned task. A highly conscientious leader has the competence and ability to handle safety issues in an excellent manner. This attribute minimise occurrences of incidents and accidents in the construction industry (Krause, 2007).A leader in a construction industry will show how valuable his tasks are and commit himself to the tasks ahead with high emotion. This will contribute the creation of safety culture and ensures that the organisation achieves its proper end (Krause, 2007).

7. Safety Practices in the Construction Industry

The Occupational Safety and Health Administration (OSHA) workplace safety requirements enshrine the provision of a safe work environment for your employees to protect them from any harm. Accident can be reduced if safety issues are attended to immediately. A comprehensive safety plan is needed to cater for hazards that occur. This should include hazards identification and handling, provision of warning signs, clearing of any material that may contribute to hazard. Training on how to handle minor injuries should be given to employees. Means of handling injured employees should be included in a detailed action plan. There should be a review on any occurrence of accident and how the problems are solved. Changes in safety policy should be made when necessary and training on new steps to be incorporated should be offered (Green, n.d.). The safety officers in the construction industry have the responsibility of ensuring that safety measures are followed strictly at the site. Construction sites activities are carried out as specified under the health and safety (H&S) regulations at workplace by the safety officer. This leads to compliance in the construction industry. He ensures the execution of industry’s policies and procedures, takes care of anything that concerns with safety, site inspection, training of new workers and upgrading of knowledge of workers on H&S and perusing legal requirements regarding workplace H&S. He also liaises with other institutions relating to programmes and issues on safety of the workplace and environment to ensure sanity at the construction sites (Petrick, n d.). The safety officer sees to the policies and procedures of the firm that comply with Occupational Health and Safety Acts (OHSA) rules. The safety officer should be conversant with the all relevant environment laws to enable him operate effectively. The safety concerns of firm in relation to complaints and reports received on dangerous working conditions at the sites for investigations. Site inspections are carried out by the safety officer with inspectors from the government agency to facilitate evaluation of construction sites. Training of employees on safety measures at workplace are carried out for effectiveness in safety practices. The safety officer also sees to the legal requirements by updating the management on legal regulations and liaises with other safety officer on behalf of his firm on safety matters. The occupational health risks management is placed on the employer under the management of Health and Safety (H&S) at Work Regulations 1999. Adeogun and Okafor (2013) asserted that a systematic planning approach is necessary to answer key questions with respect to Occupational Health and Safety (OHS).To meet these legal requirements as well as improving the organisation’s H&S performance and ultimately reduce risks and costs. The employers should have the following measures in place:

- H&S policies and procedures with practical arrangements for managing occupational health risks.
- Provision of employee awareness training on manual handling, control of substances hazardous to health, noise at work and hand arm vibration.
- Manual handling risk assessments and safe handling techniques for manual handling activities.
- Health surveillance, sickness absence management, return to work policy and stress management strategy.
- Arrangements for managing subcontractors, including procedures for managing their occupational health risks.
- Employers understanding their duties under the Construction (Design and Management) Regulations 2007 (CDM, 2007).

8. Health and Safety Improvement in the Construction Industry

It has been informed in literature that the approach used by the employers towards providing strategic safety commitment and a supportive work environment will contribute to the safety management behaviour of an organisation. Therefore, the leadership behaviours of leadership of any organisation is considered to be very important in the achievement of any organisational safety goals (Panthi *et al.*, 2012). Moreover, employers' behaviour contributes to encourage employees' safety compliance to OSH improvement in the construction industry. Jaselski *et al.* (1996 cited Zin and Ismail, 2011) are of the view that safety performance of any organisation can be achieved through the commitment and support received from management. Since management approach to safety generates and reinforces employee perceptions about what form of activity gets rewarded, supported and expected in a particular setting (Panthi *et al.*, 2012). Employees' behaviour towards H&S at the workplace can change through the type of commitment shown by management. Fernando and Janbi (2008) asserted that the employers should demonstrate their commitment through strongly realization of safety compliance to safety and ensure that everyone in the organisation is certain about their safety and health responsibilities. Bakshi *et al.* (2009) asserted that the critical factor in understanding and explaining the work related behaviour of employees in organisations should be linked with organisational commitment. Employees' behaviour will lead to the type of types of motivation for safety measures. Effective communication, training and education will also contribute to achieve safety at workplace.

8.1. EMPLOYEE BEHAVIOUR

Employee behaviour plays a significant role in workplace safety and injury prevention. Employee behaviour has been found to be one of the greatest determinants in workplace safety, especially as employees interact amid a host of varying safety issues (Schultz, 2004). Both employers and employees have very similar perceptions of the respective responsibilities of each party for health and safety in the workplaces. Health and safety is a set of rules and regulations that relate directly to safety in the workplace to ensure the general wellbeing for employees (Elgood *et al.*, 2004). Smallwood (2010) in a research conducted on excavation health and safety (H&S): a South African perspective has indicated worker attitude as one of the factors leading to unsafe act of a worker. Schultz (2004) asserted that attitude is a key to understanding employee behaviour and prevention of on-site-job injuries. It is therefore, mandatory for employer's to educate their employees on the possibility of workplace injury before any safety programme should be instituted. The organisation must undergo a culture change from the top and filter its way down to all employees for any attitudinal change to occur to every employees (Schultz, 2004). Central to this culture is the feeling that safety is a top priority and nothing else. Employee behaviour also relates to culture, and can be linked to ignorance (Smallwood, 2010). If this is checked it will lead to improvement towards health and safety in the construction industry.

8.2. TYPES OF MOTIVATION FOR SAFETY MEASURES

"According to Teo *et al.* (2005b) incentives can be used to motivate the ones who follow the safety rules on construction sites." Motivational tools including rewards and incentives influence to fostering safe work behaviour in construction sites (Teo *et al.*, 2005a). Each of these tools contains various sub tools as shown in below:

- Positive Reinforcement: Monetary reward/bonus, job promotion, certificate of recognition, rewards in kind (overseas trips), personal recognition
- Negative Reinforcement: Close and strict supervision
- Extinction: Termination of service, reporting to authorities
- Punishments: Imposing fines, suspension from work, demotion

  Teo *et al.* (2005) argues that close and strict supervision among negative reinforcement is the most effective, monetary rewards. Imposing fines and suspension from work are the third most effective way to foster safe work behaviour.

  Teo *et al.* (2005) proposed four suggestions can be used by managers to either encourage or discourage certain behaviours of workers (i.e. Positive reinforcement, negative reinforcement, punishment and extinction.

- Positive reinforcement

- Positive reinforcement provides the worker with reward consequence for performing the desired behaviour.

  Positive reinforcement enables motivation of workers to perform their jobs in a safe manner. Contractors should offer incentives, praise, monetary rewards, and promotions on the job (Teo *et al.*, 2005).

- Negative reinforcement

  Negative or avoidance reinforcement encourages workers to perform the desired behaviour in order to avoid a negative consequence. Contractors should use criticism or threat of losing job to motivate workers to perform their jobs in a safe manner (Teo et al., 2005).

- Punishment

  Punishment reinforcement gives the worker a negative consequence so that the worker can stop performing an undesirable behaviour. Concerning safety of construction site, punishments may include pay cuts, temporary suspensions, demotions and firing.

- Extinction

  Extinction reinforcement withholds positive consequences to get the worker to stop performing the undesirable behaviour. At the construction site, a worker who constantly flouts safety regulations may have his or her appointment terminated to curtail the unsafe practice.

8.3. EFFECTIVE COMMUNICATION

Effective communications is an essential consideration to safe and efficient workplace. Therefore, there is the need for effective communication in the construction industry because many construction accidents are found mainly caused by symptoms of safety non-compliance to safety requirements (Ismail and Majid, 2007). Communication can be achieved through visible behaviour, written communication of H&S policy statements and face to face discussions between employer and employee. In the visible behaviour, employer can communicates the importance of safety and health. Then, the employees soon recognize what employer regards as important and will adopt their behaviour accordingly. Thus, through negative behaviour employer can undermines the safety and health culture of the organisation (Zin and Ismail, 2011). While in the written communication of H&S policy statements, statements concerning H&S roles and responsibilities, performance standards and findings from risk assessments are made available to employees. Whereas, face to face discussions between employer and employee enable employees to make a personal contribution and helps them to feel involved in the safety and health of the organisation (Zin and Ismail, 2011). Ideally employees should be able to talk to employers during safety inspection. The interaction and communication of management with workers in terms of their commitment, support and motivation can have a positive (or negative) influence on workers. The influences are perceptions, attitudes, competence, and behaviours towards safety (Panthi *et al.*, 2012). Cooper, (2010) is of the view that employees attitude can be shaped through the leadership skills exhibited by senior management. “According to Ismail and Majid (2007) quality and consistency of leadership demonstrated by management as a role model for safety will enhance the achievement of the other safety management objectives”.

8.4. EFFECTIVE HEALTH AND SAFETY TRAINING AND EDUCATION

Accident prevention can only take place through effective health and safety training. The need for education and training of employees in all aspect of health and safety in the construction industry. Hence, education and training programmes play a significant role in enhancement of safety in construction and it is important to increase safety awareness and change behaviour of employees (Ghani *et al.*, 2010). Good relationship between employers and employees on matters such as safety talk and advice on safety matter is related to improve safety motivation and will encourage employees’ safety behaviour (Hassan *et al.*, 2007). Workers need to be aware of the hazards and risks at their workplace in order to encourage them to work in a healthy environment and safety manner (Smallwood, 2010) because lack of training is a barrier.

9. Research Design/ Methodology

The research method adopted is literature study from various sources such as literature reviews of leadership in the construction industry, strategies of effective leadership in achieving organisational goals and safety practices in the construction industry. Studies relevant to type of motivation for safety improvement, effective communication and training that will contribute to safety practices in the construction industry were also sought. The results from the literature study were analysed to obtain specific issues that are relevant to the effective leadership behaviours in construction safety practices.

10. Conclusions and Recommendations

The purpose of this academic paper was to highlight the effectiveness of leadership behaviours in construction safety practices. The review showed that leadership behaviours toward safety practices is the most powerful means of safety performance in the construction industry. The efforts shown by leadership behaviours towards occupational health issues will contribute to good safety practices in the construction industry. Management should be committed towards safety and health at the workplace to change employees' behaviour towards safety practices in the construction industry. There is the need for effective communications and good relationship between employers and employees on matters such as, safety talk and advice on safety matters. This will improve safety motivation and encourage employees' safety behaviour.

11. References

Adeogun, B.K. and Okafor, C.C., 2013. Occupational Health, Safety and Environment (HSE) Trends in Nigeri. *International Journal of Environmental Sciences, Management and Engineering Research* [online], 2(1). Available from: http:// www.ijesmer.com [Accessed 2 July 2014].

Bakshi, A., Kumar, K. and Rani, E., 2009. Organisational Justice Perceptions as Predictor of Job Satisfaction and Organisation Commitment. *Journal of International Business and Management*, 4(9), 145-154.

Hassan, C.C.R., Basha, O.J. and Hanafi, W.W.H., 2007. Perception of Building Construction Workers towards Safety, Health and Environment. *Journal of Engineering Science and Technology*, 2(3), 271-279.

Construction Industry Development Board (CIDB), 2009. *Construction Health and Safety in South Africa: Status and Recommendations* [online]. Available from: http://www.cidb.co.za [Accessed 16 June 2014].

Construction (Design and Management) Regulations (CDM), 2007. *Managing health and safety in construction. Approved Code of Practice* [online]. Available from: www.hsebooks.co.uk [Accessed 5 October 2014].

Cooper, D., 2010. Safety Leadership: Application in Construction Site. *Supplemento A, Psychologia*, 32(1), 18-23.

Educational Portal, n.d. *What Is a Team Leader? - Description, Role and Responsibilities* [online]. Available from: http://education-portal.com [Accessed 22 November 2014].

Elgood, J., Gilby, N. and Pearson, H., 2004. *Attitudes towards health and safety: a quantitative survey of stakeholder opinion*. Available from: http://www.hse.gov.uk/research/misc/attitudes.pdf [Accessed 22 May 2015].

Fernando, Y.Z.S. and Janbi, L., 2008. The Determinant Factors of Safety Compliance at Petrochemical Processing Area: Moderator Effects of Employees Experience and Engineering Background. In: *9th Asia Pacific Industrial Engineering & Management Systems Conference*. 442-1452.

Gandz, J., 2005. Leadership, Ivey Business Journal, *Improving the Practice of Management* [online]. Available from: http: /iveybusinessjournal.com [Accessed 22November 2014].

Ghani, M.K., Hamid, Z.A., Mohd, M.Z.M., Rahim, A.H.A., Kamar, K.A.M. and Rahman, M.A.R., 2010. Safety in Malaysian Construction: The Challenges and Initiatives. *Construction Research Institute Malaysia (CREAM)*, 16-19.

Green, C., n.d. *Best Safety Practices for the Workplace, Demand Media* [online]. Available from: www.http://smallbusiness.chron.com [Accessed 7 February 2015].

Hosseinian, S.S. and Torghabeh, Z.J., 2012. Major Theories of Construction Accident Causation Models: A Literature Review. *International Journal of Advances in Engineering & Technology*, 4(2), 53-66.

Ismail, F., Torrance, J.V. and Majid, A.M.Z., 2007. The Reflection of Management Commitment on OSH within the Malaysia Construction Organisation. In: *10th Conference and Exhibition of National Institute of Occupational Safety and Health (NIOSH),* Malaysia. 179-185.

Kouzes, J. M. and Posner, B. Z., 1995. *The leadership challenge: how to keep getting extraordinary things done in organisations.* California: Jossey-Bass.

Krause, T.H., 2007. *Leadership: The Effective Safety Leader: Personality, Values & Emotional Commitment* [online]. Available from: http://ehstoday.com [Accessed 18November 2014].

Michaels, D., 2012. *Outlines OSHA's Efforts to Shift the Safety Curve. National Safety Council Congress and Expo* [online]. Available from: www.EHSTODAY.com [Accessed 15 June 2014].

Ofori, G., 2012. *Developing the Construction Industry in Ghana: the case for a central agency* [online]. Available from: http://buildingcontractorsgh.com [Accessed 14 May 2015].

Ofori1, G. and Toor, S.R., 2012. Leadership Development for Construction SMEs. In: *EPOC 2012 Conference, Working Paper Proceedings, Engineering Project Organisations Conference*, Rheden, Netherlands 10-12 July 2012.

Panthi, K., Farooqui, R.U. and Umar, M., 2012. Assessment of Current Safety Attitudes and Approaches of Contractor Management in the Construction Industry- In: *The U.S Experience 48th ASC Annual International Conference Proceedings*, 2012. Associated Schools of Construction.

Petrick, J., 2015. *Duties of a safety manager Chron. Demand Media* [online]. Available from: http://work.chron.com [Accessed 22 November 2014].

Schulz, D., 2004. *Employee Attitudes-A Must Have* [online]. Available from: http://ohsonline.com/Articles/2004/06/Employee-AttitudesA-Must-Have.aspx [Accessed 22 May 2015].

Smallwood, J. J., 2010. Excavation health and safety (H&S): A South African perspective. In: Egbu, C., ed. *26th Annual ARCOM Conference,* UK 6-8 September 2010, Leeds: Association of Researchers in Construction Management, 233-241.

Teo, E. A., Ling, F. Y. and Chong, S., 2005a. Fostering Safe Work Behaviour in Workers at Construction Sites. *Engineering, Construction and Architectural Management*, 12(4), 410-422.

Teo, E. A, Ling, F. Y. and Chong, A. F., 2005b. Framework for Project Managers to Manage Construction Safety. *International Journal of Project Management*, 23(4), 329-341.

Tracy, B., 2008. *The Role of a Leader, Leaders are made, not born* [online]. Available from: http://www.entrepreneur.com [Accessed 23 November 2014].

Zin, M.S. and Ismail, F., 2011. Employers' Behavioural Safety Compliance Factors toward Occupational, Safety and Health Improvement in the Construction Industry, ASEAN. In: *Conference on Environment-Behaviour Studies*, Savoy Homann Bidakara Bandung Hotel, Bandung, Indonesia.

FEASIBILITY OF THE DELAY AND DISRUPTION PROTOCOL FOR CLAIMS MANAGEMENT IN SRI LANKAN CONSTRUCTION INDUSTRY

R.A.N.M. Pathirana* and L.D. Indunil P. Seneviratne
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Delay and disruption claims are difficult to resolve due to issues in claims management in construction industry. Those issues are occurred due to wrong practices in the industry and having vague areas in delay and disruption. Although, there are some methods to diminish delay and disruption events, still there is no proper way to deal with those issues. Having a guideline for claims management is an effective mechanism. In that scenario, Society of construction law's (SCL) delay and disruption protocol is the commonly used guideline in other countries and which have comprehensive scope. Hence, it is required to discover how far SCL protocol is appropriate to Sri Lankan construction industry. Therefore, the aim of this research is to investigate the feasibility of adopting SCL protocol for dealing with issues in delay and disruption in claims management in Sri Lankan construction industry. A comprehensive literature review, a questionnaire survey and semi structured interviews were done as the research method for this paper. Interviewees were selected from questionnaire survey. The findings of this study prove that having a guideline for claims management is important and awareness of SCL protocol in Sri Lanka is comparatively less. Further, it demonstrates that adopting SCL protocol to Sri Lankan construction industry is feasible. Management can achieve sustainable construction practices such as using human resource efficiently, willingness to work and effective time management. Finally, it confirmed that implementing SCL protocol will improve knowledge related claims management and it will enable to improve the claim practitioners' practices.

***Keywords**: Claims Management; Delay and Disruption; SCL.*

1. INTRODUCTION

Project delay and disruption are most critical problems in the construction industry (Aibinu and Jagboro, 2002). Chan *et al.* (2010) described delay and disruption in construction can occur due to a number of reasons such as late provision of information and drawings, design changes instructed by consultant, insufficient resources, incomplete and unclear drawings and poor risk management. Therefore, delay and disruption claims are quite seen often in the construction industry. However, delay and disruption events noticeably affect to the construction industry through time overrun and cost overrun (Aibinu, 2009). Nevertheless, Ward (2005) explained that time which is used to perform a construction work is very important for both client and contractor. But the problem is that even though, there are some well-established claims management practices, most of time delay and disruption claims develop as complicated when it comes to resolve because having issues in delay and disruption (Scott *et al.*, 2004). Those issues are occurred due to wrong practices in the industry and having unclear areas in delay and disruption. Therefore, most of claims remaining unresolved and lead to disputes (Ward, 2005). Hence, it is not unexpected that there should be a way to deal with these issues and to resolve the delay and disruption claims properly. In order to that it is important to evade those issues. Kumarswami and Yogeswaran (2003) concluded that it is worthy if there is an appropriate way or mechanism to resolve those issues in early stages rather than waiting until issues develop as disputes. Consistent with Nisansala (2009), having a proper policy to get guide for good claim practices in the industry and to get knowledge when delay and disruption claims arise is very essential. As stated by Kumarswami and Yogeswaran

* Corresponding Author: E-mail - madhuni2si@gmail.com

(2003), so far, there are two protocols in construction industry. One is SCL (Society of Construction Law's) protocol and other is AACE 29 R (Association for Advancement of Cost Engineering) protocol. Nevertheless, SCL protocol is the widely used document in globally (Braimah, 2013a). Moreover, it has wide-ranging scope than AACE protocol (AACE 2007). Hence, the aim of this study is to investigate the feasibility of adopting SCL protocol to Sri Lankan construction industry.

This paper initially provides a comprehensive literature review in order to identify the prevailing knowledge and importance of the SCL protocol. Then, findings are obtained and further exposed to a discussion. Finally, conclusions are presented from the results.

2. DELAY AND DISRUPTION IN CONSTRUCTION

'Delays' can be commentating as the differences between scheduled time of the project and actual completion time (Ali *et al.*, 2012). 'Delay' is a circumstance which contractor or client bear for non-execution of project within established contract period (Kumarswami and Yogeswaran, 2003). According to these statements, delay can be defined as late execution of the project compared to contract time period. On other hand, 'disruption' can be connoting interruption to normal working procedures (Jayalath, 2013). Consequently, 'disruption' is a circumstance which preventing the construction works (Barry, 2009). When considering these, 'disruption' can be defined as resulting the lower efficiency in contractor's normal working procedures due to disturbance or interruption. However, Beattie (2005) mentioned that delay and disruption are the most prevalent and most costly risks in the industry. Delays and disruptions in construction can cause due to a number of reasons. As stated by Menesi (2007), risk and complexity of modern projects, late provision of information and drawings, design changes instructed by consultant on behalf of client are some causes to arise delay and disruption events in the industry. Furthermore, Birkby and Brough (1993) reported that unforeseeable ground conditions, delayed payments and variance of weather conditions are difficulties for execution of the project. Consequently, consistent with these findings, it can be determined that delays and disruptions occurred frequently in construction industry.

2.1. IMPACT ON DELAY AND DISRUPTION CLAIMS IN CONSTRUCTION

Construction claim is a statement of demand for compensation or extra time by way of evidence formed and point of views advanced by a party (Kululanga *et al.*, 2001).Quantity surveyors, project managers, architects, engineers, external claim consultants and estimators often involve to preparation and assessment of delay and disruption claims (Braimah, 2008). As indicated by research findings of Baduge and Jayasena (2012), delay claim process can be included claim identification, claim notification, claim examination, claim presentation, claim evaluation and claim negotiation.

When contractor identified that he has right for an extension of time or compensation then claim notice has been submitted by the contractor to Engineer. Formerly, during the examination contractor have to use analysis methods to substantiate his claim. After doing analysis contractor should submit the claim to the Engineer with supporting documents then Engineer must examine the claim to evaluate compensation or whether extension of time (EOT) is deserved or not (Hasan, 2013). Then, if contractor does not satisfy with the decision of Engineer then alternative dispute resolution methods have to be taken. Hence, even though there is a well-established delay claim process, claims are difficult to resolve due to having issues in delays and disruptions (Scott *et al.*, 2004). Therefore, most of the time disagreements are occurred between parties. A study by (Barry, 2009) showed that it will not always help to give fair conclusion to the delay claim. Those difficulties are arisen due to wrong practices and having some unclear areas in delay and disruption claim management (Braimah, 2013a).

Some issues are occurred due to wrong practices in the industry such as not updating the construction programme, lacking of updating construction programmes, incorrect mechanism of updating programs, inaccurately use of impacted and as-built programs (Gorse, 2004).

Although, records and documentation system is very important in delay and disruption situation, principle problems are weaknesses in claim notification and presentation as well as most of records and information submitted by the parties are not relevant to the delaying event or not relevant to master programme (Nisansala, 2009).

According to Jayalath (2013), some issues are occurred related vague areas in delay and disruption. Vague areas mean that those are not clearly expressed, known or described in construction industry. Ward (2011) stated that evaluating the delay claims become very complicated when concurrent delay occurred in the project, because both employers and contractors use the concurrent delay as protection tool. Concurrent delays mean that delays are occurred in a one period of time which more than one event occurred at same time (Barry, 2009). Another issues in current delay and disruption claims practices are problems in assessing process in float such as “who owns the float” (Braimah, 2008). According to Ward (2011), float is the time period which activity or group of activities can be shifted in time without affecting for delay to a completion. On the other hand, researches and practitioners of construction industry use many techniques to evaluate and assess the delay and disruption (Menesi, 2007). Therefore, most of time valuations the delays are become complex due to the inconsistency and not having uniformity of delay analysis techniques (Braimah, 2008). Kumarswami and Yogeswaran (2003) mentioned that it is important to acquire skills and knowledge about delay and disruption events to resolve the claims properly. However, when considering aforementioned literature findings it is clear that still delay and disruption claims are difficult to resolve due to having earlier mentioned issues.

As stated by Aibinu (2009), time overrun, cost overrun, disputes, arbitration, total abandonment and litigation are mainly occurred due to difficulties and complex to resolve the claims. Additionally, Ward (2005) stated that the unresolved claims affect poor commercial and legal relationships, client dissatisfaction, damage to the image and reputation in the construction industry. Considering all the facts cited above, it is clear that overall cost of the project and disputes in construction projects will be high due to unsettled delay and disruption claims. Therefore, it is required to study about the mechanism and proper ways to resolve the claims in appropriate ways by mitigating the aforementioned issues related delay and disruptions.

2.2. CONSTRUCTIONS PROVISIONS OF CONTRACTS

According to Dandeniya (2012) most of contracts in Sri Lanka based on FIDIC and SBD documents. Moreover, Dandeniya (2012) indicated that most of standard forms of contracts in Sri Lanka do not define about disruption. It was demonstrated by stating that 82% is not addressing about disruption in standard forms like SBDs and 75% is not addressing in standard forms like FIDIC. Hence, preparing and evaluating the delay and disruption claims in a fair and reasonable manner have converted in to more challenging problems in construction industry. A study by Nisansala (2009) showed that most of contracts in the industry are not providing much details related delay and disruption.

However, issues related delay and disruption claims management should be managed, possibly to the extent of preventing a dispute resulting from the issues. Therefore, it is required to study about the mechanism and proper ways to resolve the claims in appropriate ways by mitigating the aforementioned issues related delay and disruptions.

Although there are some dispute resolutions which parties can utilize such as, litigation, arbitration, negotiation, mediation, and dispute review boards disputes can be more complicated or even worse when involving a third party (Birky and Brough, 1993). In addition, Thomas (1993) explained that arbitration and litigation is quite costly and time consuming.

Hence, better way is avoiding these problems and conflicts before develop as disputes. Braimah (2008) explained that establishing a guideline is better solution for delay and disruption claims before it become complex situations.

On the same way, Hasan (2013) mentioned that since, standard form of contracts not provide considerable details for the delay and disruption issues, it is essential to have a proper guidance to both parties in construction industry.

Nowadays, certain standard guidelines in the world are emerging to avoid the problems in delay assessment and to eliminate disputes or facilitate settlement of disputes (Hasan, 2013). Industry practitioners have introduced two guidelines up to now like AACE and SCL to select appropriate techniques of delay analysing as follows.

- Society of Construction Law's Delay and Disruption Protocol (SCL Protocol)
- Forensic Schedule Analysis (AACE 29R-03)

AACE is a protocol which can be used in delay analysing and purpose of AACE is to provide a combining technical reference for the forensic application of critical path method (CPM) of scheduling (AACE 2007).

But conversely, AACE (2007) itself recommended that SCL delay and disruption protocol has wider scope than AACE protocol. UK's Society of Construction Law produced SCL delay and disruption protocol by aiming to provide useful guidance to all parties who involve in delay and disruption process in construction. Hence, SCL protocol is the widely used one in other countries (Braimah, 2013b). Therefore, it is worth study to find about the significance of SCL protocol in detail.

2.3. BENEFITS AND IMPORTANCE OF SCL PROTOCOL

There are four sections in SCL protocol which provide useful guidelines mentioned as follows. SCL (2002) explained some key areas in delay such as, entitlement of extension of time, procedure of extension of time, float, concurrency, and acceleration disruption under section one in the protocol. Guidelines about construction programme and documentation have discussed under section two.

Extension of time procedure has explained in section three and further explained how parties should establish a suitable claim procedure (Hasan, 2013). In guidance section four, dealing with disputed extension of time issues after completion of the project have discussed. Under this section, the terms of contract, the nature of proof required, the factual material available and the amount in dispute and the cost of the analysis are described (Gorce, 2004).

Aibinu (2009) discussed that SCL protocol is a useful guidance and as well as a useful framework for delay and disruption events. Moreover, Aibinu (2009) explained the protocol can be used when negotiating, illustrative, and making agreement regarding rules for assessing and quantifying estimated delay and disruption claims at the pre-contract stage as well as post contract stage. Gorce (2004) indicated that SCL protocol is designed to use as a guided document before enter in to a contract and as well as for dealing with compensation and resolving disputes during the construction of project. The benefits of the use of the protocol's model clauses such as reduction disputes costs, improving site efficiency, image of transparency and professionalism are considered to be valuable advantages (Ward, 2011).

However, according to aforementioned literature findings, it can be concluded SCL protocol is very important to mitigate the issues related delay and disruption claims.

But the problem is that "what is awareness of SCL protocol among industry claim practitioners in Sri Lankan construction industry?" and "how far SCL protocol is suitable to Sri Lankan industry?" Therefore, the data collection and analysis were done in order to find the answers to these problems.

3. RESEARCH METHODOLOGY

A comprehensive literature survey was carried out through journals, books, articles, reports, government publications, dissertations, previous research investigations and web pages to identify the basic facts and the theories already subjected to discussion about claims management and SCL protocol. Then, pragmatic research approach was used since this contains both quantitative and qualitative approaches. As data collection techniques, questionnaire survey used to find the awareness of SCL protocol among industry claim practitioners. Consequently, the survey sample unit was identified as professionals who involve in claims management. Questionnaires were distributed to claim practitioners who have experienced more than 5 years by selecting professionals from snowball sampling technique. Fellows and Liu (2003) proposed that qualitative approach was better approach to obtain in depth information. Hence, semi structured interviews were done to find feasibility of adopting the SCL protocol to Sri Lankan construction industry since it contains mostly qualitative and lengthy. Interviews were taken from industry practitioners who have used SCL protocol for delay and disruption claim management and selected from questionnaire survey. According to findings, there were ten SCL protocol users. Even though ten SCL protocol users were selected as respondents for semi structured interviews, it was stopped when it come up to seven practitioners. Because data saturation was occurred during collecting the data. The data collected from questionnaire survey was analysed using statistical analysis to find the percentage of awareness of the SCL protocol and content analysis was selected to analysis the data collected from semi structured interviews to investigate the suitability of the protocol.

4. FINDINGS THROUGH QUESTIONNAIRE SURVEY

Respondents comprises with 43% contractors, 30% consultants and 27% clients/developers in questionnaire survey. The respondents perform various roles in their particular organisations. Most of respondents were contract administrators and there were six project managers, six head office quantity surveyors, five claim consultants, four site quantity surveyors and two arbitrators/adjudicators. Average experience of professionals who were responded to questionnaire surveys is from seven years to 25 years.

4.1. ISSUES IN DELAY AND DISRUPTION CLAIMS MANAGEMENT IN LOCAL CONSTRUCTION INDUSTRY

According to results, the three most likely issues relevant to delay and disruption highlighted by respondents are irregular updating of construction programme, deficiencies in documentation - record keeping and lacking of providing much guidance on delay and disruption claim management in standard form of contracts used by the industry. Further, as next main issue respondents were identified that most of the conditions relating to extension of time (EOT) in contracts may not define how to assess an EOT claim and how to evaluate the delay events. Moreover, respondents decided that having disagreements between parties also cause for disputes occurred. In addition, selecting suitable delay and disruption analysis method also the most important issue to be considered. The results suggest that parties in construction industry still face significant problems in determining delay and disruption claims.

Issues on vague areas like concurrent delays, float, disruption and acceleration were ranked as lowest. On the other hand, selecting suitable delay and disruption analysis method also identified as major issue in literature findings. Eventually, in order to deal with this issues appropriately, it is important to first find how far can get guidance from standard form of contracts. Therefore, it is essential to discover the extent of addressing the key areas in the standard form of contracts.

As important consideration, respondents were asked to indicate the extent of addressing of key areas related delay and disruption in standard forms of contract such as FIDIC 1999 red book and SBD documents. Results are illustrated in Table 1.

Table1: Key Areas Related Delay and Disruption Events in Standard Form of Contracts

Key Areas	RII	Rank
Delay analysis methods	84.67%	1
Updating construction programme	80.67%	2
Float ownership in the programme	79.33%	3
Global claims	74.00%	4
Concurrent Delay	70.67%	5
Disruption	62.00%	6
Claim for payments of interest	55.33%	7
Acceleration	53.33%	8
EOT and compensation	44.67%	9
Valuation of variations	42.00%	10

Based on the results, even though delay analysis methods, updating construction programme and float ownership in the programme identified as least addressed key areas in standard form of contracts it has obtained relative importance more than 75%.

4.2. NEED FOR A GUIDELINE

Through the findings of literature review it was understood that there is a need for a guideline to mitigate these issues in delay and disruption. In order to further confirmation respondents were asked to indicate their opinions on the need for a guideline for delay and disruption to the local industry.100% of the respondents from contracting firms, 89% of the respondents from consulting firms and 88% of respondents from developers firms stated that there is a need a guideline. When consider overall results the 93% of the respondents considered the need for a guideline to the industry.

4.3. AWARENESS OF PROTOCOLS

Findings show that 54% from contractors, 33% from consultants and 25% from developers are aware about the SCL protocol and while 23% from contractors, 22% from consultants and 13% from developers are aware about the AACE 29R protocol. Based on the summary of result most popular protocol among contractors, consultants and developers, is SCL delay and disruption protocol. AACE 29R forensic analysis protocol has least awareness. When consider overall picture, in local construction industry, 40% of total respondents are aware about the SCL protocol and 20% of total respondent are aware about the AACE 29R forensic analysis protocol.

4.4. USAGE OF PROTOCOLS

When consider with respondents who aware the protocols, then 83% are using the SCL protocol and 33% are using the AACE protocol. Only 33% from total respondents are using SCL protocol and 7% are using AACE protocol. However, consistent with literature findings, Braimah (2013a) stated that SCL protocol is the widely used guidance document in other countries. Although, industry practitioners are not frequently using these guidelines, when compare with AACE document, SCL protocol is the most frequently using guideline than AACE document. Moreover, to investigate the practical usage of these protocols, further respondents were asked the extent of using of the protocols. Nevertheless, interesting finding is that most of SCL users have been used it in medium extent.

5. FINDINGS THROUGH INTERVIEWS

Consequently, interviews were done to investigate the feasibility of adopting the SCL protocol to local industry.

5.1. IMPORTANCE OF SCL PROTOCOL

As the first step to investigate the feasibility of SCL delay and disruption protocol, general opinions about SCL protocol were investigated. Consistent with results, 6 respondents (86%) of the interviewed experts believed that having guidance such as SCL delay and disruption protocol in Sri Lanka is important for claims management in construction. These opinions are in line with ideas given by Aibinu (2009) who explained that SCL protocol is a useful guidance and a useful framework for claims management. One respondent said that "*most of the issues in claims related concurrent delay, float, construction programme, global claims are addressing in SCL protocol. Therefore, SCL can be used as guide in these areas*". The next most common opinion given by the interviewees was "*this is the only effective document which can be used in any delay claim situation*". Furthermore, when consider other opinions; protocol has the power to manage employer's own risks of change during the construction period rather than having to depend upon the contractor. Supplementary, respondents indicate that SCL protocol help to reduce disputes and cost of the project. However, majority was indicated that having SCL delay and disruption protocol is very effective.

When considering the theoretically accuracy of the guidance in SCL protocol, all respondents (100%) were agreed for that and mentioned all guidance are theoretically accurate. five respondents (71%) from interviewees indicated that there are no any guidance which contradict with generally using standard form of contracts in Sri Lanka such as FIDIC and SBD documents. However, two respondents (29%) from interviewees were mentioned "*guidance of prolongation cost in protocol can't be used. Those are different kind of conditions of contract*".

On the other hand, the analysis of collected data it is revealed that all seven respondents (100%) were expressed that there is no any guidance in SCL which contradict with the country law in Sri Lanka.

Although SCL protocol is that much important for proper claims management, respondents said that protocol is not widely used in Sri Lanka. As said by respondents, most probable reason for less popular practice of SCL protocol is unfamiliar and unawareness. Less interesting of employers for use SCL protocol also another reason. Moreover, consistent with the interviewees, not having qualified persons in the industry, bureaucratic procedures, and government requirements and thinking attitudes of professionals are also causes for less practice of the SCL protocol in Sri Lanka.

5.2. WAY OF ADOPTING SCL PROTOCOL

Since, SCL protocol is not widely used in Sri Lankan construction industry, analysis is concentrated on applying protocol's guidance into contract document as contractual provisions in order to improve the usage. Nevertheless, respondents mentioned that section 1 and section 4 guidance can be used as contract provisions. But section 2 and section 4 cannot be used because construction programme and delay analysis details cannot be contractual. Because if Construction programme make as contractual, then disputes will be occurred. As well as delay analysis depend on project to project, event by event, person to person.

Therefore, as adopting way, all respondents were pointed out that SCL protocol should use as separate document in claims management. Nevertheless, except three respondents other four respondents indicate that SCL protocol should be used as only guideline. One respondent indicated that "*this protocol should use as separate document. Because this is only guideline. It can't be put in to the contract document*". Because of according to another respondent "*then disputes can be occurred. Since, parties are bound to do with contract document*". Moreover, other respondents described that the protocol is not put forward as part of contract document but as a general guide whose endorsements are to be willingly applied with agreement and common sense. Hence, above respondents asserted that parties should themselves refer the SCL protocol's guidance when a situation comes. Because of if try to put in to contract document then parties are bound to do according the protocol and if they do not done along with it then another issues can be occurred. Apart from those believes there were some contradicting ideas of respondents. Moreover, two respondents said that if it does not include then even though, one party prepare delay and disruption claims according to SCL protocol by referring guidance but other party may reject by saying that "*This SCL is not in contract document so there is no any legality to accept*". Hence, that respondent pointed out there should be legally force to do along with protocol.

Furthermore, according to analysis, five respondents think that protocol should be customised in order to proper implementation. However, there were two respondents who thought that it is not necessary to customize. Those two respondents indicated that the protocol can use as it is because it is the only guideline. If go customise it, other issues can arise. As a consequence of SCL has prepared by experiments over years and experienced persons. When consider other opinion, other five respondents stated that, "*there is a gap between Sri Lankan construction industry level and level mentioned in Protocol. SCL is worthy. But Sri Lankan construction practice is not good*". Because, respondents indicated that not having qualified persons and not having good construction culture in Sri Lanka are the main reasons.

Consistent with respondents, suggestions for customisation of sections 3 and 4 in protocol have illustrated in table 2.

Table 2: Suggestions to Customize the SCL Protocol

Section	Suggestions
Section 2	▪ Details on breakdown the programme
	▪ Details on link
	▪ Details on putting lags in construction programme
	▪ Submitting sequence of the programme
	▪ Details on including miles stone
	▪ Details on what records should keep in each situation
Section 4	▪ Details on claim preparation
	▪ Details on analysing the delays

Eventually, when consider all above analysis it is revealed that there is a need to implementing a guideline such as SCL protocol to manage the time of the project by doing proper delay and disruption claims in Sri Lankan construction industry. For that, improving knowledge on programming, and teaching SCL guidance in universities and in institutes understanding of SCL should be improved. Supplementary, SCL protocol can be familiarise among employers and other industry practitioners by having workshops and by increasing the awareness of SCL among clients.

6. CONCLUSIONS

Claims are inevitable in the construction industry due to the complexity and the multi-disciplinary involvement in the project. As well as, delay and disruption claims are quite seen often in the industry. However, delay and disruption claims are difficult to resolve due to having issues in claims management. Issues in claims management are deficiencies in documentation and recordkeeping, improper updating construction programme, problems in unclear areas such as concurrent delays, float and not having proper method to select suitable delay analysis technique. Since, most of contracts not providing much details related delay and disruption, if there is a guideline can be mitigate those issues in delay and disruption claims management in Sri Lanka. The SCL protocol is very beneficial document because it addresses vague areas in claims, help to manage the time of construction and transfer the risk fairly among parties. Conversely, it is only effective document which has comprehensive scope prevailing in the industry. Awareness of SCL protocol among claims practitioners in Sri Lanka is comparatively less. There is high usage of SCL protocol among industry practitioners who aware about the protocol. However, as whole there is less usage of the protocol in Sri Lankan construction industry. On the other hand, using the SCL protocol in Sri Lankan construction industry is feasible. Ultimately, there should be improvement of the construction culture in Sri Lanka through enhancing the professionals' thinking, mind and attitudes in order to effective implementation of the SCL protocol to claims management. However, SCL protocol will enable to account the delay and disruption claims more accurately and will benefit to mitigate issues in claims management in Sri Lankan construction industry.

7. REFERENCES

AACE International Recommended Practice, 2007, January. *Forensic Schedule Analysis TCM Framework: 6.4 – Forensic Performance Assessment* (Publication No. 29R-03) [online]. Available from: http://www.aacei.org/non/rps/29r-03.pdf [Accessed 8 June 2014].

Aibinu, A.A., 2009. Avoiding and Mitigating Delay and Disruption Claims Conflict: Role of Pre-contract Negotiation. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 1(1), 47-58.

Aibinu, A.A. and Jagboro, G.O., 2002. The Effects of Construction Delays on Project Delivery in Nigerian Construction Industry. *International journal of project Management*, 20(8), 593-599.

Ali, A., Smith, A. and Pitt, M., 2012. Contractors' Perception of Factors Contributing to Project Delay: Case Studies of Commercial Projects in Klang Valley, Malaysia [online]. *Journal of Design and Built Environment*, 7(1). Available from: http://fbe.um.edu.my/images/fab/Files/JDBEVOL7/vol7-04.pdf [Accessed 22 April 2014]

Baduge, S. and Jayasena, H.S., 2012. Application of Concurrency Delay Claims. In: *World Construction Conference 2012 – Global Challenges in Construction Industry* [online]. 69–78. Available from: http://www.academia.edu/1772698/Application_of_Concurrency_in_Delay_Claims [Accessed 2 March 2014].

Barry, D., 2009. Beware The Dark Arts! Delay Analysis and the Problems with Reliance on Technology. In: *A paper presented at Society of Construction Law International Conference* [online]. 1-13. Available from: http://www.scl.org.uk [Accessed 8 May 2014].

Beattie, C.S., 2005. Apportioning the Risk of Delay in Construction Projects: A Proposed Alternative to the Inadequate "No Damages for Delay" Clause [online]. *William & Mary Law Review*, 46(5), 1857-1885. Available from: http://scholarship.law.wm.edu/cgi/viewcontent.cgi?article=1297&context=wmlr [Accessed 12 May 2014].

Birkby, G. and Brough, P., 1993. *Extension of Time Explained*. London, UK: RIBA publications Ltd.

Braimah, N., 2008. *An Investigation into the Use of Construction Delay and Disruption Analysis Methodologies* [onine]. Thesis (MSc.). University of Florida, USA. Available from: http://wlv.openrepository.com/wlv/bitstream/2436/38824/3/Braimah_PhD%2520thesis.pdf?ev=pub_ext_btn_xdl [Accessed 12 June 2014].

Braimah, N., 2013a. Approaches to Delay Claims Assesment Employed in UK Construction Industry. *Buildings*, 3(1), 598-620.

Braimah, N., 2013b. Construction Delay Analysis Techniques—A Review of Application Issues and Improvement Needs. *Buildings*, 3(3), 506-531.

Chan, M., Coffey, V. and Trigunarsyah, B., 2010. Steering Towards Pinnacle of Success: The NEC Tenets in Australian Construction Contracting. In: *W113 - Special Track 18th CIB World Building Congress* [online], 402-415. Available from: http://www.lawlectures.co.uk/w113/documents/wbc2010-proceedings.pdf [Accessed 21 April 2014].

Dandeniya, D.A.D.M., 2012. *Contractor's Perspective Concerning Provisions for Disruption Claims in Conditions Of Contract*. Unpublished Dissertation (BSc). University of Moratuwa. Sri Lanka.

Fellows, R. and Liu, A., 2003. Research Methods for Construction [online]. 2nd ed. Available from: http://books.google.lk/books?hl=en&lr=&id=bHXPKARZLSwC&oi=fnd&pg=PR8&dq=Fellowes,+R.+%26+Liu,+A.(2003).+Research+methods+for+construction+(2nd+ed.).&ots=x2SpdeBPr9&sig=D8Q2alNTgHAoAHUuKf24vzULVLM&redir_esc=y#v=onepage&q&f=false [Accessed 21 April 2014].

Gorse, C. A., 2004. Monitoring, Planning and Tracking: Delay, Disruption and Legal Risk Management. In: *20th Annual ARCOM Conference Association of Researchers in Construction Management* [online], 1247-1256. Available from: http://www.arcom.ac.uk/-docs/proceedings/ar2004-1247-1257_Gorse.pdf [Accessed 7 February 2014].

Hasan, K.T., 2013. *Extension of Time (EOT) and Related Costs in Construction* [PowerPoint slides] [online]. Available from: http://fidic.org/sites/default/files/FIDIC%20Lecture%20%20EOT%20%26%20Related%20Costs%20in%20Construction.pptx. [Accessed 5 May 2014].

Jayalath, C., 2013. *Arguing Construction Claims.* Colombo: S. Godage and Brothers (Pvt) Ltd.

Kululanga, G.K., Kuotcha, W. and McCaffer, R. 2001. Construction Contractors' Claim Process Framework. *Construction Engineering and Management*, 309-313.

Kumarswami, M.M. and Yogeswaran, K., 2003. Substantiation and assessment of claims for extentsions of time. *International Journal of project Management*, 21(1), 27-38.

Menesi, W., 2007. *Construction Delay Analysis under Multiple Baseline Updates*. Available from: http://hdl.handle.net/10012/2737 [Accessed 18 July 2014].

Nisansala, M., 2009. *Management of Delay Claims*. Unpublished Dissertation (BSc.). University of Moratuwa, Sri Lanka.

Scotts, S., Harris, R.A. and Greenwood, 2004. Assessing the New United Kingdom Protocol for Dealing with Delay and Disruption [online]. *Journal of Professional Issues in Engineering Education and Practice*, 130(1), 50-59. Available from: http://cedb.asce.org/cgi/WWWdisplay.cgi?139669 [Accessed 18 July 2014].

Society of Construction Law, 2002. *SCL Delay and Disruption protocol* [online]. Available from: http:/www.scl.org.uk/scl-delay-and-disruption-protocol [Accessed 4 August 2014].

Thomas, R.W., 1993.*Construction Contract Claims*. London, UK: The Macmillan Press Ltd.

Ward, P., 2005. The SOCL's Delay and Disruption Orotocol and the Australian Construction Industry. In: *21st Annual ARCOM Conference* [online],1165-1174. Available from: http:/hdl.handle.net/1959.13/35635 [Accessed 16 August 2014].

Ward, P., 2011. A UK and Australian Perspective of the Suitability of the SCL Protocols' Provisions for Dealing with Float for Adoption and Use by the Australian Construction. In: *27th Annual ARCOM Conference* [online]. 5-7. Available from: http://www.arcom.ac.uk/-docs/proceedings/ar2011-0623-0632_Ward.pdf [Accessed 19 May 2014].

FRAMEWORK FOR ENSURING EFFECTIVENESS OF MAINTENANCE IN BUILDING SERVICES

D.P.S.D. Jayasinghe, P.A.P.V.D.S. Disaratna and R.P.N.P. Weerasinghe*
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Maintenance management of building services has become one of the critical issues among building sector professionals recently. The interruptions or damages to the building services extensively affect the core operation of the business. Therefore, appropriate maintenance management arrangements are required to sustain a proper building services system. Building practitioners tackle various issues and seek a variety of alternative solutions to deliver an effective maintenance strategy for the building services. However, the lack of consideration on the overall effectiveness of maintenance services has faced frequent problems such as human errors, health and safety issues, resource scarcities, and time delays. In order to address those problems, this research has been carried to develop a framework that ensures the effectiveness of maintenance activities of the building services in Sri Lanka.

An extensive literature review was mainly carried to discover the impact of effective maintenance activities towards the building services. Afterwards, a preliminary experts' survey was conducted to obtain the factors affecting to effectiveness of maintenance activities. Subsequently, a questionnaire survey was conducted among maintenance personals to rank identified factors according to their impact. Further, semi-structured interviews have been carried out mainly to identify the limitations of maintenance work.

The framework highlights the factors that affect the effectiveness of maintenance activities of building services. Further, the framework facilitates to address the limitations of maintenance activities of building services. The framework can be used as clear evidence to convince both top management and owners of organisations to ensure the effectiveness of maintenance activities as well.

Keywords: *Building Services; Commercial Buildings; Effectiveness; Maintenance Activities; Maintenance Staff*

1. INTRODUCTION

Maintenance management of building services has become one of the essential functions that enriches the building and organisational performance. Inappropriate maintenance and operation of the building services liable for the high percentage of unnecessary energy consumption of (Wu *et al.*, 2010) and poor building performance. Mainly, building services provides warmth, power, security, light, air quality, water, sound control, transport, communication and sanitation for buildings in order to provide safe and healthy living or working environment for both people and processes (John *et al.*, 2005). However, the functionality of these systems is doubtful, without an appropriate and effective maintenance management system. Effective maintenance management plays a significant role to achieve organisational goals by enhancing the overall efficiency of building services (Abreu *et al.*, 2013). Accordingly, appropriate and sufficient maintenance events are required in order to minimize the plant failures and to enhance the reliability of machineries (Wang, 2012).

Numerous problems such as communication and attitudes in between operations and maintenance process impede the effective maintenance functions (Jonsson, 1997). Various authors have suggested appropriate steps, sequences and practices to manage maintenance activities (Marquez *et al.*, 2009) effectively by addressing those problems. Mishra *et al.* (cited Marquez *et al.*, 2009) noted that there should be an ideal

* Corresponding Author: E-mail - nilminiweerasinghe@ymail.com

model for building services maintenance activities in order to achieve the efficient and effective maintenance activities accomplishing organisational objectives. The authors developed a framework for maintenance management, which has not entirely covered the area in terms of effectiveness of maintenance activities except some techniques such as Balance score card, Criticality analysis and Failure root cause analysis which can be used to measure the effectiveness of maintenance activities. Nevertheless, there is no proper guidance to improve the overall effectiveness of maintenance activities of building services. The lack of knowledge and consideration regarding overall effectiveness of maintenance activities in building services was encouraged to address in this research. Accordingly, the aim of this research is to develop a framework that ensures the effectiveness of maintenance activities of building services. The following objectives are set to achieve the aim of this research.

1. Recognize the impact of effectiveness of maintenance activities in building services,
2. Identify the existing factors affecting the effectiveness of maintenance activities of building services,
3. Investigate the limitations prevailing within maintenance management.

2. LITERATURE REVIEW

2.1. MAINTENANCE MANAGEMENT

Maintenance is one of the most essential expenditure and major cost reduction programme in the operating budget (Tsang, 2002). Panchdhari (2003) defined maintenance as the effort which carries out to retain, restore or enhance every-facility within each part of building, services and surroundings of the building to tolerate facility's utility values and presently-accepted standards. Thus, maintenance can be identified as an important support function in an organisation for which invests significant physical assets in order to achieve organisational goals (Obiajunwa, 2013).

Since, maintenance contributes to the security of the process, return on investment control, performance enhancement, solid image and interpersonal relationships of the organisations, industries have given considerable attention towards maintenance activities (Abreu *et al.,* 2013). Mobley (Pun *et al.* 2002) explained that in most situations, maintenance is required to achieve organisation's maximum profitability. Similarly, maintenance activities can be able to add value to business processes using ISO 14001:1996 and ISO 9001:2000 Standards (Bamber *et al.,* 2004).

The approach towards the maintenance has changed considerably throughout the last century. Yam *et al.* (2000) mentioned that several types of maintenance strategies such as equipment failure-driven, time-based, condition-based preventive, reliability centered and proactive type maintenances are introduced recently. In general, to enhance the effectiveness of maintenance activities some maintenance approaches such as Total Productive Maintenance (TPM), Reliability Centered Maintenance (RCM), Profit Centered Maintenance and Proactive Maintenance would be helpful for any type of organisation (Pun *et al.,* 2002).

2.2. MAINTENANCE MANAGEMENT IN BUILDING SERVICES

Building service systems are installed to support the requisite business functions such as mechanical, security, safety, electrical, communication and information systems (Wu *et al.,* 2010). The building services systems include lighting, air conditioning, electricity, gas supply, fire protection and detection, vertical transportation, water supply and drainage and other numerous installations such as waste disposal systems, external wall access, cleaning facilities and building automation systems (Yik and Lai, 2005). Wu *et al.* (2010) stated that maintenance is still required for building services systems to fulfil user requirements, even though these systems perform well as per manufacturers' perspective. Generally, buildings will not be valuable assets without proper operations and maintenance. Therefore, to preserve aesthetic appearance, water-tightness and structural integrity, maintenance is required. Moreover, without having proper operations and maintenance of building services, tenant complaints, unnecessary energy consumption and environmental damages (reducing indoor air quality) can be occurred (Wu *et al.,* 2010). It is required to conduct operations and maintenance function for building services systems in order to keep proper environmental condition inside the building without reducing the quality of the facilities given to the occupants (Yik and Lai, 2005).

2.3. ISSUES ASSOCIATED WITH MAINTENANCE ACTIVITIES

The lack consideration on maintenance activities has been highlighted recently, as managers ignored the relationship between profitability and maintenance properly (Jonsson, 1997). The communication gap between the persons who control the technical aspects and the persons who control the financial aspects of maintenance has created adversarial influence on maintenance practices (Mostafa, 2004).

Abreu *et al.* (2013) identified several issues in maintenance management, such as deficiency of maintenance reporting with respect to local and corporate perception and deficiency of action improvements with respect to business process. The authors further stated that maintenance shall not consider as a “poor relative” to the organisation and only considered as some source of expense to the organisation. Au-Yong *et al.* (2014) stated that poor knowledge and skill of labours is a major barrier that affects the effectiveness of maintenance management. Moreover, Lind and Muyingo (2012) argued that the maintenance budget allocation may not always be enough for the maintenance operation. Further, Jonsson (1997) explained that, many organisations establish only a few goals for maintenance activities, although goals and strategies are required to achieve the effectiveness of maintenance activities.

2.4. EFFECTIVENESS OF MAINTENANCE ACTIVITIES

Various authors have proposed approaches that evaluate the performance of maintenance to improve its effectiveness (Aoudia *et al.*, 2008). Marquez *et al.* (2009) explained that effectiveness indicates how well a function or department meets its company needs or goals, and is frequently conversed regarding service provided quality in the customer’s perspective. Further, effectiveness focuses on required outcome and the accuracy of the process. Moubray (cited Ahuja and Khamba, 2008) mentioned that the effective incorporation of maintenance activity with engineering activity in the organisation, supports to save numerous useful resources such as time and money in dealing with maintainability, reliability, performance issues and availability.

In the past, maintenance have considered on equipment’s aspects rather than human aspects. But, Effective Centred Maintenance (ECM) mainly focuses on customer’s aspect and consists with several features which improves the performance of maintenance activities (Pun *et al.*, 2002). According to Wang and Hwang (2004) allocating optimal combination of maintenance cycle and maintenance personnel would upports to determine the efficient and effective maintenance plans and schedules.

Moreover, Campbell (cited Zhu *et al.* 2002) explained that maintenance process should be able to retain assets in a predetermined operating condition to satisfy the primary business process. Similarly, Kelly (cited Zhu *et al.* 2002*)* mentioned that the interrelationship between primary processes and the maintenance process is necessary in order to meet effective maintenance management. Sherwin (2000) suggested that proper resources’ deployment, form of maintenance materials and spare parts, manpower, necessary instruments and tools and organisational life cycle profit are the significant factors which affect the effectiveness of maintenance management.

Jonsson, (1997) presented a model of five linked maintenance management components as strategy, human aspects, support mechanisms, tools/techniques and organisation Further, the author stated that the effectiveness of maintenance management policy, highly depends on the soundness of each above elements and their individual effectiveness. Sherwin (2000) mentioned that every maintenance activity should be fully documented in order to collect information regarding the operation, maintenance, modifications, failures and cost associated with each machineries and equipment. In addition, most of maintenance management failures have occurred since the absence of management commitment towards maintenance activities rather than lack of concepts or techniques (Bamber *et al.*, 2004). The effectiveness of maintenance activities highly depends on problems of communication and attitudes between maintenance and operations (Jonsson, 1997). Similarly, various authors have highlighted a variety of factors that affect the effectiveness of maintenance activities.

Table 1 comprise the factors identified through journals and books in relation to the effectiveness of maintenance activities. Since Table 1 basis for the final framework, factors affecting to effectiveness of maintenance activities have been gathered by considering common maintenance activities related to building services. In addition, most of those factors have been justified in terms of authors' perspective.

Table 1: Effectiveness of Maintenance Activities: Literature Findings

Factors \ **Author(s) Name**	Yam *et al.*, 2000	Jonsson, 1997	Sherwin, 2000	Bamber *et al.*, 2004	Ben-Daya *et al.*, 2009	Pintelon *et al.*, 1999	Horner *et al.*, 1997	Lewis *et al.*, 2011	Tsang, 2002	Al-Ghanim, 2003	Wang and Hwang, 2004	Mostafa, 2004	Au-Yong *et al.*, 2014	Allen, 1993	Reis *et al.*, 2009	Tam and Price, 2008	Ali and Mohamad, 2009
Attitude and Communication Problem		×															
Proper Documentations			×	×									×				
Manager's Commitment		×	×	×													
Equipment history file					×												
Information Technology						×											
Spare Part Inventory	×				×	×	×			×			×				
Outage Control	×																
Human Resource Management/man power	×						×										
Maintenance Organisation's Structure	×																
CMMS								×									
Service Delivery Options									×								
Periodic Maintenance			×							×							
Legal Regulations			×														
Personnel Competencies										×							
Equipment Handling											×						
Staff Trainings												×			×		
Level of Sophistication of the tools													×				
Frequency of Inspection and Monitoring													×				
Maintenance Audit														×			×
Prioritization																×	

3. RESEARCH METHODOLOGY

An extensive literature review was conducted to identify the maintenance activities of building services, the effectiveness of maintenance activities and factors that affect to ensure effectiveness of maintenance activities of building services respectively. The aim of this research is to develop a framework to ensure the effectiveness of maintenance activities. Considering the nature of this research, mixed methods research approach was used.

Firstly, the preliminary expert survey was carried out as semi structured interviews among four maintenance managers, who have more than 10 years' experience in the maintenance field in commercial buildings. During the expert survey, the relevance and importance of ensuring the effectiveness of maintenance activities of building services were discussed in order to ensure the practicability of the aforementioned factors in the Sri Lankan context. In addition, personal opinions and comments of experts regarding the nature of maintenance operations in their organisation were discussed. Subsequently, a questionnaire was developed based on the findings from the preliminary survey. The main objective of the questionnaire survey is to identify the criticality of factors which are affecting to maintenance activities of building services. Therefore, these fixed response types' questionnaires along with provisions for comments were distributed among a judgmental sample of maintenance staff members in the commercial building sector. In addition, a semi structured interview survey was carried out to attain the fourth objective of this study. The study selected 12 persons who are currently working in the maintenance field to identify the most common limitations available in the maintenance field.

In this research content analysis technique was used to analyse the data gathered from semi-structured interviews. In addition, NVIVO software was also used to carry out content analysis. In order to rank the criticality of the factors RII method was applied since it indicates the level of significance of a particular factor through the given questionnaires. For that following formula was used.

$$Relative\ Important\ Index = \frac{\sum wn}{AN} \times 100\% \qquad \text{(Eq. 01)}$$

Where, W is the weighting given to each factor by the respondent, ranging from 1 to 5, n is the frequency of responses, A is the highest weight and N is the total number of samples.

4. RESEARCH FINDINGS

4.1. PRELIMINARY EXPERT SURVEY

Collected data was analysed under following two broad headings:

- Overview of maintenance activities of building services, and
- Effectiveness of maintenance activities.

4.1.1. OVERVIEW OF MAINTENANCE ACTIVITIES OF BUILDING SERVICES

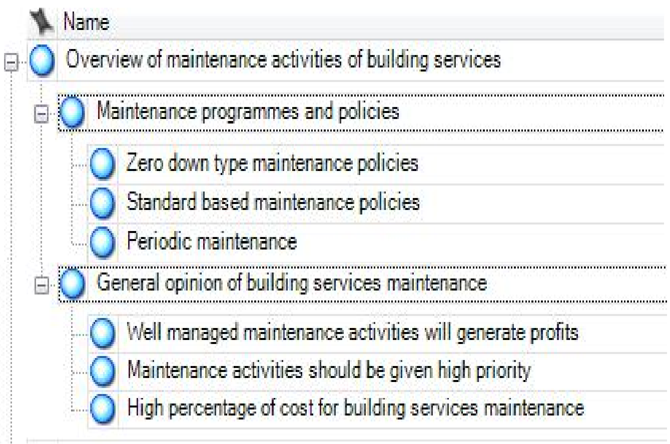

Figure 1: Overview of Maintenance Activities

The initial step was to obtain the information on existing building services maintenance activities. Thus, the interviewees were questioned on their general opinions and experiences on maintenance activities of building services. Accordingly, NVIVO software was supported to categorise received data into two sections as in Figure 1. Overview of maintenance activities of building services is discussed with the general opinion of building services maintenance and maintenance programme and polices.

It was identified that the experts in maintenance field have very much similar ideas regarding maintenance activities and their loopholes. Four interviewees highlighted three common opinions on the general opinion of building services maintenance as i) well managed maintenance activities of building services generate profits, ii) high priority should be given to maintenance activities and iii) maintenance occur highest cost in the operating budget. Further, interviewees roughly mentioned that more than 50% of the maintenance budget is allocated for maintenance activities of building services.

The interviewees also pointed out several policies and programmes which are commonly used in each organisation as well. Most organisations are practicing preventive and predictive maintenance programmes rather than reactive maintenance in order to reduce difficulties of maintenance activities. Further, one of the Experts said that *"Since we never want the equipment to breakdown, we are practicing Zero downtime Type maintenance policy"*. According to the expert's views, most of organisations uses zero down time based maintenance since they have identified the importance of uninterrupted building services. In addition, it is noticed that most of the organisation is following various standards such as British Standards when designing maintenance policies. Therefore, it is revealed that practitioners are more concerned in conducting effective maintenance management activities in their buildings.

4.1.2. EFFECTIVENESS OF MAINTENANCE ACTIVITIES

Secondly, personalal views regarding the effectiveness of maintenance activities of building services were identified. This was discussed based on four topics as shown in Figure 2. The experts were questioned on their personal opinion of the effectiveness of maintenance activities. It was noticed that, reducing minor defects into huge deficits or financial losses, the concept of "Do it right at the first time" and efficiency of the work as their common opinion towards the effectiveness of maintenance activities.

During the discussions, it was identified that most of the building maintenance practitioners are implementing various approaches to ensure the effectiveness of maintenance activities and obtaining a number of benefits. Waste reduction, time savings, service quality, reduction of pending work, reduction of complaints, quality of materials, less breakdowns, increasing equipment lifetime, enhancement of communication procedures and customer satisfaction were identified as benefits throughout the expert survey.

Expert survey was used to identify the additional factors which affect the effectiveness of maintenance activities and validate the literature findings according to the expert's opinions. Experts agreed with the findings of a literature survey and further added following factors.

- Addressing grievances
- Alternative options for equipment
- Approval process
- Building Management Systems
- Cost consciousness
- Data Logging systems
- Usage of personal protective equipment and safety procedures
- Employee motivation
- Financing for maintenance activities
- High interaction with managers and other maintenance staff
- Life cycle costing
- Personnel replacement
- Promoting teamwork
- Quality of material
- Statistical analysis of maintenance status
- Tool box talk
- Pre planning the way of doing maintenance activities

These factors were categorised into human related factors, technical factors, managerial factors and other factors with the comments of interviewees. The human related factors were directed at individuals or team of maintenance operational staff. The Technical factors were related to the equipment and machine issues and managerial factors were related to the management process. Any other factors which does not fall into the above three categories were considered with other factors.

4.2 STRUCTURED QUESTIONNAIRE SURVEY FINDINGS

The main objective of this research is to identify the factors, mostly affect to effectiveness of maintenance activities of building services. Hence, the structured questionnaire survey was conducted and factors were ranked with reference to the impact of each factor to ensure the effectiveness of maintenance activities using the Relative Importance Index (RII).

Structured questionnaires were distributed among the persons who are currently working in the maintenance field. 35 questionnaires were distributed and 30 completed questionnaires back to comment with the response rate of 85.6%.

Table 2: RII of Selected Factors

Rank	Factor	RII
	Human Factors	
1	Employee motivation	88.00
2	Human Resource Management/man power	87.33
3	Promoting teamwork	84.67
4	Attitude and communication	84.00
5	Staff Trainings	82.00
6	Usage of personal protective equipment and safety procedures	80.00
7	Cost consciousness	76.00
8	High interaction with managers and other maintenance staff	74.67
9	Personnel competencies	74.00
10	Personnel replacements	73.33
11	Addressing of grievances	71.33
	Technical Factors	
1	Quality of material	92.00
2	Equipment handling	81.33
3	Building Management systems	76.67
4	Tool box talk	76.00
5	Alternative options for equipment	74.67
6	Level of sophistication of the tools	72.67
7	Data Logging System	72.67
8	Computerized Maintenance Management System	69.33
9	Information Technology	64.67
	Managerial Factors	
1	Pre planning the way of doing maintenance activities	86.00
2	Periodic maintenance	84.00
3	Manager’s commitment	82.67
4	Frequency of inspection and monitoring	82.67
5	Prioritization	82.00
6	Work orders planning and control	80.67
7	Outage Control	76.00
8	Maintenance Organisation’s Structure	74.00
9	Service Delivery Options	70.67
10	Maintenance Audit	70.00
	Other	
1	Financing for maintenance activities	85.33
3	Spare part Inventory	83.33
2	Proper documentations	82.67
4	Approval process	80.00
5	Statistical analysis of maintenance status	76.67
6	Equipment history file	72.67
7	Life Cycle Costing	69.33
8	Legal regulations	67.33

4.3. LIMITATIONS / PROBLEMS AFFECT TO EFFECTIVENESS OF MAINTENANCE ACTIVITIES

There are limitations in building services maintenance field as mentioned previously in the literature review. However, identification of those limitations will be very much important in order to eliminate them through the factors which positively affect the effectiveness of maintenance activities. By conducting semi-structured interviews with the selected 12 persons who are currently working in maintenance field the most common limitations available in the maintenance field have been identified. The identified limitations are given in Table 3 with the factor categories. With the aid of semi structured interviews, currently available limitations in the building maintenance industry were identified. 25 limitations which faced by the maintenance teams were identified. The practitioners who are currently working on commercial buildings as maintenance engineers and managers and other maintenance professions such as assistant maintenance engineers, supervisors, and chief technical officers with 5 years or more experiences, were selected for the interviews.

Table 3: Available Limitations in the Maintenance Field

Limitation / Problem	**Applicable Factor Category**				**Interviewees**											
	Human	Technical	Managerial	Other	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I 10	I 11	I 12
Less manpower backup	√				√	√		√				√				
Having huge purchasing procedure	√		√		√											
High time spending for purchasing process	√		√		√											
Difficulty of convince needs for contractors	√				√											
Lack of specialist /qualified technicians	√					√		√				√		√		
Not having enough time for activities	√	√	√			√		√						√	√	
Difficult to give promotions			√			√										
Leaving organisation by technicians	√							√	√							
Limited budget allocation				√				√	√				√	√	√	
Difficulty of getting approval				√						√	√					
Legal problems/Government rules				√					√	√						
Negligence in periodic maintenance			√							√						
Poor store management process			√	√							√					
Lack of trainings for maintenance activities	√										√					
Communication problems	√															√
Dislike to use PPE	√											√				
Less quality material		√							√							
Less salaries for maintenance staff				√					√							
Customer disturbances		√	√												√	
Weather conditions		√					√									
Not having some spare parts in Sri Lanka/Scarcity of spare parts				√	√		√			√		√				
People require high cost for work at abnormal hours			√			√										
Not having enough trust between maintenance team	√									√						
Unawareness/less knowledge regarding maintenance work	√								√					√		√
Not having special way to prove material quality		√							√							

5. FRAMEWORK DEVELOPMENT

The framework has been developed in order to provide a broad idea regarding effectiveness of maintenance activities of building services. It is important to notice that, this framework only provides the most important factors and limitations which can be easily identified in the maintenance field in commercial buildings. Firstly, framework highlights the factors which affect to effectiveness of maintenance activities of building services in commercial buildings under four topics as human, technical, managerial and other. These factors are categorised based on the level of impact to the effectiveness of maintenance using the RII score. Afterwards, the limitations of each factor are presented. Maintenance practitioners can be adhered to, this framework in order to ensure the effectiveness of maintenance activities successfully.

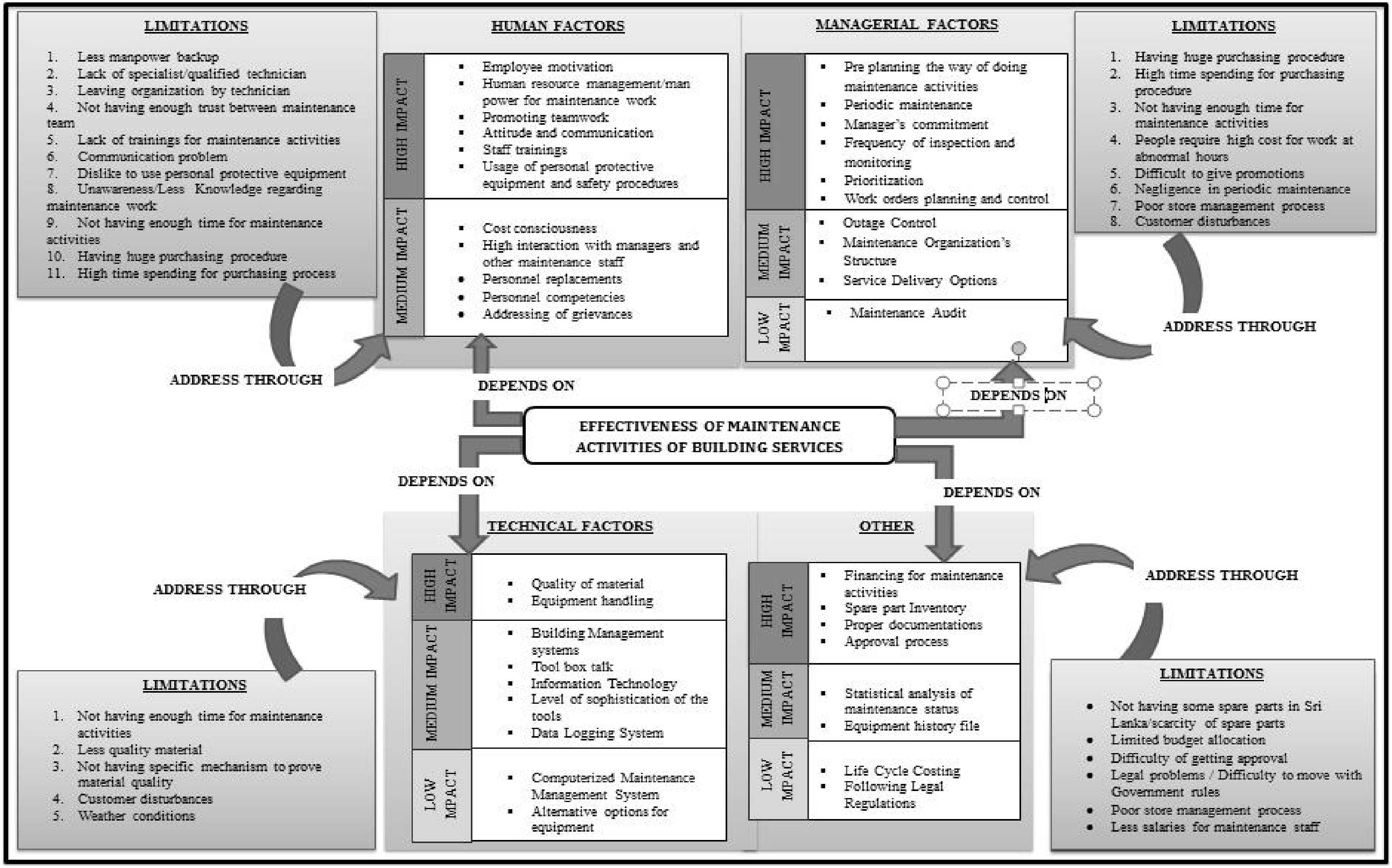

Figure 2: Framework for Ensuring Effectiveness of the Maintenance Activities in Building Service

6. CONCLUSIONS

Effective maintenance activities ensure uninterrupted building services systems. In practice, a considerable amount of organisations have given a significant attention to maintenance activities of building services. This research focused on identifying the factors that underpin effective maintenance activities in building maintenance in commercial buildings. The study mainly focused on internal factors of organisation rather than external factors and identified under human, managerial, technical and other categories. The research has been identified 38 factors which affect to effectiveness of maintenance activities and 25 limitations when performing maintenance activities. These factors were further categorized as high, medium and low. Quality of materials, Employee motivation, manpower for maintenance activities, pre planning the way of doing maintenance activities and financing for maintenance activities identified as the most critical high impact factors. Limited budget, not having enough time for maintenance activities, lack of qualified technicians and scarcity of spare parts highlighted as frequent limitations. The limitations available in maintenance activities of building services can be addressed by awakening the factors which affect to effectiveness of maintenance activities.

7. REFERENCES

Abreu, J., Martins, P.V., Fernandes, S. and Zacarias, M., 2013. *Business Processes Improvement of Maintenance Management: A Case Study*, 9, 320-330.

Ahuja, I.P.S. and Khamba, J.S., 2008. Total Productive Maintenance: Literature Review and Directions. *International Journal of Quality and Reliability Management*, 25(7), 709-756.

Al-Ghanim, A., 2003. A Statistical Approach Linking Energy Management to Maintenance and Production Factors. *Journal of Quality in Maintenance Engineering*, 9(1), 25-37.

Ali, M., and Mohamad, W. M.N.B.W., 2009. Audit Assessment of the Facilities Maintenance Management in a Public Hospital in Malaysia. *Journal of Facilities Management*, 7(2), 142-158.

Allen, D., 1993. What is Building Maintenance?. *Facilities*, 11(3), 7-12.

Aoudia, M., Belmokhtar, O. and Zwingelstein, G., 2008. Economic Impact of Maintenance Management Ineffectiveness of an Oil and Gas Company. *Journal of Quality in Maintenance Engineering*, 14(3), 237-261.

Au-Yong, C.P., Ali, A.S. and Ahmad, F., 2014. Improving Occupants' Satisfaction with Effective Maintenance Management of HVAC System in Office Buildings. *Automation in Construction*, 43, 31-37.

Bamber, C.J., Sharp, J. M. and Castka, P., 2004. Third Party Assessment: The Role of the Maintenance Function in an Integrated Management System. *Journal of Quality in Maintenance Engineering*, 10(1), 26-36.

Ben-Daya, M. and Duffuaa, S.O., 1995. Maintenance and Quality:The Missing Link. *Journal of Quality in Maintenance Engineering*, 1(1), 20-26.

Garg, A. and Deshmukh, S.G., 2010. Engineering Support Issues for Flexibility in Maintenance. *Asia Pacific Journal of Marketing and Logistics*, 22(2), 247-270.

Horner, R.M.W., El-Haram, M.A. and Munns, A. K., 1997. Building Maintenance Strategy: A New Management Approach. *Journal of Quality in Maintenance Engineering*, 3(4), 273-280.

John, G.A., Clements-Croome, D.J., Fairey, V. and Loy, H.M., 2005. Contextual Prerequisites for the Application of ILS Principles to the Building Services Industry. *Engineering, Construction and Architectural Management*, 12(4), 307-328.

Jonsson, P., 1997. The Status of Maintenance Management in Swedish Manufacturing Firms. *Journal of Quality in Maintenance Engineering*, 3(4), 233-258.

Lewis, A., Elmualim, A. and Riley, D., 2011. Linking Energy and Maintenance Management for Sustainability through Three American Case Studies. *Facilities*, 29(5/6), 243-254.

Lind, H. and Muyingo, H., 2012. Building Maintenance Strategies: Planning under Uncertainty. *Property Management*, 30(1), 14-28.

Marquez, A.C., Leon, P.M., Fernandez, J.F.G., Marquez, C.P. and Campos, M.L., 2009. The Maintenance Management Framework. *Journal of Quality in Maintenance Engineering*, 15(2), 167-178.

Mostafa, I.S., 2004. Implementation of Proactive Maintenance in the Egyptian Glass Company. *Journal of Quality in Maintenance Engineering*, 10(2), 107-122.

Obiajunwa, C.C., 2013. Skills for the Management of Turnaround Maintenance Projects [online]. *Journal of Quality in Maintenance Engineering,* 19(1), 61-73. Available from: http://www.emeraldinsight.com/doi/abs/10.1108/13552511311304483 [Accessed 10 May 2014].

Panchdhari, A., 2003. *Maintenance of Buildings*. New Delhi: New Age International Private Limited.

Pintelon, L., Preez, N.D. and Puyvelde, F.V., 1999. Information Technology:Opportunities for Maintenance Management. *Journal of Quality in Maintenance Engineering,* 5(1), 9-24.

Pun, K.F., Chin, K.S., Chow, M.F. and Lau, H.C.W., 2002. An Effectiveness-Centered Approach to Maintenance Management. *Journal of Quality in Maintenance Engineering,* 8(4), 346-368.

Reis, A.C.B., Costa, A.P.C.S. and Almeida, A.T., 2009. Planning and Competitiveness in Maintenance Management: An Exploratory Study in Manufacturing Companies. *Journal of Quality in Maintenance Engineering,* 15(3), 259-270.

Sherwin, D., 2000. A Review of Overall Models Formaintenance Management. *Journal of Quality in Maintenance Engineering,* 6(3), 138-164.

Tam, A.S.B. and Price, J.W.H., 2008. A Maintenance Prioritisation Approach to Maximise Return on Investment Subject to Time and Budget Constraints. *Journal of Quality in Maintenance Engineering,* 14(3), 272-289.

Tsang, A.H.C., 2002. Strategic Dimensions of Maintenance Management. *Journal of Quality in Maintenance Engineering,* 8(1), 7-39.

Wang, C.H. and Hwang, S. L., 2004. A Stochastic Maintenance Management Model with Recovery Factor. *Journal of Quality in Maintenance Engineering,* 10(2), 154-164.

Wang, W., 2012. An Overview of there Recent Advances in Delay-Time-Based Maintenance Modelling. *Reliability Engineering and System Safety,* 106, 165-178.

Wu, S., Neale, K., Williamson, M. and Hornby, M., 2010. Reserch Oppertunities in Maintenance of Office Building Services System. *Journal of Quality in Maintenance Engineering,* 16(1), 23-33.

Yam, R.C.M., Tse, P., Ling, L. and Fung, F., 2000. Enhancement of Maintenance Management through Benchmarking. *Journal of Quality in Maintenance Engineering,* 6(4), 224-240.

Yik , F. W. and Lai, J. H. K., 2005. The Trend of Outsourcing for Building Services Operation and Maintenance in Hong Kong. *Facilities* [online], 23(1/2), 63-72. Available from: http://www.emeraldinsight.com/doi/abs/10.1108/02632770510575901 [Accessed 10 May 2014].

Zhu, G., Gelders, L. and Pintelon, L., 2002. Object/Objective-Oriented Maintenance Management. *Journal of Quality in Maintenance Engineering, 8*(4), 306-318.

FRAMEWORK TO IMPROVE LABOUR PRODUCTIVITY FOR INDIAN BUILDING PROJECTS

Rahul Sahay*, Ritesh Kumar Agarwal and Koshy Varghese
Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India

ABSTRACT

This study explores the practice of planning and productivity measurement on Indian building construction sites and suggests a framework to improve the practice. An exploratory study based on observing several projects was initially undertaken and it was found that there was no structured method utilised to analyse and improve productivity during the construction phase. Further analysis of planning practices on 15 building construction projects revealed that while the overall milestone plan was appropriate, the critical path method schedule (macro schedule) had several limitations, which made its relevance for look-ahead planning and coordination of resources questionable. Without an appropriate model for medium term planning, the short-term plans became uncoordinated and resulted in significant wastages. Based on a comparison of observed practices with documented best practices, and constraints unique to projects in India, the gaps in developing CPM based schedule are enumerated and strategies to close the gaps are suggested.

In addition to this top-down approach to develop a realistic CPM based schedule, a bottom up approach to monitor the daily progress against the planned weekly targets is proposed. While the conventional monitoring framework mandates this approach, there were several gaps in practice that were observed. The causes for these gaps are analysed and suggestions to close the gaps are proposed. The proposed framework consisting of the top-down and bottom-up approach is expected to overcome several of the barriers to measure and improve labour productivity on Indian building projects.

Keywords: *Building Construction; Look-Ahead Planning; Productivity; Scheduling*.

1. INTRODUCTION

The Indian construction industry is labour intensive, and hence labour productivity has a significant impact on the cost and time performance of projects. Until recently project performance was assessed based on cost and as labour was considered inexpensive and usually sub-contracted, the general contractor did not focus on labour productivity. In the last two decades time performance has become increasingly a priority and this has necessitated introduction of systems to plan detailed project schedule and monitor labour productivity performance.

Today, all leading construction contractors in the country have documented systems for project scheduling and labour productivity monitoring. Based on the company specific requirements these systems are customized and typically are referred to by in-house acronyms. The scheduling systems for building projects are largely based on MS Project, while the productivity monitoring system is based on custom developed spreadsheets. Thus, most firms have formally documented procedures for scheduling and productivity monitoring which are broadly aligned with global best practices.

The need for this study arises from observing that (i) although standard documented planning systems were available, the planning practices on sites varied widely, (ii) on most projects the quantity of work done increased dramatically close to a milestone, and dropped after the milestone was passed, (iii) work sampling on site showed that only about 30% of value added work was being done by labour (iv) while

* Corresponding Author: E-mail - rahul17sahay@gmail.com

the data for labour productivity is being collected on a daily basis, only a few sites were analyzing this data for productivity improvement opportunities.

Based on these preliminary observations, the practices of scheduling and labour productivity monitoring on Indian building construction sites are benchmarked with the global best practices. The study does not seek to establish a direct comparison of practices, rather incorporates the unique aspects of Indian project delivery process to develop a framework which would be relevant to Indian construction.

This paper is organized into 7 sections. The next section discusses the literature review followed by research methodology, data collection, problem identification, analysis of problem, developed framework and conclusion.

2. LITERATURE REVIEW

There have been many research studies in the field of finding the factors affecting the labour productivity, methods of effective project scheduling and productivity measurement. However, only a few studies have addressed the details of relationships between the construction project planning, scheduling, labour productivity monitoring and improvement.

Thomas and Sudhakumar (2014) administered a questionnaire survey of project managers, site engineers, supervisors and craftsman in the state of Kerala in India to understand the factors influencing construction labour productivity. The study proved that improper project coordination, poor project planning and scheduling have been perceived by project managers as significantly impairing productivity and project managers emphasize the need for realistic project goals, deadlines, quick review and coordination among participants to improve construction labour productivity.

Absalom *et al. (*2014) administered a field survey investigating the factors influencing labour productivity on construction sites relying heavily on manual labour from contractors, project managers and developers on live construction sites in Kenya. In this study, planning and scheduling ranked second among several factors affecting the labour productivity.

There have been a few guides available for scheduling called GAO Cost Estimating and Assessment Guide (GAO-2009), GAO Schedule Assessment Guide (GAO-2012), Planning and Scheduling Excellence Guide (PASEG) (NDIA-ICPM, 2011), Construction Project Management Guidelines (IS15883, 2013). These guides introduced a set of recommended practices for schedule development. These guides although useful, are generic and do not provide an appropriate level of detail required for site implementation.

Laufer and Tucker (1987) critically examined the US construction planning process and found that for planning to become effective, methods should be changed (e.g. gathering and diffusing of information), policies should be modified (e.g. the role of planning and control), assumptions should be adjusted (e.g. attitude to uncertainty) and the overall philosophy of project management should be re-examined.

Johansen (1996) investigated the planning practices on building projects and found that plans are produced under time pressure and the commitment required for accurate planning is not available. Further, construction managers often ignore the formal project master programme and instead adopt their own approach to planning. Present study investigates how execution team can be involved in planning and a realistic schedule can be achieved and communicated to execution team so the commitment can be ensured.

Subbiah (2012) investigates the factors influencing the success of construction planning using the participant observer approach and found that planning is a process which will be successful only when it is supported by the whole project team and proved that the initial programme which is being developed with the best available information should be continuously monitored and developed to addresses changes and to take corrective actions.

In the present research apart from literature review the data is collected from past construction projects, expert opinions and field study, it is observed that less than 35% of the projects measured labour productivity effectively and about 4 out of 15 projects analysed the datato monitor and improve labour productivity.

The field study established that the problem with planning and scheduling still exists in Indian construction projects which affect labour productivity.

3. RESEARCH METHODOLOGY

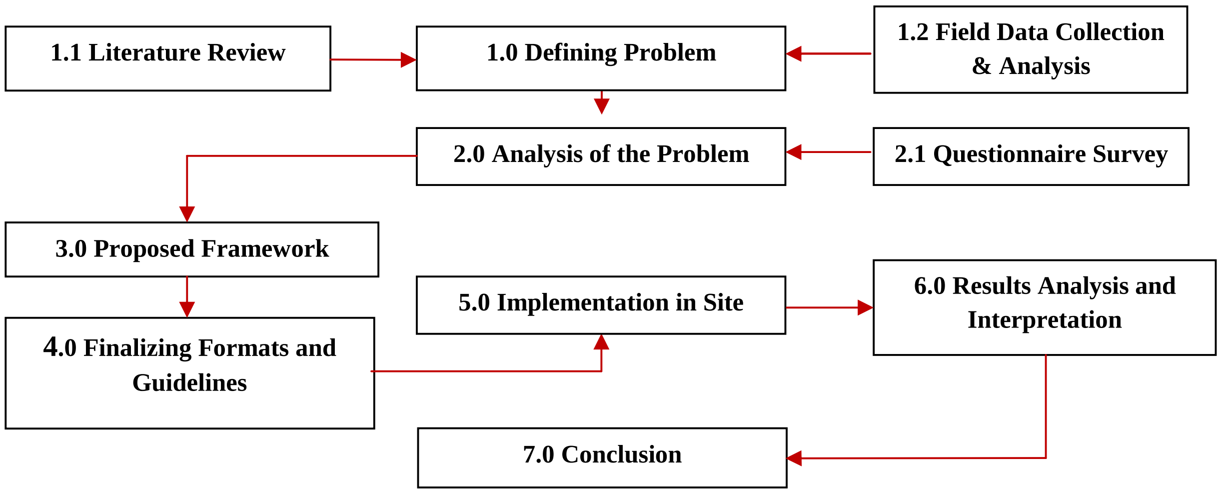

Figure 1: Study Methodology

The methodology used in this study is shown in Figure 1. As shown, the methodology adopted for this study started with review of literature and field data collection and analysis to develop a clear problem definition. Based on a question survey of experienced planners and site engineers the root causes of the problems identified in 1.0 are determined and discussed. The questionnaire survey was administered for 30 planning mangers from Indian building construction sites. The structured interviews were conducted for labour contractors and site engineers to find the root causes and impact of the identified problems in various projects. Expert opinions were sought to find a solution to the identified problem. A framework to address the problems is then proposed- this framework is based on benchmarking with the standard global practices while considering the unique aspects of Indian construction. The scope of this paper is limited to discussing the proposed framework. The site implementation and evaluation of the proposed framework is currently under progress.

3.1. DATA COLLECTION AND ANALYSIS

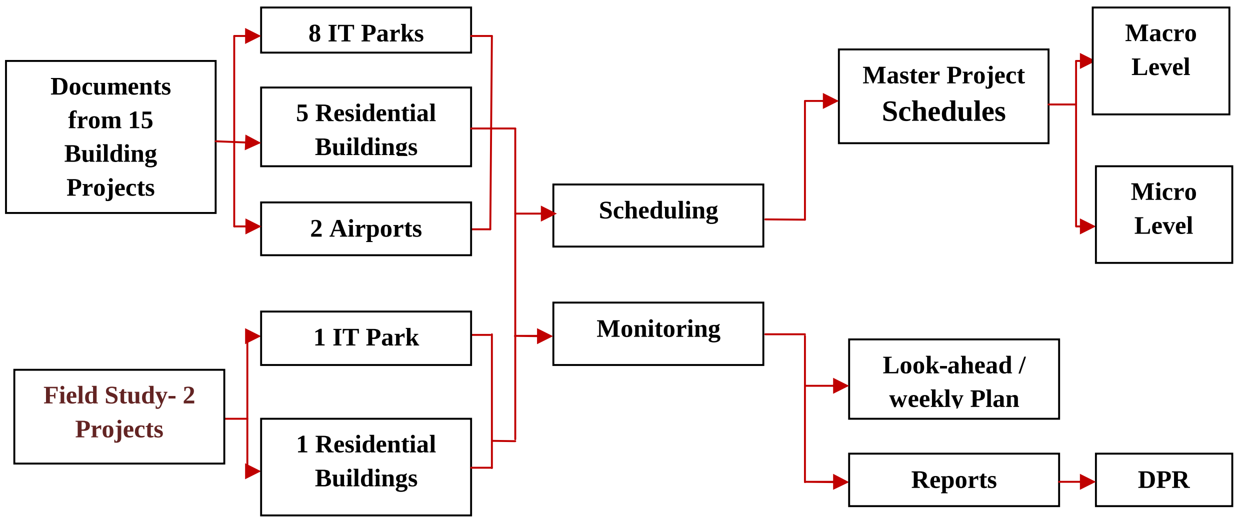

Figure 2: Data Collection Breakdown

The data is collected from 15 building projects of planning reports, labour productivity measurement reports, construction schedules monitoring and reporting schedules as shown in Figure 2. The data collected for the research includes;

- Field study in construction site
- Structured interviews and expert opinions
- Data from current and past projects
- Literature review
- Questionnaire Survey

The field study was done on two ongoing building projects, where the planning process was studied as a participant observer. The method used for measurement of labour productivity analysis was explored and the process of progress monitoring, reporting, and scheduling was critically examined to identify potential problems.

4. PROBLEM IDENTIFICATION

The analysis of data collected and observation from field study revealed that there was no structured method to analyse and improve labour productivity during the construction phase. It was found that there were several reasons for the lack of a structured approach to monitor and improve labour productivity.

One of the key challenges for implementing a structured approach to monitor and improve labour productivity was that the macro-level and micro-level schedule did not represent the actual situation on site. As a result, the execution team did not have accurate information on short-term as well as daily targets. A second key challenge was that on several projects there was no standardised procedure to record and monitor the daily productivity.

To further explore the first issue, schedules collected from all 15 projects were audited based on standard practice such as the GAO Schedule Assessment Guide (GAO-2012). It is revealed that while the overall milestone schedule was appropriate, the detailed CPM schedule had several limitations, which make the schedule irrelevant for look-ahead planning, target setting and coordination of resources. The limitations found in the schedules are enumerated below:

- ***Calendar -*** Specifically in India, the holiday's changes based on regional basis in countrywide, in schedule calendar the standard calendar were used or the exception for holidays was not made. At the same time, unexpected holidays occurred during progress was not updated in schedule. The work timings for specific construction projects were not defined.
- ***WBS -*** The Work Breakdown structure followed in scheduling varied widely among construction sites with similar works and the WBS in schedule was different from followed in site execution for Finishing and Mechanical Electrical and Plumbing work.
- ***Activity Relationships -*** The improper logical precedence linking was a major problem in all the schedules. The schedules contained open-ended activities, which break the logical network sequence and critical path becomes invalid. The start-to-start activity relationship was used in over abundance, which made the schedule unrealistic.
- ***Activity Durations -*** The duration of activities were decided based on experiences and guestimation. The labour productivity and construction methods information was not considered for duration estimation.
- ***Resource Loading -*** The resource loading was not done for the detailed construction schedules, which affected the effective utilization of labour, and labour requirement projection was done on experimental basis.
- ***Schedule Updating -*** The schedule was not updated and tracked based on the actual site progress. The detailed look-ahead schedules were not followed in accordance with master schedules.

Figure 3 shows the percentage of projects that complied with the standard scheduling practices. It can be seen that while all projects has appropriate milestone schedules, only 4 to 5 projects out of 15 complied with other requirements.

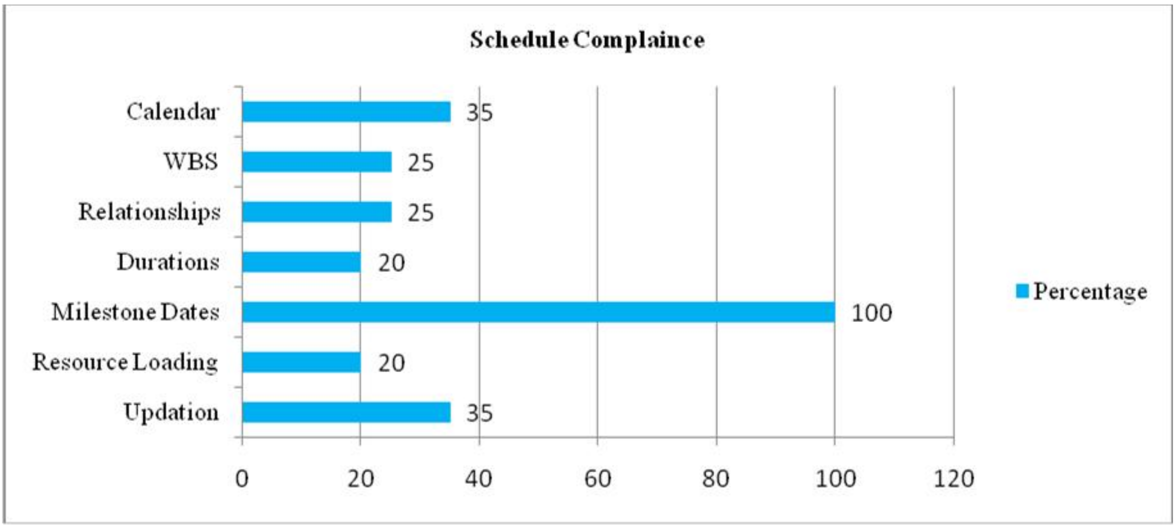

Figure 3: Schedule Compliance Analysis

As mentioned earlier, the second challenge faced in monitoring and improving labour productivity was lack of established procedure for recording daily labour productivity on most sites. Even the sites, which recorded labour productivity on a daily basis (through Daily Progress Report- DPR) did not analyse the data for improving the labour productivity. To further explore this issue the practices of the sites that were recording daily labour productivity was analysed. The following issues were found impede implementing productivity measurement and improvement processes.

- The responsibility of preparing the DPR was with the planning team. As a result, the accurate field data was not reflected in the reports,
- Although the daily quantity and man-hours spent was being recorded, the actual labour productivity was not being calculated and utilised for monitoring,
- The execution plan followed in site was not in accordance with the planned schedule due to coordination gaps between execution and planning team hence the execution team refrained from reporting progress to the planning team,
- Even on projects where labour productivity was being calculated, the labour productivity data was only reported and not considered for improving the productivity.

Interviews of labour contractors and site engineers followed by a detailed analysis of Indian labour conditions found specific constraints, which make planning and scheduling more challenging in the Indian scenario. The factors found are:

- The skill of Indian labour is highly variable, as a result planning and execution personnel are unable to estimate the actual productivity that will be achieved on site,
- On all the sites studied, the labour employed in site is on a sub contract basis, thus the commitment of the labour to a specific project is very low and they tend to abandon the project due to a variety of reasons ranging from taking extended holidays during festival season to marginal increase in wages on other sites this severely disrupts production and productivity,
- The data from the projects studied shows that the labour turnover in the entire cycle of the project was 80 to 100 times that of the peak labour required, this constant turnover has a significant influence on site labour productivity.

To understand these issues at a more detail level further assessment of the situation was done through a questionnaire survey.

5. ANALYSIS OF PROBLEM

To ratify and enumerate the root-causes of the problems faced, a detailed analysis was done. Based on the problems identified, a questionnaire survey was administered to 30 planning mangers of Indian building projects and the data from the field study was analysed. Figure 4. Shows a fish-bone diagram in which various categories of problems and their root cause are shown. Only indicative terms are used in the figure, detailed explanations are given below.

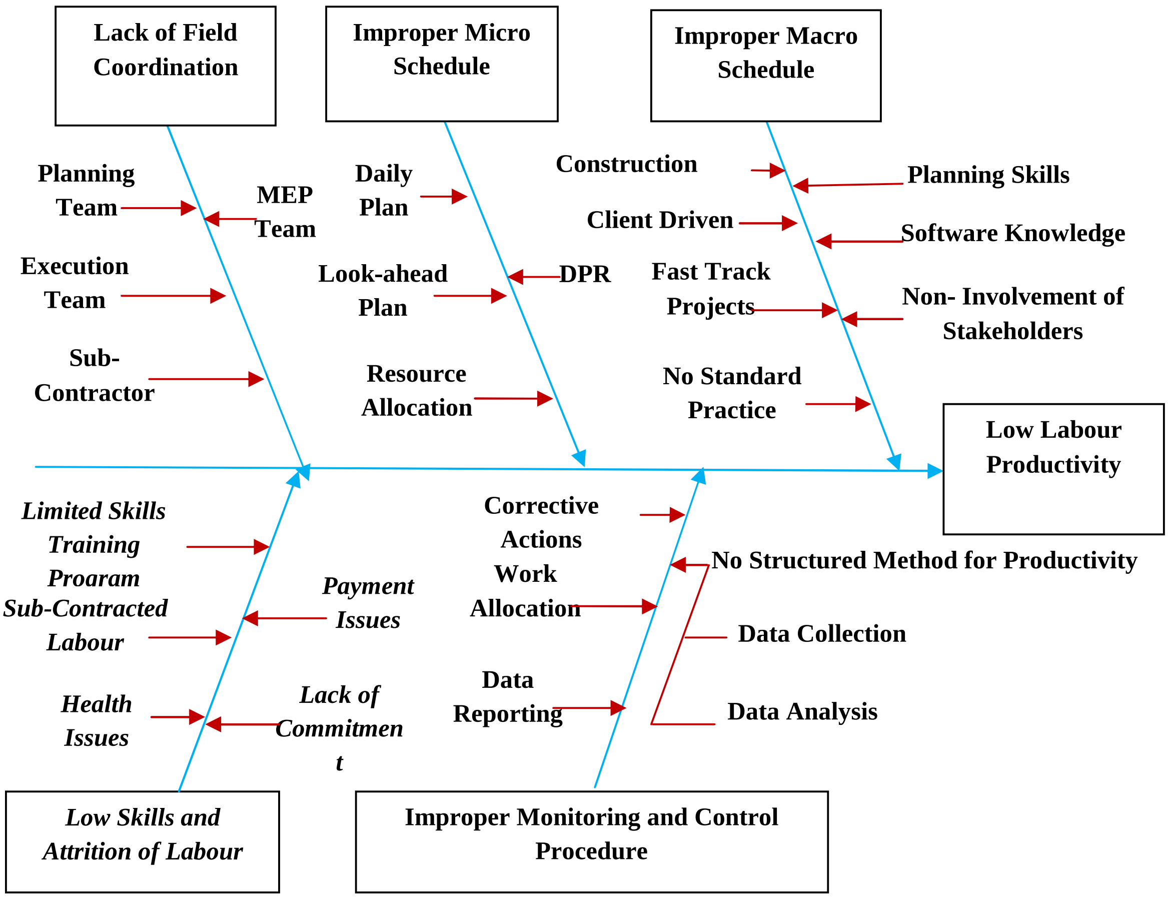

Figure 4: Causes and Effect Diagram of Low Productivity

Analysis for the first key challenge, improper macro and micro level scheduling is done and it was found that the reasons for the improper scheduling are:

- The lack of planning skills of the schedulers was a key reason for improper scheduling. In India, there is no certification of planning engineers, hence most planning personnel lack the knowledge and skills to apply planning concepts to practice.
- The scheduling software used was MS Project in all the sites, but due to inadequate skills and experience on the software effective usage of the tool was not made.
- In project schedule development, the stakeholders were not involved with planning team, which led to development of abstract and infeasible schedules that could not be used by the execution team.
- In scheduling practice, the construction methods used are not considered for deciding activity sequence and durations, this results in poor resource planning and constructability issues.
- The client makes frequent changes in the priority of work to be done with no financial implication to the client. Hence, schedules have to be revised frequently and on an urgent basis. As a result relevance of a detailed schedule is short-lived.

- Most of the building projects were fast track projects; hence, scheduling is done before the completion of design and finalization of construction methods. This results in non-availability of information on quantity and construction methods impede accurate estimation of duration of activity and sequence.
- The DPR followed in sites varied widely without any specific reasons because there was no standardised format specified.
- In most of the projects, the daily action plan, catch-up plan were not prepared and implemented. This led to large volumes of work to completion just before milestone dates. As a result, more resources were assigned to achieve the milestones dates, leading to reduced productivity.
- The available resources like equipments, materials and labour available on site were not allocated and coordinated as per the work to be performed by different stakeholders.
- In the micro level planning, there was no coordination between planning team, the execution team and MEP team for requirement and use of resources, which led to unavailability of resources during execution period.
- The daily work plan was not coordinated and discussed with sub-contractor, which resulted in uncoordinated work practices.

The root cause analysis for the second key challenges, namely monitoring and reporting labour productivity, is as follows:

- The labour productivity data collected by few sites was not analysed and reported because the purpose and use of labour productivity data analysis was not conveyed to the site engineer and foreman. Hence, level of labour productivity was not known and corrective actions were not taken.
- The progress was not monitored and reported because the site execution team on weekly basis did not prepare the look-ahead plan. Therefore, the site engineer and the foreman did not take the ownership in collecting data, monitoring, reporting and improving the same on a continuous basis.
- The daily work planning and labour allocation was done primarily based on ad-hoc requirements this led to uncertainty in execution time and resulted in wastage of resources.
- The labour productivity was not considered as a standard input in management and project decisions, hence there was no standardized process in place for monitoring and controlling productivity.
- The labour skills are low because no skill training is provided to the labour coming to construction sites and labour mainly comes from the agricultural background and rural areas. In India there are limited labour skills training institutes to meet the demand for skilled workers.
- The labour on sites was employed temporarily on sub-contracted basis. Due to that, the same labour was not available for the repetitive work during execution phase as there was no control of general contractor.
- The payment of the bill given by the contractor was delayed due to non-submission of the work measurement to the billing team, which increase the payment period to the labour. In many site due to delay in payment labour was not available.
- The lack of commitment towards work was due to festive seasons, crops harvesting season and personal commitments and the ownership of the work was not taken by the labour as the labour worked on daily wages basis, so labour was not worried about the quantity of work done.
- The labour absenteeism on work was mainly due to health problems faced by the labour in the site and due to lack of basic needs and health facilities provided by sites.

To address above identified problems a framework consisting of top-down and bottom-up approach is proposed. In top-down approach, a comparison of observed practices with documented best practices are made and constraints unique to building projects in India, the gaps in developing CPM based schedules are enumerated and strategies to close the gaps are suggested.

In the bottom up approach, a structured method is prepared for analysis and improvement of labour productivity. At the same time, to close the gap between monitoring daily progress against planned weekly and monthly targets, a methodology, which can be implemented on site, is documented.

6. PROPOSED FRAMEWORK

After a detailed analysis of problems and its causes for labour productivity, a framework adopting top-down and bottom-up approach is developed considering the unique aspects of Indian project delivery process as shown in Figure 5.

In the top down approach, a standardised approach for developing WBS, sequencing, estimating activity duration, specifying activity relationships, estimating activity duration, resource allocation and scheduling levels are specified based on the global best practices. The detailed work breakdown structure to address complex interdependency in structure, finishing and Mechanical Electrical and Plumbing (MEP) works are enumerated to facilitate correct approach for detailed scheduling based on practical detailed sequence collected from construction sites field study.

The framework scheduling approach involves the site execution team, planning team, construction methods and data from past experiences in development of schedule. The coordination in schedule development and acceptance by site execution team facilitates monitoring of project schedule. Hence, the schedule serves the purpose of appropriate tool for short-term micro planning. The framework does not address the problem of scheduling occurred due to software skills, changes by client and availability of information for scheduling in fast-track projects. These are the broad level problems in construction industry, which is a long time process for improvement.

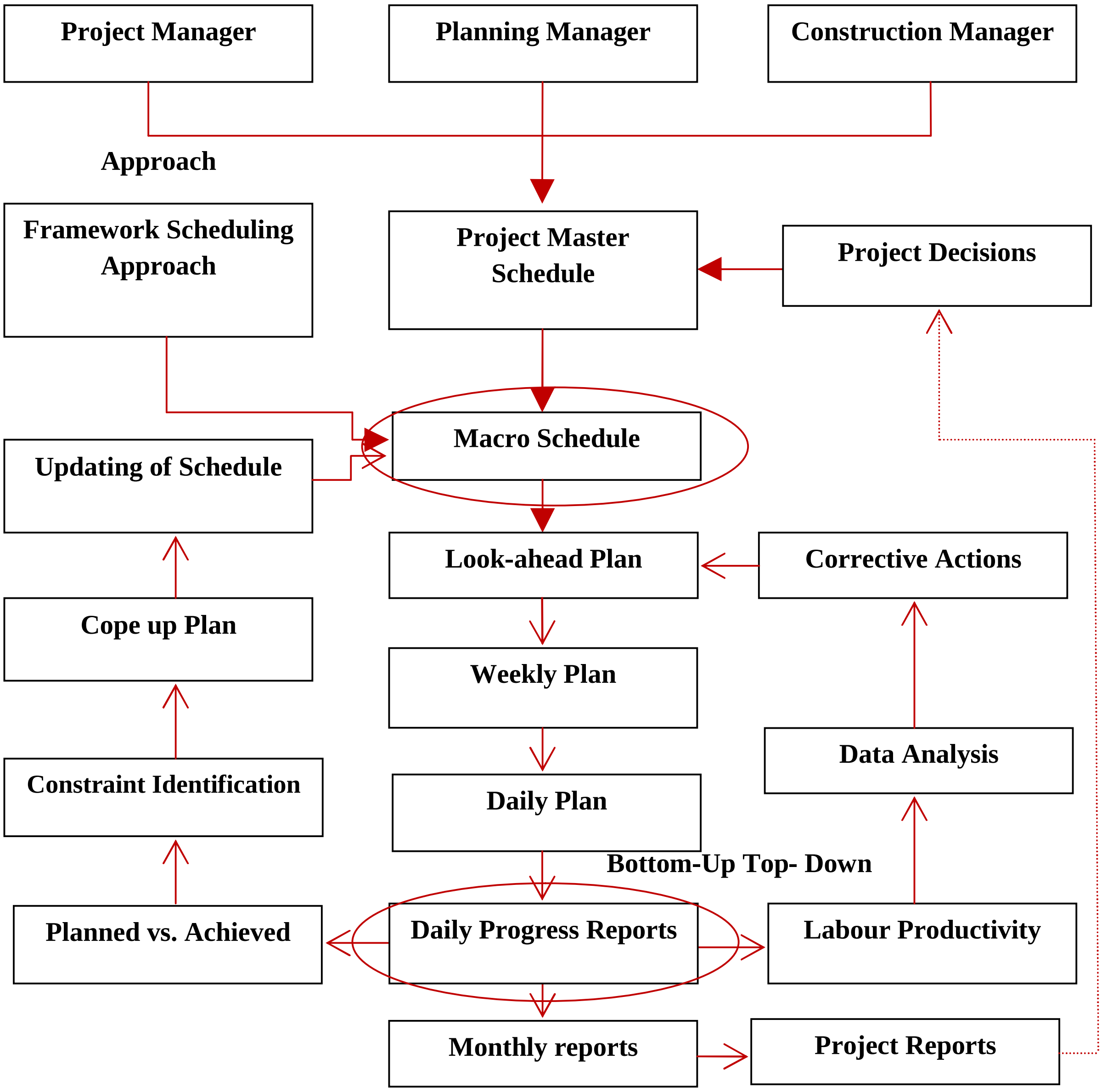

Figure 5: Framework to Improve Planning and Labour Productivity Practices

Based on realistic micro level schedule from top-down approach, the micro level planning (look-ahead schedule) is prepared by the site execution team considering available resources, quantum of work and labour productivity in site. The daily and weekly work plans are prepared from the look-ahead plan. To monitor the planned targets and productivity, in the bottom up approach for data collection, DPR followed in the sites is standardised from which the labour productivity and planned vs. achieved status report is collected and analysed. The planned vs. achieved data is used for further work planning and addressing the constraints causing low productivity. Corrective actions to increase productivity levels are identified based on the analysis and discussions.

The project schedule is updated regularly as per the progress and actual productivity in site; the updated schedule gives accurate detail of project progress and quantity of work done. Labour productivity and progress data are considered as a standard input for decision-making at higher management level. As a part of this work, a manual standardizing all formats and guidelines of developed framework for planning practice, analysis and improvement of labour productivity has been developed and is being implemented in site. The framework does not address the lack of skill and attrition problem in the bottom-up approach.

These problems can be identified from the data analysis but solution to the problems varies according to the site-specific conditions and labour employed.

7. SUMMARY AND FUTURE WORK

This paper presents a study on improving the practice of recording and monitoring of labour productivity on Indian building projects. The two key challenges, improper scheduling and lack of established procedure for productivity monitoring and control are identified and analysis is done to find the root cause of the problems faced. The root causes for low productivity found from the analysis are specific to the Indian sites, which need to be addressed for effective monitoring and control of labour productivity. A framework is proposed adopting top-down and bottom-up approach to overcome root causes. The top-down approach address several gaps in developing a project schedule and a detailed approach is given to close the gaps is suggested. The bottom-up approach proposes establishing a procedure for recording, monitoring and control of labour productivity. In combination with the top-down approach, this is expected to overcome the several limitations in analysis and improving of labour productivity in Indian building projects.

As a part of the on-going work site implementation and evaluation of the proposed framework is being done. The study can also be extended to find ways of overcoming the issues that the proposed framework does not address.

8. REFERENCES

Absalom H.V.L., Masu S.M., Wanyona G. and Gwaya, S.D.A.O., 2014. Factors Influencing Effective Productivity on Construction Sites in Nairobi County.*International Journal of Soft Computing and Engineering (IJSCE),* 4(5), 24-30.

GAO Schedule Assessment Guide: Best Practices for project schedules, 2012. *United States Government Accountability Office- Applied Research and Methods* [online]. Available from: http://www.gao.gov/assets/600/591240.pdf [Accessed 10 January 2015].

Indian Standard,2013. IS 15883 (Part 2). *Construction Project Management Guidelines.*Bureau of Indian Standard Publications: IS.

Johansen, D.E., 1996. *Planning on medium sized construction projects.*Unpublished Thesis (MPhil).University of Northumbria.

Laufer, A. and Tucker, R.L., 1987. Is Construction Project Planning really doing its Job? A Critical Examination of Focus, Role and Process,*Construction Management and Economics,* 5, 243-266.

Planning and scheduling excellence guide (PASEG), 2011. *National Defense Industrial Association (NDIA) Industrial Committee for Program Management (ICPM*) [online], Arlington :draft v1.1b-Public release. Available from: http://www.goaztech.com/paseg [Accessed 12 January 2014].

Subbiah, A., 2012. An investigation of the factors influencing the success of construction planning for the 2012 Olympic stadium: An ethnographic study. In: Smith, S.D., ed. *28th Annual ARCOM Conference,* Edinburgh 3-5 September 2012. UK: Association of Researchers in Construction Management, 1035-1045**.**

Thomas, A.V. and Sudhakumar, J., 2014. Factors Influencing Construction Labour Productivity: An Indian Case Study*, Journal of Construction in developing countries,* 19(1), 53-68.

HOW TO DESIGN DURABLE CONCRETE MIX FOR SUSTAINABILITY?

Lu Jin Ping*

Admaterials Technologies Pte. Ltd., Singapore

ABSTRACT

In order to achieve the sustainability of social development, low carbon emission has played more and more important role. In this complex world scenario, infrastructure regeneration and rehabilitation; cement and concrete materials have an undeniable part to play in enhancing the quality of human life. If we are to avoid unredeemable environmental degradation globally, sustainable development of the cement and concrete industry has to be the foundation for all construction activity in the next millennium. The durability of cement and concrete materials is closely related to low carbon emission and energy saving. High performance and high durable concrete materials can contribute to the saving of raw materials, reducing of cement usage as well as low maintenance for long life. In order to achieve the objective of low carbon emission for ready mix concrete products, the design of concrete mix should be reconsidered. In this paper, the principles of ready mix concrete design has been discussed based on the durability requirements according to the new concrete Standard SS EN206-1. In every step of the design, the requirement of low carbon emission and green materials has been considered. Examples of design procedures are also illustrated in this paper for easy reference.

Keywords: *Concrete Specification; Design; Durability; Sustainability; SS544-1,*

1. INTRODUCTION

Concrete material is one of the important construction materials with the highest volume in the construction industry today. To achieve low carbon emission for concrete industry, ready mix concrete should play very important role. To build low carbon emission building, low carbon and energy saving concrete must be available (Swamy, 2000).

Most of Singapore Standards (SS) for civil engineering are based on British Standards (BS) and BS has been integrated into European Standards. Since 2006, Spring Singapore and Building and Construction Authority (BCA) have organized experts in concrete industry to review and draft the new Singapore Concrete Standards SS EN 206-1 (Spring Singapore, 2009) and complementary Standards SS 544-1 (Spring Singapore, 2009a) and SS 544-2 (Spring Singapore, 2009b). These new standards were officially published in 2009.

In SS 544-1: Method of specifying and guidance for the specifier, the basic and additional requirements for different concrete mix are listed. In this paper, different kinds of concrete will be introduced according to SS 544-1. The design procedure and methods for different concretes will be discussed. The consideration of low carbon and green requirements has been incorporated into the mix design method. An example is used to illustrate the every step of the concrete design.

2. CONCRETE SPECIFICATION BY SS 544-1

The SS 544-1 offers five approaches to the specification of concrete (Spring Singapore, 2009):

a. Designated concretes: For many common applications, the simplest approach is to specify a designated concrete. Designated concretes were developed to make the specification of designed concretes simpler, complete and more reliable.

b. Designed concretes: Designed concretes are suitable for almost all applications. They may be

* Corresponding Author: E-mail - jimpimg@admaterials.com.sgcom.

used as an alternative to designated concrete and should be used where the requirements are outside of those covered by designated concretes.

c. Prescribed concretes: This approach allows the specifier to prescribe the exact composition and constituents of the concrete. It is not permitted to include requirements on concrete strength, and so this option has only limited applicability.

d. Standardised prescribed concretes: Standardised prescribed concretes are applicable for housing and similar construction where concrete is site-batched on a small site or obtained from a ready-mixed concrete producer who does not have accredited third-party certification.

e. Proprietary concretes: This approach is appropriate where it is required that the concrete achieves a specific performance, using defined test methods.

Generally, in Singapore, most concrete supplied in the market is designed concrete. For designed concrete, the specification requirements according to SS 544-1 are listed as below (SS 544-1, 2009):

Basic requirements:

a. a requirement to conform to SS 544-2
b. the compressive strength class (Table 1)
c. the limiting values of composition, e.g. maximum w/*c* ratio, minimum cement content or the DC-class where appropriate (Table 2)
d. where the DC-class has not been specified, the permitted cements and combinatio (Table 3)
e. the maximum aggregate size where a value other than 20 mm is required
f. the chloride class where a class other than Cl *0.4* is required
g. for lightweight concrete, the density class or target density
h. for heavyweight concrete, the target density
i. the class of consistence or, in special cases, a target value for consistence (Table 4).

Table 1: Compressive Strength Classes for Normal-Weight and Heavy-Weight Concrete

Compressive Strength Class	Minimum Characteristic Cylinder Strength N/mm^2	Minimum Characteristic Cube Strength N/mm^2
C8/10	8	10
C12/15	12	15
C16/20	16	20
C20/25	20	25
C25/30	25	30
C30/37	30	37
C35/45	35	45
C40/50	40	50
C45/55	45	55
C50/60	50	60
C55/67	55	67
C60/75	60	75
C70/85	70	85
C80/95	80	95
C90/105	90	105
C100/115	100	115

Additional requirements:

a. Special types or classes of aggregate, e.g. for wear resistance or freeze-thaw resistance
b. Where the use of coarse RA is deemed acceptable, a statement that coarse RA is permitted and a requirement for the RA to conform to SS 544-2 : 2009, 4.3
c. Restrictions on the use of certain aggregates
d. Generic type and dosage of fibres
e. Characteristics required to resist freeze-thaw attack, e.g. air content
f. Requirements for the temperature of the fresh concrete, where different from the lower limit in SS EN 206-1 : 2009, 5.2.8 or the upper limit in SS 544-2 : 2009, 5.4
g. Strength development
h. Heat development during hydration
i. Retarded stiffening
j. Resistance to water penetration
k. Resistance to abrasion
l. Tensile splitting strength
m. Other technical requirements, e.g. requirements related to the achievement of a particular finish or special method of placing
n. Any “concerning” effects together with the tests to be applied and the acceptability criteria

Table 2: Limiting Values of Composition and Properties for Concrete where a DC-Class is Specified

DC-Class	Max, w/c Ratio	Min. Cement Content for 20mm Aggregate	Cement and Combination Types
DC-1A)	-	-	All
DC-2	0.55	320	IIB-V+SR, IIIA+SR, IIIB+SR, IVB-V
	0.50	340	CEM I, SRPC, IIA-D, IIA-Q, IIA-S, IIA-V, IIB-S, IIB-V, IIIA, IIIB
	0.45	360	IIA-L or LL≥42.5
	0.40	380	IIA-L or LL 32.5
DC2z	0.55	320	All
DC-3	0.50	340	IIIB+SR
	0.45	360	IVB-V
	0.40	380	IIB-V+SR, IIIA+SR, SRPC
DC-3z	0.50	340	All
DC-4	0.45	360	IIIB+SR
	0.40	380	IVB-V
	0.35	380	IIB-V+SR, IIIA+SR,SRPC
DC-4z	0.45	360	All
DC-4m	0.45	360	IIIB+SR

A) If the concrete is reinforced or contains embedded metal, the min concrete quality for 20mm maximum aggregate size is C25/30, 0.65, 260

Table 3: Maximum Chloride Content of Concrete

Concrete Use	Chloride Content Class[a]	Maximum CI Content by Mass of Cement[b]
Not containing steel reinforcement or other embedded metal with the exception of corrosion-resisting lifting devices	Cl 1.0	1.0 %
Containing steel reinforcement or other embedded metal	Cl 0.20	0.20%
	Cl 0.40	0.40 %
Containing prestressing steel reinforcement	Cl 0.10	0.10 %
	Cl 0.20	0.20%

[a] For a specific concrete use, the class to be applied depends upon the provisions valid in the place of use of the concrete.
[b] Where type II additions are used and are taken into account for the cement content, the chloride content is expressed as the percentage chloride ion by mass of cement plus total mass of additions that are taken into account.

Table 4: Slump Class

Class	Slump in mm
S1	10 to 40
S2	50 to 90
S3	100 to 150
S4	160 to 210
S5	≥ 220

3. Low Carbon Emission Consideration for Specification

As we know, carbon emission of concrete mainly comes from cement production. One ton of carbon dioxide will be released for production of one ton of cement. There are 3 main sources of carbon emission from cement production as shown in Figure 1.

a. Energy supplied to clinker kiln : 50% (300-450kg CO_2 per ton of cement)
b. Decomposition of limestone : 50% (450kg CO_2 per ton of cement)
c. Electricity and transportation : very low percentage

Therefore, for the design of low carbon concrete the first choice is to use the minimum cement content to produce durable and high performance concrete mix to meet the requirements of structure design. Choice of suitable raw materials, including concrete admixture, is the second consideration. It is followed by usage of industry and construction waste materials. Design of durable and high performance is essential for green concrete.

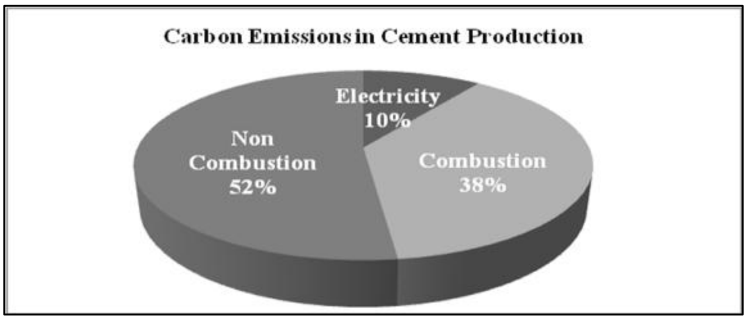

Figure 1: Carbon Emissions in Cement Production

3.1. *DESIGN OF HIGH PERFORMANCE CONCRETE TO REPLACE NORMAL CONCRETE*

Compared to normal concrete, the use of high strength concrete can reduce the structure size, so that not only the volume of concrete materials, energy consumption and manpower can be reduced; but also the usable area of the building can be increased. It is illustrated in Table 5 where, for the same loading capacity, the columns with high performance concrete can save up to 55% of concrete volume or 18% cement usage. Although the cement content per m^3 concrete is increased, the following effectiveness can be achieved:

a. Increasing of compressive strength of concrete can reduce concrete volume

b. The weight of structure is reduced, so that the size of foundations can be reduced.

c. The design for earthquakes can be reduced.

3.2. *USE SUPPLEMENTARY CEMENTING MATERIALS*

There are 27 types of cement in the new cement standards SS EN 197. With the exceptions of of CEM I and SRPC, all other cements contain supplementary cementing materials. In SS 544-2, cements are grouped into 7 categories, as shown in Table 6.

Table 7 shows the comparison of energy consumption of ordinary cement with supplementary cementing materials. To produce 1 ton of cement with 65% slag powder only needs 0.5 ton raw materials, and 1,500-1,600MJ of energy. Every ton of cement can save at least 6,000 MJ energy.

To produce one ton cement, 1.0-1.2 ton of CO_2 will be released. Table 8 provides a comparison of concrete with supplementary cementing materials. It can be seen that cement with 30% fly ash can reduce carbon emission by 20%, while cement with 50% GGBS can reduce Carbon emission by 43-50%.

Table 5: Comparison between High Performance Concrete and Normal Concrete

Type of Concrete	Normal (28 MPa)	High Performance (62 MPa)
Total binding materials (kg/m^3)	330	510
Mineral Addition (kg/m^3)	65 fly ash	24 silica fume
OPC (kg/m^3)	260	490
Column size(mm)	900 X 900	600 X 600
Concrete volume(m^3)	3.8	1.7
Volume reduction (%)	-	55
Cement reduction (kg)	1000	820
Cement reduction (%)	-	18

Table 6: Categories of Cements

CEM I	Portland Cement
SRPC	Sulfate-resisting Portland cement
IIA	PC with 6 to 20% other material
IIB-V	PC with 21 to 35% fly ash
IIIA	PC with 36 to 65% ggbs
IIIB	PC with 66 to 80% ggbs
IVB-V	PC with 36 to 55% fly ash

Table 7: Comparison of Energy Consumption

Energy Consumption		
Cement	7,500	MJ/ton
Fly Ash	150-400	MJ/ton
Slag	700-1,000	MJ/ton
CO_2 emission		
Cement	1.0-1.2	Ton/ton clinker

In conclusion, for the design of low carbon concrete, the principles for choosing cement should be as below.

a. Avoid to only use Ordinary Portland Cement
b. For normal construction, to use II B-V or III A cement (Tables 2 and 7)
c. For underground or marine construction, to use IV B-V or III B cement.

3.3. USE RECYCLED AGGREGATE TO REPLACE NATURAL AGGREGATE

Worldwide concrete industry faces the problem of shortage of aggregate resources. Looking for new sources of aggregate for concrete production started decades ago.

There are various studies on usage of sea sand, recycled concrete aggregate, mining tail and manufactured aggregate, etc. How to effectively use all available aggregate for concrete production is very important, especially for Singapore, which is a small country without any natural resource of aggregate. Compared to the old Singapore Standard on aggregate SS 31, the new Singapore Standard SS EN 12620 covers a wider range of aggregates, including natural aggregates, recycled aggregate as well as industry by-products. Complementary Singapore Standards for concrete SS 544-2 provides the definition and requirements for recycled aggregate.

Table 8: Comparison of carbon emission

Carbon emission ($kgCO_2/m^3$)			**Comparison to Normal concrete**	
Normal concrete	**30% fly ash concrete**	**50% slag concrete**	**30% fly ash concrete**	**50% slag concrete**
208	161	104	78%	50%
217	174	109	80%	50%
291	233	155	80%	53%
310	252	170	81%	55%
342	281	196	82%	57%

The definition of recycled aggregate in SS EN 206-1, Clause 3.0:

- Manufactured aggregate : Aggregate of mineral origin resulting from an industrial process involving thermal or other modification.
- Recycled aggregate : Aggregate resulting from the processing of inorganic material previously used in construction

The definition in SS 544-1, Clause 3.1:

- Recycled aggregate (RA) : Aggregate resulting from the reprocessing of inorganic material previously used in construction.

- Recycled concrete aggregate (RCA) : Recycled aggregate principally comprising crushed concrete.

The definition of recovered aggregate in SS EN 206-1, Clause 5.2.3.3:

- Recovered aggregate : Aggregate recovered from wash water or fresh concrete may be used as aggregate for concrete.

SS 544-2 specified the quality requirements of recycled aggregate as shown in Table 9.

SS 544-2 limits the usage of recycled coarse aggregate only for the concrete as listed in Table 10.

Clause 6.2.2 of SS 544-2 limits the usage of recycled aggregate: Where coarse RA or RCA is to be used in designated concretes *RC20/25* to RC40/50, its proportion shall be not more than a mass fraction of 20 % of coarse aggregate except where the specification permits higher proportions to be used. RA or RCA shall not be used in any of the FND or PAV designated concretes nor in designated concrete RC50XF.

In SS EN206-1, undivided recovered aggregate shall not be added in quantities greater than 5 % of the total aggregate. Where the quantities of the recovered aggregates is greater than 5 % of the total aggregate, they shall be of the same type as the primary aggregate and shall be divided into separate coarse and fine fractions and conform to SS EN 12620.

3.4. USE OF CONCRETE ADMIXTURE

Concrete properties can be modified by concrete admixtures. By using a concrete admixture, high performance durable concrete can be designed with low cement content, good workability, so that saving of raw materials, carbon emission, manpower and energy can be achieved. Table 10 shows the saving of cement content by using of concrete admixture.

In summary, for design of low carbon emission concrete the following points shall be considered:

- Use supplementary cementing materials to replace OPC, for normal construction, CEM II B-V or III A cement should be used, while for underground and marine construction, CEM IV B-V or III B cement should be used
- Use of concrete admixture
- Use of recycled aggregate to replace natural aggregate
- Avoid overdesign.

Table 9: Requirements for Coarse RCA and Coarse RA

Type	**Requirement A)**					
	Max Masonry Content	**Max Fines**	**Max light-Weight Material B)**	**Max Asphalt**	**Max other Foreign Material e.g. glass, plastics, metals**	**Max Acid- Soluble Sulfate (SO_3)**
RCA A)C)	5	5	0.5	5.0	1.0	1.0
RA	100	3	1.0	10.0	1.0	- D)

A) Where the material to be used is obtained by crushing hardened concrete of known composition that has not been in use, e.g. surplus precast units or returned fresh concrete, and not contaminated during storage and processing, the only requirements are those for grading and maximum fines.
B) Material with a density less than 1000 kg/m^3.
C) The provisions for coarse RCA may be applied to mixtures of natural coarse aggregates blended with the listed constituents.
D) The appropriate limit and test method needs to be determined on a case-by-case basis.

Table 10: Limit of Recycled Coarse Aggregate for Concrete

Type of Aggregate	**Limitations on use**	
	Maximum strength class[A)]	**Exposure classes** [B)]
RCA	C40/50	XO, XC1, XC2, XC3, XC4, XF1, DC-1

[A)] Material obtained by crushing hardened concrete of known composition that has not been in use and not contaminated during storage and processing may be used in any strength class.。
[B)] These aggregates may be used in other exposure classes provided it has been demonstrated that the resulting concrete is suitable for the intended environment, e.g. freeze-thaw resisting, sulfate-resisting.

Table 11: Use of Concrete Admixture to Reduce Cement Content

Water Reducing Rate (l/m^3)	**Water Reducing Rate (%)**	**Cement Reducing (kg/m^3)(@0.55 w/c)**	**Cement Reducing (kg/m^3)(@ 0.40 w/c)**
10	5.6	18	25
15	8.3	27	37
20	11.1	36	50
25	13.9	45	62
30	16.7	54	75

4. DESIGN PROCEDURE OF LOW CARBON CONCRETE

4.1. DESIGN PROCEDURE ACCORDING TO SS 544-1

The design procedure for specifying concrete mix recommended by SS 544-1 is explained (Harrison and Brooker, 2005) as below:

- Step 1: Using Table A.1 in SS 544-1 to identify relevant exposure classes (Figure 3). If an aggressive chemical class is included, then go to Step 2. If not, then go to Step 10.
- Step 2: Using Table A.2 to classify ground conditions.
- Step 3: Using Table A.3 to select structural performance level.
- Step 4: Using Table A.4 to select DC-Class and number of APMs.
- Step 5: Are APMs recommended? If yes, go to Step 6, if no, go to step 10.
- Step 6: Are starred or double-Starred classes available? If yes, go to Step 4. If no, go to step 7.
- Step 7: Using table A.5 to select APMs
- Step 8: Is APM 1 included? If yes, go to Step 9, if no, go to step 10.
- Step 9: Increase DC-Class by 1 class for each application of APM1.
- Step 10: From Scheme design, note intended working life, compressive strength class, cover and margin (Δc).
- Step 11: Consider and note other factors to be considered.
- Step 12: Using Table A.10 to A.16 for each of the relevant exposure classes, note the nominal cover, limiting values and properties.
- Step 13: Select the limiting values to be used in the specification.
- Step 14: Is the resulting strength class or nominal cover different from that noted in Step 10? Are APMs other than APM1 required. If yes, go to step 15. If no, go to step 16.
- Step 15: Take account of the changes in the design.
- Step 16: Specify the basic requirement using clause 4.3.2 in SS 544-2 as a checklist.

- Step 17: Specify any additional requirements and provisions using clause 4.3.3 as a checklist.
- Step 18: Add, where relevant, information from the specifier using clause 5.1 as a checklist.
- Step 19: Where required, list information required from the producer using clause 5.2 as a checklist.

4.2. EXAMPLE OF THE DESIGN PROCEDURE

This example follows the steps illustrated on the above. Suspended reinforced concrete internal office slab that will be carpeted. The concrete will be pumped, compacted with a beam vibrator and finished with a bull-float. The columns of this building require C32/40 concrete. As the slab is carpeted, there are no abrasion considerations. From Figure 2, the only relevant exposure class is XC1. For the determination of exposure class, Figure 2 can be referred to.

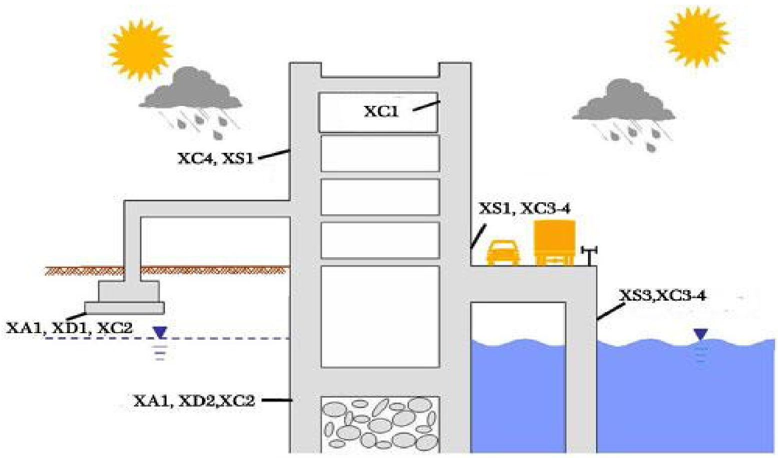

Figure 2: Exposure Class

As there are no aggressive chemical classes, refer step 10. As this is a normal building structure, EN 1990: Basis of design, recommends an intended working life of (at least) 50 years. The scheme design was done to EN 1990 and this assumed a C25/30 concrete with 25 mm nominal cover. There is also a need to select the margin and express the nominal cover as a minimum cover plus the margin (Δc). EN 1992–1: Eurocode 2: Design of concrete structures - Part 1: general rules and rules for buildings gives guidance on the selection of the margin Δc. It indicates that the value should be a function of the level of control on site. However the consequence of low cover should also be a factor in its selection and as this is an internal environment with no real durability concerns, a value of 5 mm for Δc with normal levels of workmanship is appropriate. A value of 5 mm for Δc is selected. The nominal cover from the scheme design is therefore (20 + 5) mm.

Refer step 11 the specifier should select the maximum aggregate size and the consistence class (or target value). The specifier selects a maximum aggregate size of 20 mm. The concrete is reinforced and the specifier decides to follow the guidance in clause 4.2A in SS 544-1 for the chloride class, namely Cl 0.4. The specifier selects slump class S3 as being suitable for the pumped concrete. As the concrete will be ready-mixed, the specifier decides that accredited third party certification is required. Refer to Table A.4 in SS 544-1, the limiting values and properties of concrete and the nominal cover to reinforcement for the XC1 exposure is nominal cover for durability is (15 + 5) mm and concrete C20/25, 0.70, 240 (from Table 12 for maximum aggregate size of 20 mm) and all cements/combinations in Table A.6.

There are no other exposure classes to consider. Refer step 13 for a nominal cover of (15 + 5) mm, the limiting values and properties of the concrete are C20/25, 0.70, 240, 20 mm maximum aggregate size and any cement/combination. Cement or combination types IIIB and IVB are normally specified for situations requiring high resistance to chlorides, sulphates or other aggressive chemicals. They also tend to have low rates of strength development in thin sections. Because the exposure classes do not include XD, XS or aggressive chemicals, cement/combination types IIIB and IVB were discarded at this stage of the process. As SRPC is also a special cement used for producing sulphate-resisting concrete, it is also discarded.

Refer step 14. There are differences between the durability design and the preliminary scheme design. Then refer step 15. The requirements are less onerous than those given in the scheme design, i.e. the strength class is down from C25/30 to C20/25 and the nominal cover is down from 25 mm to 20 mm. The designer then has the choice of leaving the scheme design unchanged or seeing if a more efficient design is possible. In this case, a check on the structural design showed that both the cover and concrete strength class could be reduced without material change to member sizes or reinforcement quantities. Hence the reduced cover and concrete strength are adopted.

Refer step 16. Basic specification requirements:

a) The concrete shall conform to SS 544–2 and SS EN 206–1

b) Compressive strength class: C20/25

c) Maximum w/c ratio: 0.70; minimum cement/combination content: 240 kg/m3

d) Cement or combination types I, II, IIIA from SS 544–2: 2002, Table 1

e) Maximum aggregate size: 20 mm

f) Chloride class: Cl 0.40

g) do not apply

h) do not apply

i) Consistence class: S3

Table 12: Durability Recommendations for Reinforced or Pre-stressed Elements with an Intended Working Life of At Least 50 Years (Extracted from Table A.4, SS-544-1)

Nominal Cover B) mm	**Compressive Strength Class Where Recommended, Maximum Water-Cement Ratio and Minimum Cement or Combination Content for Normal-Weight Concrete C) with 20 mm maximum aggregate size)**							**Cement/ Combination Types**
	15 +Δc	20 + Δc	25 +Δc	30 +Δc	35 +Δc	40 +Δc	45 +Δc	50 +Δc	
Corrosion induced by Carbonation (XC Exposure Classes)									
XC1	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	*C20/25* 0.70 240	All in Table A.6
XC2	-	-	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	All in Table A.6
XC3/4	-	*C40/50* 0.45 340	*C30/37* 0.55 300	*C28/35* 0.60 280	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	All in Table A.6 except IVB-V IVB-V
	-	-	*C40/50* 0.45 340	*C30/37* 0.55 300	*C28/35* 0.60 280	*C25/30* 0.65 260	*C25/30* 0.65 260	*C25/30* 0.65 260	

Refer step 17.

Additional requirements (see Step 11):

The producer shall operate an accredited quality system meeting the requirements of SS ISO 9001.

When tested in accordance with BS EN 1367–4, the aggregate drying shrinkage shall be not more than 0.075%. The SS EN 12620 Los Angeles category of the coarse aggregate shall not be greater than LA40.

Go to step 18.

Information from the specifier to producer: The concrete will be pumped, compacted with a beam vibrator and finished with a bull-float. Go to step 19.

Information required from the concrete producer: The specifier identifies that items f) and g) are relevant and therefore requests this information as follows:

Following information are supplied prior to delivery:

a. If RCA or RA is to be used, the type of material and the proportion to be used.

b. Where RCA or RA is not classed as highly reactive with respect to alkali-silica reaction, the proof on which the lower classification was based.

5. SUMMARY

- Design of concrete specification must follow the new Singapore Standards SS EN 206-1, SS544-1 and SS 544-2
- To design and produce high performance and durable concrete is meaningful for low carbon emission and sustainability of concrete industry
- The design of concrete specification for low carbon and durable concrete can follow the principles as below
- Use supplementary cementing materials to replace OPC, for normal construction, CEM II B-V or III A cement should be used, while for underground and marine construction, CEM IV B-V or III B cement should be used
    - Use of concrete admixture
    - Use of recycled aggregate to replace natural aggregate
    - Avoid overdesign

6. REFERENCES

Harrison, T. A. and Brooker, O., 2005. *How to Use BS 8500 with BS 8110*. The Concrete Centre.

Spring Singapore, 2009a. *SS 544-1: 2009 Concrete- Complementary Singapore Standard to SS EN 206-1, Part 1: Method of Specifying and Guidance for the specifier* [online]. Available from :http://pdfoiobx.org/k-19224861.html [Accessed 8 May 2014].

Spring Singapore, 2009b. *SS 544-1: 2009 Concrete- Complementary Singapore Standard to SS EN 206-1, Part 2*: *Specification for Consitutent Materials and Concrete* [online]. Available from :http://pdfoiobx.org/k-19224861.html [Accessed 8 May 2014].

Spring Singapore, 2009. *SS EN 206-1:2009, Specification for Concrete, Part 1 : Specification, performance, production and conformity* [online]. Available from : http://pdfoiobx.org/k-19224861.html [Accessed 8 May 2014].

Swamy, R., 2000. *Designing Concrete and Concrete Structures for Sustainable Development. Two-Day CANMET/ACI International Symposium on Concrete Technology for Sustainable Development*. Vancouver.

IDENTIFYING THE SUCCESS FACTORS AND FAILURE FACTORS OF GREEN BUILDING PROJECTS

Vignesh Venkataraman* and Jack C.P. Cheng
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong

ABSTRACT

There is a global trend of green building projects over the world. In mature green building markets like the United States and Australia, there are well established green building certification systems and advanced technologies are often used in green building projects. On the other hand, in developing green building markets such as India and Korea, green building certification systems are still evolving and there is a steady increase in the number of green building projects. Despite the difference in the two kinds of green building markets, green building projects may face similar needs and challenges for successful project execution. Through questionnaire survey, this study aims to identify the success factors and failure factors of green building projects, and to compare the factors in mature green building markets with those in developing green building markets. Over 37 green building experts have completed the survey in this study. The findings show that commitment from project participants and effective collaboration among participants are common key success factors for green building projects, whereas cost consideration and lack of incentives from government are major failure factors in both kinds of green building markets. The findings also show different perceived importance of issues like collaboration, green building technologies, and project delivery methods in the two kinds of markets. This study helps practitioners in the industry to strategize and manage their green building projects effectively.

Keywords: *Failure Factor; Green Buildings; Project Management; Success Factors.*

1. INTRODUCTION

Buildings are the major contributors to energy consumption in any country. Both commercial and residential buildings together are responsible for between 20% and 40% of the world's energy consumption and these values are rising steadily every year (Pérez-Lombard *et al.*, 2008). Construction of green buildings involves innovative and at times complex design initiatives and faces a lot of challenges and obstacles during its design and construction. Since green buildings are designed and built to minimize environmental impact and consume less energy and resources than traditional buildings, successful execution of these projects is imperative. However, the growth of green buildings is not evenly spread across the world. Some countries like the United States and Australia adapted to this practice early and have evolved in terms of establishing green building certification systems and use of advanced technologies. Governments in these countries have passed laws to make green building measures mandatory. The Energy Efficiency Directive passed a legislation that requires EU governments should only purchase buildings which are highly energy efficient and EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans (Energy Efficiency Directive, 2012). States in the US have enacted green building legislation, in which it is mandatory to satisfy Leadership in Energy and Environmental Design (LEED) standards in building construction (Washington State Legislature, 2005). On the other hand, in countries and regions like Hong Kong, India and Korea, green building certification systems are still evolving and there is a steady increase in the number of green building projects (Hwang and Tan; 2012b, Chan *et al.*, 2009). While the adoption of green building standards and technologies in developing green building markets started later than the mature green building markets, the rise of green building industry has been steady in

* Corresponding Author: E-mail - vvaa@ust.hk

the developing markets. Despite the differences, delivering successful green building projects and minimizing failure are top priorities in both types of markets. Therefore, the objectives of this study are (i) to identify the factors affecting the success and failure of green building projects, and (ii) to compare the importance of success and failure factors in mature and developing green building markets. This study considers countries like United States and Australia as mature green building market and countries or regions like Hong Kong, India and Korea as developing green building markets, according to the history of green building certification system adoption. Success and failure factors have been identified based on literature review. A questionnaire survey was conducted to determine the importance of the factors in two different green building markets.

2. LITERATURE REVIEW

2.1. GREEN BUILDINGS

When addressing green buildings, the terms 'green building' and 'sustainable construction' are commonly used and interchangeable in general. The United States Environmental Protection Agency (US EPA) defines green buildings as "the practice of increasing the efficiency with which buildings and their sites use energy, water and materials, and reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal- the complete building life cycle" (USEPA, 2015). The International Council for Research and Innovation in Building and Construction (CIB) defines 'sustainable construction' as "a holistic process aiming to restore and maintain harmony between the natural and built environments, and to create settlements that affirm human dignity and encourage economic equity" (CIB, 1999). Regardless of these perceptions, green buildings have been growing rapidly worldwide. In the United States alone, buildings contribute 41% of energy consumption and an estimated 40-48% of new non-residential construction by value will be green by the year 2015 (USGBC, 2015). There are over 10,000 USGBC LEED certified projects. On the other hand, the BEAM Plus certification system has certified over 600 projects in Hong Kong, where as the Green Mark certification system has certified over 250 building projects in Singapore by 2009 and is projected an increase of 68% in the next three years (McGraw Hill Construction, 2013; HKGBC, 2015). It can be observed from the numbers that countries like the US and Australia have adopted green buildings/sustainable practices at an early stage and have grown considerably in recent years in terms of number of buildings certified. Asian countries in general picked up green buildings/sustainable practices in the mid-late 2000s. Countries and regions like Hong Kong, India, and Korea have now established their own green building standards and showed growing numbers of green buildings and adoption of green buildings technologies. Despite the differences in the two kinds of green building markets, green building projects may face similar needs and challenges for successful project execution. While previous literatures have studied the challenging nature of green building projects, there is a gap in identifying various success and failure factors in green building projects and studying their importance in different green building markets. This study aims to fill the gap by collecting expert opinions from a questionnaire survey.

2.2. SUCCESS FACTORS

In this study, success denotes when a project meets or exceeds all its initial requirements in terms of schedule, cost, quality, green building certification, etc. Based on studied literature, the success factors were classified into four different categories, which are *(1) cost, (2) project management, (3) technology and human resources, and (4) green building codes and rating standards*. Providing innovative financial methods can reduce the high premium costs of green building projects and help more people involved. Effective collaboration and selection of integrated and collaborative delivery process will foster project relations and create more flexibility during project delivery (Lippaiova and Sebestyen, 2012). Design charrates, engaging community during project discussions and innovative management approaches can eliminate design errors and contribute to the project success by saving costs (Robichaud and Anantatmula, 2010). In terms of technology and human resources, use of advanced technologies and having skilled project participants will help achieve high performance and higher green building grade

(Heerwagen, 2000). Studies on case study projects cited engaging green building specific participants and clarity in green building standards can help participants understand the green building projects better and make the overall process straight forward. Table 1 lists the selected success factors from literature review and case study analysis with their categories.

Table 1: Success and Failure Factors

Success Factors	**Failure Factors**
Cost	
A1: Innovative financing and adequate finance	A1: High premium cost
	A2: Lack of government incentives
Project Management	
B1: Effective collaboration among participants	B1: Lack of collaboration within project team
B2: Selection of companies relative to project size	B2: Setting ambitious project goals
B3: Integrated and collaborative delivery process	B3: Lack of a flexible procurement and bidding process
B4: Design charrettes and community engagement	B4: Lack of management and time for green practices
B5: Innovative management approaches	
Technology and Human Resources	
C1: Skilled project participants	C1: Lack of green building expertise
C2: Support from senior management	C2: Lack of interest from client and market demand
C3: Early involvement of the project participants	C3: Lack of interest from project participants
C4: Commitment of all project participants	C4: Resistance to change to green practices
C5: Use of advanced machinery and innovative technologies	C5: Lack of information regarding green technologies
C6: Effective feedback and troubleshooting	
Green building Codes and Rating Standards	
D1: Effective environmental compliance and auditing programs	D1: Complex green building codes and regulations
D2: Early involvement of LEED professional	D2: Conflicts in LEED credits or process selection

2.3. FAILURE FACTORS

Failure denotes when a project fails to meet its initial requirements in terms of schedule, cost, quality and green building certification, etc. Similar to the success factors, the failure factors were classified into four afore mentioned categories, namely *(1) cost, (2) project management, (3) technology and human resources, and (4) green building codes and rating standards*. Common cost related factors are high premium cost and lack of government incentives. The factor high premium cost is constantly mentioned during the discussions of green building challenges. Green building projects involves installation of advanced technologies and green building materials which costs significantly higher than traditional materials. Hence there is a high investment upfront for green building projects and a major obstacle for since its early days (Yudelson, 2007). In addition, lack of governmental incentives provides no motivation for owners to pursue green buildings. In the project management category, factors like lack of collaboration and flexible procurement bidding process will minimize collaboration and give less time for participants to work together (Kibert, 2007). Setting ambitious goals can cause scope creep and make execution tough for project participants when meeting project goals and deadlines (Kibert, 2007). Lack of proper management techniques to implement green practices can also cause failure as majority of the savings are achieved in the operational stage and in the technology and human resources category, lack of green building expertise will be more challenging for project participants to execute complex green building tasks (Hwang and Tan, 2012a). Lack of interest from client, project participants and market demand will be another cause of failure as the non-commitment of the client and project participants will hamper the efficiency of the project and no demand in the local market will have a negative impact on project finance. Resistance to change to green practices and lack of information regarding green building practices will also cause significant challenge in green building projects, particularly in the indoor environmental quality category (Kibert, 2007). In addition to published literature, green building case studies have identified complex codes and the low level of involvement of green building consultants as a major factor in project failure. The summarized failure factors with their corresponding categories are shown in Table 1.

3. METHODOLOGY

To identify and rank the different success and failure factors, an online questionnaire was prepared to collect expert opinions. Information on respondents profile and the importance of success and failure factors were collected. Respondent profile information included country, role, years of construction experience and years of green building experience. Success and failure factors are rated by a Likert scale measurement of 1-5 with 1 being strongly disagree to 5 being strongly agree. Countries with most green building projects and countries with an increase in trend of green building projects were targeted in this study. The targeted countries or regions were Australia, United States, Hong Kong, India and Korea. Among the selected countries or regions, Australia and United States were classified as mature green building market while Hong Kong, India and Korea were classified into developing green building market. Targeted population of the survey were green building professionals and a total of 300 questionnaires were sent with 50 responses received. Out of the 50 received responses, 37 responses were valid and complete. These 37 responses were then used for analysis. Out of the 37 respondents, 15 were from Australia, 9 from the US, 6 from Korea, 5 from Hong Kong and 2 from India. Majority of the respondents were engineers and contractors whereas respondents from client, project management and education sectors were also present. Out of the 37 respondents, 40% respondents had 15 or more years of experience in the construction industry and 48% of the respondents were involved in more than five green building projects. From the responses we found that the perceived failure rate of green building projects by the participants was 14%. This highlights the existence of challenges in green building projects and the need for identifying the factors leading to failure of green building projects.

4. RESULTS

4.1. SUCCESS FACTORS

Respondents were asked to rate each success factor on a scale of 1 to 5 with 1- strongly disagree, 2- disagree, 3- neutral, 4- agree and 5- strongly agree where the numbers 1 to 5 were assigned as weights for each option. Table 2 lists all the success factors and their importance as perceived by the green building experts. The weighted average of each factor has been calculated and listed along with the percentages of respondents who have chosen the option ‘agree’ or ‘strongly agree’. This helps us to identify how many participants agree with the selected list of success factors. The overall rank of each factor is listed in the last column. Table 2 shows that the percentage of participants agreeing with the success factors was more than that of failure factors. Among the different success factors, majority of the respondents agreed on the success factors that fall under the technology and human resource category. Key success factors includes, effective collaboration, having skilled participants, support from senior management, early involvement of all project participants and early involvement, commitment from all project participants and effective feedback and troubleshooting. The agree percentage of these factors were more than 70% thus emphasizing their importance. In addition to these factors, innovative financing methods, selection of integrated delivery process, design charrates and community engagement, effective environmental compliance and involvement of green building consultants were agreed by more than half of the respondents.

Table 2: Importance of Success Factors

Category	Factors	Weighted Average	Agree (%)	Rank
A. Cost	A1: Innovative financing and adequate finance	21.2	69	6
B. Project Management	B1: Effective collaboration within participants	23.4	83	1
	B2: Selection of companies relative to project size	16.4	35	14
	B3: Selection of an integrated and collaborative delivery process	20.4	62	8
	B4: Design charrettes and community engagement	20.4	55	8
	B5:Innovative management approaches	19.4	48	10
C. Technology and Human Resources	C1: Skilled project participants	21	79	7
	C2: Support from senior management	21.4	72	5
	C3: Early involvement of the project participants	22.8	79	3
	C4: Commitment of all project participants	23.2	79	2
	C5: Use of advanced machinery and innovative technologies	17.4	41	13
	C6: Effective feedback and troubleshooting	22	76	4
D. Green Building Codes and Certification Standards	D1:Effective environmental compliance and auditing programs	18.2	55	12
	D2: Early involvement of LEED professional	19.2	52	11

4.2. *FAILURE FACTORS*

Similar to success factors, respondents were asked to rate each failure factor on a scale of 1 to 5 with 1- strongly disagree, 2- disagree, 3- neutral, 4- agree and 5- strongly agree where the numbers 1 to 5 were assigned as weights for each option. Table 3 lists all the failure factors and their importance as perceived by the green building experts. The weighted average of each factor has been calculated and listed along with the percentages of respondents who have chosen the option ‘agree’ or ‘strongly agree’. The overall rank of each factor is listed in the last column. It can be noted that cost related factors like high premium cost and lack of government incentives have a higher percentage of acceptance than other categories. Lack of collaboration, setting ambitious project goals, and lack of management and time to implement green practices were considered the most important in the project management category. Lack of interest from client and market demand and resistant to change to green practices were agreed by more than half the respondents in the technology and human resources category. Respondents also believed complex and different green building codes can also be a great challenge in pursuing green building projects as it can cause confusion in terms of which standard to adopt and which technology to pursue.

Table 3: Importance of Failure Factors

Category	Factors	Weighted Average	Agree (%)	Rank
A. Cost	A1: High premium cost	24.6	75.6	1
	A2: Lack of government incentives	21.6	69.5	2
B. Project Management	B1: Lack of collaboration within project team	20.6	55.6	5
	B2: Setting ambitious project goals	18.8	64.8	9
	B3: Lack of a flexible procurement and bidding process	17	45.7	13
	B4: Lack of management and time for green practices	20	58.4	6
C. Technology and Human Resources	C1: Lack of green building expertise	18.4	50	10
	C2: Lack of interest from client and market demand	21	69.5	3
	C3: Lack of interest from project participants	19	49	8
	C4: Resistance to change to green practices	19.4	54	7
	C5: Lack of information regarding green technologies	17.4	44	12
D. Green Building Codes and Certification Standards	D1: Complex green building codes and regulations	20.8	52.7	4
	D2: Conflicts in LEED credits or process selection	18.4	41.7	10

4.3. COMPARISON: MATURE VS DEVELOPING GREEN BUILDING MARKETS

Previous sections listed the importance of success and failure factors by all the participants. This section will compare the responses from the mature and developing green building markets to identify the change in perception in different green building markets. Table 4 lists the ranking of certain success factors in both the markets. Most of the success factors were perceived similarly in both the markets. Ranks of success factors with major differences are listed in the table. Developing green building markets consider the cost related factor, innovative financing methods and adequate financial budgets important for project success. Mature green building markets perceive project management factors like skilled project participants and early involvement of project participants as key factors of success. Developing green building markets rates design charrates and use of advanced technology and machinery higher than mature markets. From the results, it can be understood that developing green building markets emphasize more on project cost and innovative technologies whereas mature green building markets focus more on project management related factors.

Table 4: Comparison of Success Factors

Factors	Rank in Mature Markets	Rank in Developing Markets
Innovative financing methods and adequate financial budgets	8	1
Design charrettes and community engagement	10	6
Skilled project participants	6	9
Early involvement of the project participants	3	6
Use of advanced machinery and innovative technologies	14	11

As for the failure factors, Table 5 shows that cost related failure factors like high premium cost and lack of government incentives were perceived important in both the types of markets. Lack of collaboration within project team was also considered an important failure factor in both the markets. On the other hand, other project management related factors like setting ambitious goals, lack of management and time to implement green practices, and lack of interest from client and market demand were perceived differently. It is interesting to find that developing green building markets perceive setting ambitious goals as an important factor of failure whereas mature markets do not. Similarly, lack of interest from project participants is given more importance in developing green building markets than mature green building markets. In mature green building markets, lack of management and time to implement green practices is considered more important than in developing green building markets. This shows that while developing green building markets focuses on issues related to project design and execution, mature green building markets are emphasizing more on the operational stages of the project.

Table 5: Comparison of Failure Factors

Factors	**Rank in Mature Markets**	**Rank in Developing Markets**
High premium cost	1	1
Lack of government incentives	2	2
Lack of collaboration within project team	4	4
Setting ambitious project goals	12	6
Lack of management and time to implement green construction practices	5	10
Lack of interest from client and market demand	3	3
Lack of interest from project participants	8	4
Complex green building codes and regulations	6	6

5. CONCLUSIONS

This study compares different success and failure factors in two different green building markets. Results show interesting perceptions of the two markets. Overall, project management and human resources factors were considered as key success factors whereas cost and project management factors were considered as key failure factors. While respondents were in agreement with the success factors, certain respondents' responses to failure factors were conservative. The authors think that the reason behind the conservative responses is to show their lack of involvement in many failure projects. Developing green building markets focused more on issues related to cost, design and execution of green building projects and mature green building markets emphasized more on project management, human resources and operational issues. It is a direct indication of the evolution in development of mature green building markets and the rise of green building trends in developing green building markets. This study contributed to the identification and perception of success and failure factors in two different green building markets. In addition, it assists practitioners in the industry to strategize and effectively plan their green building projects.

Despite getting responses from green building experts from around the world, getting equal number of respondents from both the markets was not possible. This could have caused a certain skew in the final results. This study used a simple ranking of factors based on weighted average and an agree percentage measurement to identify the importance of factors. To make the analysis more robust, future work will focus on applying various statistical analysis techniques and case study validations to supplement the results and avoid anomalies if existed. In addition, impact of success and failure factors on various project performance metrics will also be considered to help practitioners focus on issues related to individual project requirements.

6. ACKNOWLEDGEMENT

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7. REFERENCES

Chan, E.H., Qian, Q.K. and Lam, P.T., 2009. The market for green building in developed Asian cities—the perspectives of building designers. *Energy Policy,* 37**,** 3061-3070.

The International Council for Research and Innovation in Building and Construction CIB, 1999. Agenda 21 for Sustainable Construction in Developing Countries. Pretoria:CSIR Building and Construction Technology, (Bou/E0204).

Energy Efficiency Directive, 2012. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32. *Official Journal,* 315**,** 1-56.

Heerwagen, J., 2000. Green buildings, organisational success and occupant productivity. *Building Research & Information,* 28**,** 353-367.

HKGBC, H.K.G.B.C., 2015. *BEAM Plus Statistics* [online]. Available from: https://www.hkgbc.org.hk/eng/BEAMPlusStatistics.aspx [Accessed 22 May 2015].

Hwang, B.G. and Tan, J.S., 2012a. Sustainable Project Management for Green Construction: Challenges, Impact And Solutions.In:Senarathne S., 1st *World Construction Conference 2012-Global Challenges in Construction Industry.*28-30 June 2012, Colombo.1-9.

Hwang, B.G. and Tan, J.S., 2012b. Green building project management: obstacles and solutions for sustainable development. *Sustainable development,* 20**,** 335-349.

Kibert, C.J., 2007. *Sustainable construction: Green building design and delivery*. 2nd ed. Canada:Wiley.

Kibert, C.J., 2012.*Sustainable construction: Green building design and delivery*. 3rd ed. Canada:Wiley.

Lippaiova, R. and Sebestyen, Z., 2012. Green Construction Project Management. In: *10th micro CAD International Scientific Conference,* 29-30 March 2012, Hungary :University of Miskolc, 1-7.

Waidyasekara K.G.A.S, De Silva M.L. and Rameezdeen, R., 2013. Comparative study of green building rating systems: In terms of water efficiency and conservation. In: Senarathne S. and Sanadanayaka Y.G., ed. *2nd world construction symposium 2013. Socio-economic sustainability in construction: Practice, policy and research* , 14 -15 June 2013, Colombo:CIOB**,** 108-117.

Hill Construction, 2013. *SmartMarket Report World Green Building Trend* [online]. California: McGraw-Hill Construction. Available from: http://construction.com/about-us/press/world-green-building-trends-smartmarket-report.asp [Accessed 22 May 2015].

Pérez-Lombard, L., Ortiz, J. and Pout, C., 2008. A review on buildings energy consumption information. *Energy and buildings,* 40**,** 394-398.

Robichaud, L.B. and Anantatmula, V.S., 2010. Greening project management practices for sustainable construction. *Journal of Management in Engineering,* 27**,** 48-57.

USEPA, 2015. Green Building [online]. Available from: http://www.epa.gov/greenbuilding/pubs/about.htm [Accessed 22 May 2015].

Washington State Legislature, 2005. *High-Performance Public Buildings* [online]. Available from: *https://stars.aashe.org/media/secure/497/6/475/2712/Chapter%2039.35d%20RCW_%20HIGH-PERFORMANCE%20PUBLIC%20BUILDINGS.pdf* .[Accessed 22 May 2015].

Yudelson, J., 2007. *The green building revolution*. London:Island Press.

INDOOR ENVIRONMENTAL QUALITY AND OCCUPANTS' PRODUCTIVITY: GREEN CERTIFIED OFFICE BUILDINGS IN SRI LANKA

Harshini Mallawaarachchi* and Lalith de Silva
Department of Building Economics, University of Moratuwa, Sri Lanka

R. Rameezedeen
School of Natural and Built Environments, University of South Australia, Australia

ABSTRACT

There is a potential link between indoor environment and occupants' productivity, which has identified in previous literature. Especially, there is an effect of the quality of indoor environment, where, people spend 90% of their time indoors. Indoor Environmental Quality is become a growing concern to ensure occupants' health, wellbeing, and personal productivity. However, the deficiency of research in this area gave an importance to conduct this study. Accordingly, this research is to determine the relationship between Indoor Environmental Quality and occupants' productivity in green buildings. Survey approach was selected under quantitative phenomenon, as this research is focused to determine the relationship between variables quantitatively. Both questionnaire survey and semi-structured interviews were conducted among occupants in green certified office buildings in Sri Lanka. The survey data was analysed using nonparametric statistical analysis techniques; significance testing and Spearman's Correlation. SPSSv.20 software was used in data analysis. The Indoor Environmental Quality factors identified through literature were evaluated to identify significant factors influencing occupants' productivity. According to the test statistics, seven significant factors were identified as the first stage of data analysis where they showed statistically significant correlation to the major Indoor Environmental Quality dimensions. As the second stage of analysis, the relationship between Indoor Environmental Quality factors and occupants' productivity was determined. As the test results showed, air quality and acoustical partitioning factors confirmed a statistically significant weakly positive monotonic correlation whilst system control showed strongly positive monotonic correlation to the occupants' productivity in green buildings. The test results were further discussed by stating the qualitative findings and extant literature. As the outcome of this research, the relationship between significant Indoor Environmental Quality factors and occupants' productivity was reviewed and evaluated. As per the findings of the research, facilitating more provisions on air quality and acoustic quality would effect to ensure the productivity improvements of green building occupants.

Keywords: *Green Buildings; Indoor Environmental Quality; Occupants' Productivity; Sri Lanka.*

1. INTRODUCTION

In recent years, the topic of Indoor Environmental Quality (IEQ) seems as a growing concern where, it was identified as a major factor influencing occupants' health, wellbeing and productivity. Specially, much more attention has focused on the indoor environment in offices in light of growing concern about worker productivity. Further, occupants who are satisfied with the overall environmental quality of their workspace are widely assumed to be more productive (Leaman and Bordass, 2007). Indoor environment mainly includes indoor air quality, thermal quality, visual quality and acoustical quality. The improvement the quality of all these four would ensure the improvement of occupants' comfort, satisfaction and productivity (Clausen and Wyon, 2008). According to a study by Khalil and Husin (2009), building occupants are looking for comfortability to be productive in their workplace. Further, occupants prefer to have comfortability in using and utilizing the facilities and services as it must be fit

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

for purpose of the user. In light of facilitating a high quality indoor environment for the building occupants, green building concept is gaining momentum. As many studies found, occupants are more favourably disposed to green buildings due its benefits. Specially, green buildings serve their major expectation of obtaining a comfortable workplace (Leaman and Bordass, 2007; Abbaszadeh *et al.*, 2006 cited Deuble and Dear, 2012). The occupants who satisfied with the overall quality of their working environment are widely assumed to be more productive (Leaman and Bordass, 2007).Even though many previous researches have conducted in the similar research setting, there is a deficiency of the research on the relationship between IEQ factors and occupants' productivity improvements. Further, most of them have focused only on single aspects of the built environment. Thus, this research is aimed to determine the relationships between IEQ factors and occupants' productivity in green buildings.

2. LITERATURE REVIEW

2.1. INDOOR ENVIRONMENTAL QUALITY (IEQ)

The indoor environment is where people spend 90% of their time (Kosonen and Tan, 2004). As the majority of people spend most of their time indoors, there is a continuous and dynamic interaction between occupants and their surroundings that produce physiological and psychological effects on the person (Lan and Lian, 2009). 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). According to a study by Kamaruzzaman *et al.* (2011), it is essential for buildings to have a good quality indoor environment, as it affects the productivity and health of the occupants of the building. 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. Henceforth, IEQ generally encompasses factors such as temperature, humidity, ventilation, indoor air quality, day lighting and lighting quality, thermal comfort and access to views. Furthermore, Day lighting and thermal comfort contributed to better IEQ, and had a positive effect on occupant's perception of productivity and performance (Prakash, 2005; Lan and Lian, 2009). As further verified by Atsusaka (2003 cited Chan *et al.,* 2009), enhanced daylight and reduced toxicity in indoor environments can increase employee productivity by up to 16%. Kim and Dear (2011) declared when a building's lighting is perceived as comfortable there is a positive improvement in occupant overall workspace satisfaction (Kim and Dear, 2011).

2.2. INDOOR ENVIRONMENTAL QUALITY IN GREEN BUILDINGS

The quality of the built environment is one of the main goals in many green certification systems. This is because green building certification schemes require building designers and managers to consider the impact of the indoor environment on the health and wellbeing of the office worker. Further, once the evaluation and assessment of the environmental impact of a building is carried out before it is built and when only the representation of the building is available, environmental impacts of that building could be prevented. The first assessment tool was the Building Research Establishment Environmental Assessment Method (BREEAM) (Baldwin, 1998 cited Lacouture *et al.*, 2008) and, the most representative and widely used green assessment tools are Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) and Green Star. Although the existing methods and tools have an extended use, LEED has established strong credibility among the experts by increasing its affiliates (Pulselli *et al.,* 2007 and Ding, 2008 cited Lacouture *et al.*, 2008). The following Table 1 shows the Indoor Environment Quality parameters available in green buildings. The indoor environment is one of the major criteria in many green certification systems such as, LEED, and CASBEE etc, which is required to ensure by building designers and managers to obtain the green certification for buildings.

Table 1: IEQ Parameters in Green Buildings

IEQ Factor	LEED	BREEAM	Green Star	CASBEE
Thermal Quality	Controllability of Systems	Local Temperature Control		Room Temperature Setting Variable Loads And Following-Up Control Zoned Control Temperature and Humidity Control
Visual 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
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
Acoustic Quality	Controllability of Systems	Noise	Internal Noise Levels	Background Noise Equipment Noise Sound Insulation of Openings Sound Insulation of Partition Walls Sound Absorption

Source: Boonstra and Pettersen (2003); Haapio (2008); Wallhagen, (2010)

2.3. *GREEN BUILDINGS IN SRI LANKA*

Similarly in Sri Lanka, most of modern buildings have tended to be green certified building to obtain its vital benefits because of indoor environment quality is an important aspect which has received practically no attention in built environments (Ileperuma, 2000). Further, facilitating a high quality working environment for the building occupants is one of the major concerns of obtaining a green certification rather stays as a traditional building. GREEN$^{SL®}$ Rating System of Green Building Council Sri Lanka (GBCSL) has been introduced, with the main aim of fundamentally changing the built environment by creating energy efficient, healthy, productive buildings that reduce or minimise the significant impacts of buildings on the environment (GBCSL, 2010). The Green Building Council of Sri Lanka (GBCSL) came into existence as a result of an emerging trend towards applying the greener concepts for building environment. Moreover, it is uniquely supported by both industry and government institutions across the country. Further, green Buildings in Sri Lanka show a higher completion rate in comparison to other countries in the world. Specially most of office buildings have turned their buildings to green with the expectation of obtaining its ultimate benefits, especially, energy efficiency and IEQ improvements.

Figure 1 shows IEQ parameters considered in GREEN$^{SL®}$ National Green Rating System.

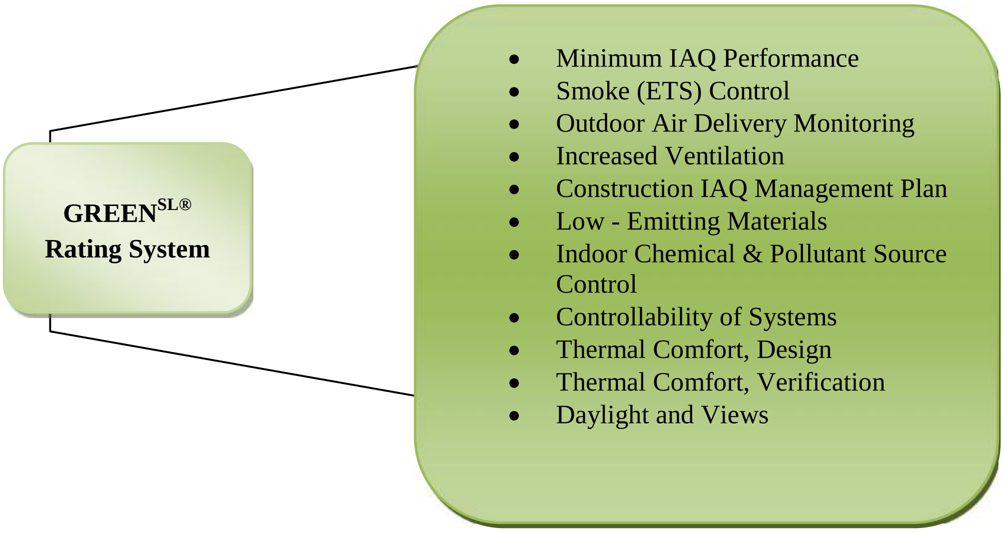


Figure 1: IEQ Parameters in GREEN$^{SL®}$

2.4. OCCUPANTS' PRODUCTIVITY IN GREEN BUILDINGS

A number of case studies suggest that productivity gains through better quality office environments may be possible. According to case studies by Urban Catalyst Associates (2005) occupants 'productivity is the most significant benefit of green buildings, even though the value of improved occupant productivity and healthier built environments is difficult to calculate. According to the Jones Lang LaSalle's Global Sustainability Perspective (2011), green buildings and their attention to high quality indoor environments provide therefore an ideal background for such considerations. Whilst green developers and builders create healthier working, learning, and living environments, it is not only reducing utility bills, operation and maintenance cost but also increasing occupants' productivity.

2.5. OCCUPANTS' PRODUCTIVITY IN OFFICE ENVIRONMENT

Rolloos (1997 cited Hameed and Amjad, 2009) defined the occupants' productivity as, "productivity is that which people can produce with the least effort". Productivity is also defined by Sutermeister (1976 cited Hameed and Amjad, 2009) as, "output per employee hour, quality considered." However, there is no clear definition of productivity in the office environment. It is because that the office can consist of different jobs and tasks, making it difficult to compare or aggregate and thus, there is a great variation among them (Sullivan*et al.,* 2013). Measuring productivity of occupants in an office environment is a great challenge as it consists of the variety of different jobs and tasks. Among the productivity measurement methods available, most of them are based on quantitative data on operations. As Hadi (1999 cited Miller *et al.*, 2009) believes, productivity measures should be split into three sections, such as, quantifiable and tangible measures, indirect measures, and organisational measures. The technique of perceived productivity was selected as the best approach to evaluate occupants' productivity in this study. Further, it is a widely used rating technique, being relative simple, quick and cheap. Considering the measures and scales used in similar previous studies, five points Likert (ordinal) scale was developed to rate perceived productivity of occupants and the influence of IEQ factors.

2.6. IEQ FACTORS INFLUENCING OCCUPANTS' PRODUCTIVITY

According to a study by Kamaruzzaman *et al.* (2011), it is essential for buildings to have a good quality indoor environment, as it affects the productivity and health of the occupants of the building. Once most of the numerous studies have been verified the relationship between built environment and occupants' productivity, several IEQ factors influencing occupants' productivity were identified by critically reviewing the previous literature (Clements-Croome, 2000; Bartlett and Howard, 2000; Heerwagen, 2000;

Mahdavi and Unzeitig, 2004). Accordingly, 27 IEQ factors influencing occupants' productivity were identified in relation to the thermal quality; visual quality, IAQ and acoustic quality (refer Table 2).

Table 2: IEQ Factors Influencing Occupants' Productivity

Major IEQ Dimensions	Sub Factors
Thermal Quality	Personal Control on Ambient Conditions
	Temperature
	Opening Windows
	Personal Thermal System Control
Visual Quality	Provisions of Day Lighting
	Radiation and Electromagnetic Fields
	Electric Lighting Quality
	Glare
	Controllable Task-Lighting
	Illuminance
	Controllable Lighting Installations
	Lighting Intensity
	Colour
	Personal/Task Lighting
	Proximity to a Window
	View to Outdoor Environment
Iaq	Indoor Air Temperature
	Air Quality
	Dust
	Odour
	Air Freshness
	Air Movement
Acoustic Quality	Background Sound Level
	Acoustical Partitioning
	Sound Privacy
	System Controls
	Sound Absorption Materials

As this research aimed, the relationship between the identified factors and occupants' productivity was evaluated. The following section describes the methodology adopted in this study.

3. RESEARCH METHODOLOGY

The survey approach was selected for this study under the quantitative phenomenon as this research aimed to identify the relationship between IEQ and occupants' productivity improvements in green buildings.

A questionnaire survey was conducted among occupants in green certified office buildings in Sri Lanka. Here, the occupants of green certified office buildings in Sri Lanka were selected as the population sample to collect the data. Considering the minimum sample of 30 and, the importance of having a large sample to generalise the survey findings to whole selected population, '100' was selected as suitable sample size for this study. Accordingly, 100 occupants of green certified office buildings in Sri Lanka were selected randomly to distribute questionnaires. 65 questionnaires were returned from the distributed 100 questionnaires.

Although questionnaires may be used as the only data collection method, it may be better to link them with other methods in a multiple-methods research design (Saunders *et al.*, 2009). Hence, semi-structured interviews were conducted with ten selected building occupants and professionals in green buildings in order to further prove the validity of research findings. Hence, the test results of correlation were analysed along with the facts which were obtained from the interviews conducted.

3.1. SIGNIFICANCE TESTING AND CORRELATION ANALYSIS

The ordinal data collected from the questionnaire survey were evaluated and analysed by using significance testing and correlation analysis.

As this research requires testing the relationship between built environment factors and occupants' productivity in green buildings, Significance testing was used. It is useful technique to test the likelihood of the relationship (or one more extreme) occurring by chance alone, if there really was no difference in the population from which the sample was drawn (Robson 2002). If the probability of the test statistics or one more extreme having occurred by chance alone is very low (usually $p<0.05$ or lower), there is a statistically significant relationship. This refers to rejecting the Null hypothesis whilst accepting the hypothesis.

Where,

H_0 : $p = 0$ (Null hypothesis)

H_1 : $p \neq 0$

The relationship is not statistically significant when the probability (p-value) is higher than 0.05 (Gardner, 2007).

Statistical significance was tested by setting the significant level to 0.05 to reduce the occurrence of Type I errors. The level of significance of each factor was considered when determining the critical built environment factors, which showed probability less than 0.05.

Correlation analysis is used where a change in one variable is accompanied by a change in another variable, but it is not clear which variable caused the other to change (Saunders, Lewis and Thornhill, 2009).As the survey of this research was designed with five point Likert scale (ordinal scale), Spearman's Correlation was selected as an appropriate method to analyse the data. Statistical analysis was done by using Statistical Package for the Social Science (SPSS) v20 software.

Spearman's Correlation

$$\text{Spearman's coefficient of correlation } (r_s) = 1 - \left[\frac{6\sum d_i^2}{n(n^2-1)}\right] \qquad \text{(Eq.01)}$$

where, di = difference between ranks of ith pair of the two variables

n = number of pairs of observations

$$t_{cal} = r_s \frac{\sqrt{n-2}}{\sqrt{1-r_s^{\,2}}}$$ Distributed "t" with "n-2" degree of freedom

r_s - Rank Correlation Coefficient

d_i - Difference between each rankings

n - Number of objectives

Null Hypothesis H0 : $° = 0$ (There is no correlation between rankings)

Alternative Hypothesis H1 : $° \neq 0$ (There is a correlation between rankings)

" ° " is the standard symbol of Correlation Coefficient. In this hypothesis " ° " is the Rank Correlation coefficient (Crawshaw and Chambers, 2001).

The correlation between IEQ factors and occupants' productivity was evaluated and the significant factors were determined based on the strength and the significance of correlation.

As Saunders et al (2009) mentioned that, the correlation coefficient could take on any value between -1 and +1. A value of +1 represents a perfect positive correlation. The value of -1 represents a perfect negative correlation. Correlation coefficients between -1 and +1 represent weaker positive and negative correlations, a value of 0 meaning the variables are perfectly independent as illustrated in following Figure 2.

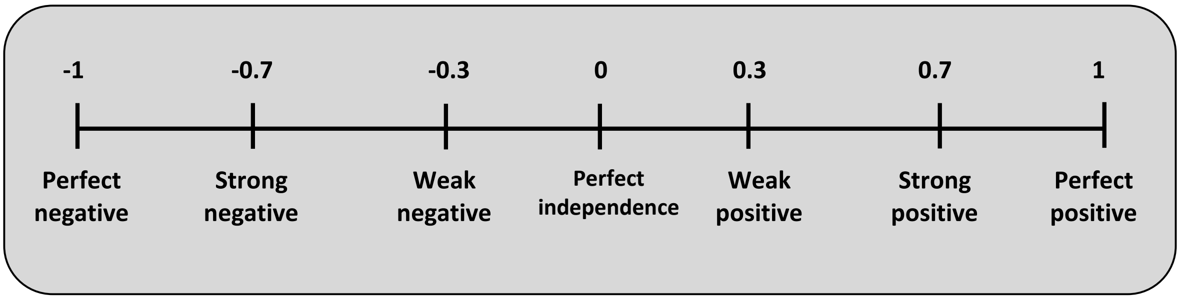


Figure 2: Values of the Correlation Coefficient
Source: Saunders *et al.* (2009)

Considering the rule of thumb in social science research and the evaluation criteria introduced by Saunders *et al.*, (2009), it was considered in this study to interpret the strength of the monotonic correlation of research variables as illustrated in following Table 3.

Table 3: Interpretation of Correlation in This Study

Size of Correlation	Interpretation
0.70 to 1.00 (-0.70 to -1.00)	Perfect correlation
0.30 to 0.70 (-0.30 to -0.70)	Strong correlation
0.00 to 0.30 (0.00 to -0.30)	Weak correlation
0.00	Perfect independence

Source: Saunders *et al.* (2009)

The correlation test results of built environment factors and its interpretation are presented subsequently.

4. RESULTS AND DISCUSSION

4.1. *SIGNIFICANT INDOOR ENVIRONMENTAL QUALITY (IEQ) FACTORS*

The research analysis was conducted to explicate the potential relationships between the built environment factors and the occupants' productivity in green office buildings. As the first step, significant IEQ parameters were determined by testing the correlation between major IEQ dimensions and the sub factors identified.

Table 4: Significant IEQ factors

	Spearman's Correlation	Sig. (2-Tailed)	N
Thermal Quality			
Opening Windows	.285*	.022	65
Visual Quality			
Controllable Lighting Installations	.260*	.037	65
Personal/Task Lighting	.248*	.047	65
View to Outdoor Environment	.388**	.001	65
Indoor Air Quality			
Air Quality	.253*	.042	65
Acoustic Quality			
System Control	.281*	.023	65
Acoustical Partitioning	.248*	.047	65

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

The above Table 4 illustrates the significant factors selected for subsequent analysis. Among the other thermal quality related factors, opening windows showed a significant correlation to the major dimension. As further correlation coefficient, it was determined as weakly positive monotonic correlation, thus, selected (Spearman's rho= .285, p= .022).

Controllable lighting installations, personal lighting and view to outdoor environment factors were selected as significant visual quality factors influencing occupants' productivity. Among those, first two factors showed a weakly positive correlation to the visual quality with the correlation coefficient (Spearman's rho) of .260 and.248 respectively (where the Probability values (p-values) are .037 and .047 subsequently). However, according to the evaluation, view to outdoor environment showed a strong positive correlation, as it owned .388 of correlation coefficient (p= .001). According to the sounders' *et al.* (2009), the correlation coefficient values from 0.3 to 0.7 are considered as strong positive correlations, thus selected.

Air quality was selected as another significant factor which showed significant and weakly positive monotonic correlation to the IAQ (Spearman's rho= .253, p= .042). Under the acoustic quality, system control (Spearman's rho= .281, p= .023) and acoustical partitioning (Spearman's rho= .248, p= .047) were determined as significant factors as they showed significant weakly positive correlation to the acoustic quality. Accordingly, seven significant IEQ factors, such as, opening windows,Controllable lighting installations, personal lighting, view to outdoor environment, air quality, system control and acoustical partitioning were determined whilst others are rejected based on the statistical significance of the strength of correlation.

4.2. *THE RELATIONSHIP BETWEEN INDOOR ENVIRONMENTAL QUALITY (IEQ) AND OCCUPANTS' PRODUCTIVITY*

The significant built environment factors were selected as independent variables whilst occupants' productivity was concerned as dependent. The relation between dependent and independent variables was evaluated by performing rank correlation test.

4.2.1. *ASSESSMENT OF CORRELATION*

The following Table 5 illustrates the correlationsassessed between significant IEQ factors and occupants' productivity in green buildings, as per the test results of Spearman's Correlation. The test results were extracted from SPSS v.20.

Table 5: Rank Correlation Teat Results of IEQ Factors

	Spearman's Correlation	**Sig. (2-tailed)**	**N**
Occupants' Productivity			
Opening Windows	.091	.473	65
Controllable Lighting Installations	.065	.607	65
Personal/Task Lighting	.006	.964	65
View To Outdoor Environment	.022	.862	65
Air Quality	.258*	.038	65
System Control	.347*	.005	65
Acoustical Partitioning	.257*	.039	65

According to the test results of Spearman's Correlation, opening windows showed statistically insignificant correlation to the occupants' productivity (p=.473), even though it showed weak positive monotonic correlation (Spearman's rho=.091). Similarly, controllable lighting installations, personal lighting and view to outdoor environment confirmed a weak positive correlation to occupants' productivity, with the correlation coefficient values of .065, .006 and .022 respectively. However, none of them showed a statistically significant correlation where respective p-values are .607, .964 and .862. Thus, all those four factors were rejected.

As per the test statistics of Spearman's Correlation, three IEQ factors were determined as critical factors influencing occupants' productivity in green buildings where they showed statistically significant correlation to the occupants' productivity with the high statistical significance. Among those, air quality showed statistically significant weakly positive monotonic correlation to occupants' productivity (Spearman's rho= .258, p=.038), whilst, system control showed strongly positive monotonic correlation with the high significance (Spearman's rho=. 347, p= .005). Acoustical partitioning was identified as another critical factor influencing occupants' productivity with the statistically significant weakly positive monotonic correlation (Spearman's rho= .257, p= .039).

4.2.2 DISCUSSION OF SURVEY WITH INTERVIEW RESULTS

From the overall assessment, significant IEQ factors were selected. According to the test statistics, three factors were selected as significant which showed statistically significant weak and strong monotonic correlation to occupants' productivity in green buildings. However, none of the factors were generally perceived as perfectly (positive or negative) correlated factors.

This confirm in the extant literature and the findings of the qualitative inquiry, that indeed the potential of selected IEQ factors. Therefore, the factors which showed statistically significant correlation to the major dimension were selected for subsequent analysis even though the strength of the relationship was at moderate and weak levels.

As Hinkle et al., (1998) further verifies that, "a small correlation coefficient is just as good as a high correlation, because such most relationships are a long way from perfect" (Hinkle *et al.*, 1998)

"Typically, a single independent variable in social research seldom accounts for more than 25% to 30% of the variance in a dependent variable, and often for as little as 2% to 5%" (Knoke *et al.*, 2002, p.132)

Further, the overall assessment of the strong or weak correlation to influence occupants' productivity also confirms that indeed of having a varying significance to influence occupants' productivity. The following Table 6 indicates the overall assessment of the significant built environment factors.

Table 6: Significant IEQ Actors Influencing Occupants' Productivity in Green Buildings

IEQ Factor	Statistical Significance (P-Value)	Coefficient of Correlation (Spearman's Rho)	Strength of Correlation			
			Perfect	Strong	Weak	Perfect Independence
Air Quality	.038	.258*			√	
System Control	.005	.347*		√		
Acoustical Partitioning	.039	.257*			√	

The discussion of test results along with the qualitative findings and the extant literature is presented subsequently.

4.2.3. AIR QUALITY AND OCCUPANTS' PRODUCTIVITY

According to the test statistics of probability and Spearman's Correlation, air quality was identified as critical IEQ factor influencing occupants' productivity. Air quality showed a significant and weakly positive monotonic correlation to the occupants' productivity (Spearman's rho=.258, p=.038). As it confirms, the slightly improvement of air quality in green buildings would slightly increase the occupants' productivity. The results would be further verified by qualitative findings. As stated by Human Resource Manager in o green building B, *"it is really comfortable to work in green buildings with the high quality indoor air provided. We are maintaining required air quality standards to provide* *workers a comfortable environment. And, the complaints from our workers are considerably less and they also work very efficiently."* It is further proved by an Engineer in Green Building C as *"there is an optimum use of natural air inside the building with the less use of air conditioning. However, our workers have changed them suited to work in this green environment. I also work very happily thus; personal productivity is at high level."*

As it is further proved by the study of Heerwagen (2000), the improved air quality is likely to have a greatest impact on wellbeing and personal productivity. Further, studies using self-assessments of productivity have found strong relationships to air quality factors. Among those, air quality was identified as a critical factor influencing occupants' productivity in green buildings by testing the literature existed on the relationship between air quality and occupants' productivity.

Nonetheless, the existing studies have shown a strong association between Indoor Air Quality, Sick Building Syndrome symptoms and work performance (Heerwagen, 2000; Atkin and Brooks, 2000). Accordingly, a significant effect of air quality to enhance occupants' productivity in green buildings could be identified. Hence, it creates an importance to introduce further provisions on IAQ, which will enhance the occupants' productivity, as they work with comfort and greater satisfaction in green working environment. Hence, air quality requires a further consideration, as it showed significant relationship to occupants' productivity in green office buildings. Hence, the existing provisions of air quality in GREEN$^{SL®}$ National Rating System could also be important to revise by adopting new provisions and strategies, such as, the implementation of air quality standards of Occupational Safety and Health Administration (OSHA) and Illinois Department of Public Health (IDHP) to fulfill the IAQ requirement of green buildings etc.

4.2.4. ACOUSTIC QUALITY AND OCCUPANTS' PRODUCTIVITY

Noise is distracting the concentration on work or study and provides less than ideal working and learning environments, thus influencing occupants' productivity. Among the other acoustic quality related factors, system control and acoustical partitioning were identified as the significant factors which showed statistically significant correlation to the acoustic quality in green buildings. In the correlation analysis, system control and acoustical partitioning factors (independent variables) were evaluated with the occupants' productivity (dependent variable).As SPSS output showed, both of them proved a significant association to the occupants' productivity, where, system control showed strongly positive monotonic correlation (Spearman's rho=.347, p=.005) whilst acoustical partitioning showed weakly positive monotonic correlation (Spearman's rho=.347, p=.005). The monotonic correlation of both factors confirms the improvement of occupants' productivity in green buildings with respect to the provisions provided on acoustic comfort in green buildings.

Hence, the provisions of system control and acoustical partitioning can increase to ensure occupants' productivity improvements. As stated by Quantity Surveyor in Green Building C "*we are working here very happily as the environment is comfortable with this natural environment than our previous building. However, it would be beneficial to further concern on controlling the noise generated inside and outside of the building."* It is further proved by Branch Manager in Green Building A as *"Green building is a new concept and we have introduced to this new building. Environment is really comfortable to work and, it increases our productivity as you asked from me. But, I would like to highlight one area that needs to be improved further. The noise generated inside the building is really disturbing to our day to day works. As I think, more provisions should be introduced to reduce that noise generation."*

According to the previous productivity related studies, acoustic quality has a potential link to occupants' productivity (Mahdavi and Unzeitig, 2004),Clements-Croome, 2002; Kim and Dear, 2011). A study by Frontczak and Wargocki (2010) further proved that noise is distracting the concentration on work or study and provides less than ideal working and learning environments. Further, it could be from internal sources such as, building systems, office works and workers etc. and from background noise generating sources. One of main reasons is that the design techniques that are utilized in green buildings to improve energy efficiency, sustainability, and other IEQ aspects of buildings tend to worsen acoustic defects. Often design team members are simply not aware of the impact of their design decisions on the acoustics of the building (Hodgson, 2008). Henceforth, major consideration should be given on the acoustic quality in green buildings. According to the research findings, system control and acoustical partitioning have potential relationship to occupants' productivity. Hence, the rating system should provide relevant provisions to ensure acoustical quality in green buildings. The provisions and strategies are required to enhance the controllability of systems to reduce the noise generated. Office spaces could also design with acoustical partitioning to reduce both internal and external noises. Use of sound absorbers, acoustical ceiling over building system installed areas; acoustical tiling can be identified as further provisions to enhance acoustic quality in green buildings.

Accordingly, the relationship between indoor environment quality and occupants' productivity was tested and determined. Based on both statistical and qualitative findings, air quality, system control and acoustical partitioning were identified as the significant IEQ factors influencing occupants' productivity in green buildings. Further, the relation between those factors and occupants' productivity was identified and further improvements on green buildings were suggested.

5. SUMMARY

In light of growing concern on facilitating a quality indoor environment for building occupants, green building became momentum. Most of organisations tend to be green from their tradition work setting so as to obtain its ultimate benefits. Specially, much more attention has focused on the indoor environment in offices as it was identified as a major factor influencing occupants' productivity. Indoor environmental quality mainly refers to the thermal quality, visual quality, IAQ and the acoustic quality. By reviewing key literature, 27 IEQ factors influencing occupants' productivity were identified. As the purpose of this research, correlation analysis was performed to identify significant factors influencing occupants' productivity. According to the test results of Spearman's Correlation, seven significant factors were determined such as, opening windows, air quality, controllable task lighting, personal lighting, and view to outdoor environment, system control and acoustical partitioning. As the second stage of analysis, the relationship between IEQ and occupants' productivity was determined. As the test results showed, air quality and acoustical partitioning factors showed a statistically significant and weakly positive correlation whilst system control showed strongly positive monotonic correlation to occupants' productivity in green buildings.

Thus, facilitating more provisions specially to ensure air quality and acoustical quality would effect to ensure productivity improvements of green building occupants.

6. REFERENCES

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

Boonstra, C. and Pettersen, T.D., 2003. Tools for environmental assessment of existing buildings. *Sustainable Building and Construction*, 1, 80-83.

Chan, A.P.C., Yung, K.H.E., Lam, P.T.I., Tam, C.M. and Chueng, S.O.,2009. Application of delphi method in selection of procurement systems for construction projects. *Construction Management and Economics*, 19(3), 699-718.

Clausen, G. and Wyon, D.P., 2008. The combined effects of many different indoor environmentalfactors on acceptability and office work performance. *HVAC and Research*, 14(1),10-13.

Clements-Croome, D., 2000. *Creating the productive work place*. London: CRC Press.

Crawshaw, J. and Chambers, J., 2001. A concise course in advanced level statistics with worked examples. Cheltenham: Nelson Thornes.

Deuble, M.P. and Dear, R.J., 2012. Green occupants for green buildings: The missing link. *Building and Environment,* 56(1), 21-27.

Green Building Council in Sri Lanka. 2010. GREENSL® rating system for built environment [online]. GBCSL: Sri Lanka. Available from: http://srilankagbc.org/built_env [Accessed 25 May 2015]

Haapio, A., 2008. *Environmental assessment of buildings*. Dissertation (Doctoral), Helsinki University of Technology, Finland.

Hameed, A. and Amjad, S., 2009. Impact of office design on employees' productivity: a case study of banking organisations of Abbottabad, Pakistan. *Journal of Public Affairs, Administration and Management*, 3(1), 1-13.

Heerwagen, J. 2000. Green buildings, organisational success and occupant productivity. *Building Research and Information*, 28 (5/6), 353-367.

Hinkle, D.E., Wiersma, W. and Jurs, S.G., 1998. Applied Statistics for the Behavioral Sciences, 4th ed. Boston: Houghton Mifflin Company.

Hobday, R., 2011. *Indoor environmental quality in refurbishment* [online]. Scotland:Alba Aosmhor. Available from: http://www.historic-scotland.gov.uk/technicalpaper12.pdf [Accessed 25 May 2015]

Hodgson, M., 2008. Acoustical evaluation of six 'green' office buildings. *Journal of Green Building*, 3(4), 108-118.

Illeperuma, O.A., 2000. Environmental pollution in Sri Lanka: a review. *Journal of National Science Foundation Sri Lanka*, 28(4), 301-325.

Jones Lang LaSalle, 2011. *Green buildings driving employee productivity*[Online]. Available from:http://webcache.googleusercontent.com/search?q=cache:T_LOYWJndjEJ:www.joneslanglasalle.com/GSP/en-gb/Pages/Global-SustainabilityPerspective.aspx+&cd=1&hl=en&ct=clnk&gl=lk [Accessed 25 May 2015]

Kamaruzzaman, S. N., and Sabrani, N.A., 2011. The Effect of Indoor Air Quality (IAQ) Towards Occupants' Psychological Performance in Office Buildings. *IAQ in Office Building*, 4, 1985-6881.

Khalil, N., and Husin, H. N., 2009. Post occupancy evaluation towards indoor environment improvement in Malaysia's office buildings. *Journal of Sustainable Development*, 2(1).186.

Kim, J., and Dear, R.D., 2011. Nonlinear relationships between individual IEQ factors and overall workspace Satisfaction. *Building and Environment*, 49(1), 33-40.

Kosonen, R., and Tan, F., 2004. The effect of perceived indoor air quality on productivity loss. *Energy and Buildings*,36, 981–986.

Lacouture, C., Sefair, J., Florez, L., and Medaglia, A. L., 2008. Optimization model for the selection of materials using a LEED-based green building rating system in Colombia. *Building and Environment*, 44(1), 1162-1170.

Lan, L. and Lian, Z., 2009. Application of statistical power analysis - how to determine the right sample size in human health, comfort and productivity research. *Building and Environment*, 45, 1202–1213.

Leaman, A. and Bordass, B., 2007. Are users more tolerant of 'green' buildings?. *Building Research and Information*, 35(6), 662-673.

Lee, Y. S., 2010. Office layout affecting privacy, interaction, and acoustic quality in LEED-certified buildings. *Building and Environment*, 45, 1594–1600.

Lee, Y.S., Denise, A. and Guerin, A., 2009. Indoor environmental quality differences between office types in LEED-certified buildings in the US. *Building and Environment*. 45, 1104-1112.

Levin, H., 1995. *Building ecology: an architect's perspective on healthy buildings* [online]. Availbale from: http://www.buildingecology.com/articles/building-ecology-an-architects-perspective-on-healthy-buildings [Accessed 25 May 2015]

Mahdavi, A., and Unzeitig, U., 2003. Occupancy implications of spatial, indoor-environmental, and organisational features of office spaces. *Building and Environment*, 40, 113–123.

Miller, N. G., Pogue, D., Gough, Q. D. and Davis, S. M., 2009. Green building and productivity. *Journal of Sustainable Real Estate*, 1(1),1-31.

Prakash, P., 2005. *Effect of indoor environmental quality on occupant's perception of performance: a comparative study.* Master's thesis. University of Florida, Florida.

Saunders, M., Lewis, P. and Thornhill, A., 2009, Research methods for business Students. 5th ed. Harlow: Pearson Education Limited.

Sullivan, J., Baird, G. and Donn, M., 2013. *Measuring productivity in the office workplace,*Wellington: Centre for Building Performance Research.

Urban Catalyst Associates. 2005. *Case studies of sustainable development in Michigan*, University of Michigan: Michigan.

Wallhagen, M. 2010. *Environmental Assessment of Buildings and the influence on architectural design.* Thesis (M.Sc). Royal Institute of Technology, Stockholm, Sweden.

IS 'HUMAN RIGHTS' THE END OR THE MEANS OF SUSTAINABLE URBANIZATION?

Buddini Chatumaduri Dharmawardhana
Attorney-at-Law, Sri Lanka

Mahesh Devinda Abeynayake* and Nazeer Fathima Sabrina Aashik
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Urbanization is one of the inventible phenomena in the 21st century. People migrate to urban areas due to social, cultural, environmental, political and economic reasons. Rapid and unplanned urbanization lead to huge social, economic, cultural and environmental challenges. Therefore, sustainable development, more particularly sustainable urbanization is required in order to prevent adverse effects of rapid and unplanned urbanization. In other words development that meets the needs of the present generation without compromising future generations to meet their own needs as emphasized by the Brutl and Commission should be an essential feature in the urbanization process. It is apparent that urbanization causes serious violation of human rights including social, economic, cultural, civil and political rights which are indivisible and interdependent. These violations of human rights can be prevented through sustainable urbanization. In other words, achievement of sustainable development and sustainable urbanisation guarantees the human rights of people. Also on the other hand it is argued that rights-based approach is the best method to achieve sustainability. The objective of this paper is to evaluate as to whether the 'Human Rights' is the end result of sustainability or whether 'rights-based' approach is the way to achieve sustainability. In concluding the paper it is noted that 'human being' should be the paramount consideration and central concern of development and 'Human Rights' is the "END" as well as the "MEANS" of sustainable urbanization.

Keywords: *Human Rights; Sustainable Urbanisation.*

1. INTRODUCTION

In the 21st Century 'the change in the dominant habitat of world population makes the process of urbanization' (UN Habitat, 2012) is one of the remarkable trends occurred at global level. Cities and urban areas are no more perceived as a space for settlement, housing or occupying. At present urban areas are viewed as places which have a significant impact on development of a country. In other words even though there is a close relationship between the growth of population and urbanization, urbanization is not merely a demographic phenomenon. It greatly shapes social, political, economic, cultural and environmental conditions of a country.

The aim of this paper is to examine as to whether sustainable urbanization is a way to protect or guarantee human rights or whether 'human rights' is used as a tool to achieve sustainable urbanization. In order to achieve this aim the following issues are evaluated and analyzed;

a) What is urbanization, reasons for it and adverse effects of urbanization?

b) What are sustainable development, sustainable urbanization and three pillars of the same?

c) What are Human Rights? and

d) Ascertain as to whether human rights is the end or means of sustainable urbanization.

* Corresponding Author: E-mail – abey92@hotmail.com

2. LITERATURE REVIEW

2.1. URBANISATION

Urbanisation refers to the process by which rural areas become urbanized as a result of economic development and industrialisation. Demographically, the term urbanisation denotes the redistribution of populations from rural to urban settlements over time (Peng, Chen and Cheng, 2012). The expansion of urban boundaries and the formation of new urban centres also contribute to urbanisation (McGranahan and Satterthwaite, 2014). However, urbanization cannot be deemed as a stand-alone process and it is intrinsically intertwined with social, economic, cultural and political system of a country. There are various reasons for people to migrate to urban areas. Lack of access to resources and opportunities such as education, training and employment, armed conflicts, eviction from their land consequent to a development project, climate change and adverse impact on some of the extreme environmental conditions such as landslides, Tsunami and floods can be some of the possible reasons which lead to urbanization (Soja and Kanai, 2007). In addition to the reasons aforementioned tendency of migrating to urban areas have increased mainly due to globalization and liberalization of economy. Though people migrate to urban areas for different reasons, they commonly seek one thing, namely the improvement of their living standards. They leave their native places along with their cultures and compromise everything to have a better lifestyle (Cohen, 2006). It is apparent that after migrating to the urban areas people do not act in accordance with the nature. They are compelled to adapt to the new different environment which causes tension and confusion.

Not only in Asia but also in Europe and Austria, growth of urban population is increasing rapidly. It is estimated by the UN HABITAT Program that density of urban areas will increase by 10% by 2020 (United Nations Population Division, 2014). It is also estimated that nearly a billion people live in slums across the globe. Furthermore, one third of urban population in China and India are living in slums. Increasing number of urban population is a common sight in rich Gulf countries like United Arab Emirates as well as in small islands such as Bahrain and Qatar (Mihr, 2009, p.11). Also it is estimated that 80% of population in the world will live in urban areas by 2030 (Mihr, 2009, p.12). At present 56% of urban population in Mumbai, India live in insecure and informal settlements without having access to basic needs including the access to pure water and sanitation (Levy, 2009, p.1).

Also the people live in megacities such as Mexico and Lagos encounter much hardship in relation to the right to shelter, access to health and education. There are many adverse effects arisen from urbanization. For instance in African cities environmental pollution, inadequate and poor housing schemes, increasing poverty, traffic congestion and lack of health and education facilities are common sights (Cohen, 2006). Also it has been predicted that population in Lagos will be nearly 24.3 million by 2015 and it will become the third largest urban area in the world. Lagos in sub-Sahara faces many challenges such as floods during rainy seasons, poor sewage systems, traffic congestions, insufficient bridges and arteries and problems of waste and garbage disposal, increasing demand for health, education and housing. In addition to these problems, it is evident that Nigeria as a nation is facing environmental issues such as loss of bio-diversity, devastation of agricultural land, water and air pollution and desertification as well as socio-economic issues such as insanitation, slums, violence and crimes.

In this backdrop, it is worthwhile to discuss the concept of sustainable development and sustainable urbanization in order to prevent adverse effects of unplanned urbanization.

2.2. SUSTAINABLE DEVELOPMENT AND SUSTAINABLE URBANIZATION

Although the concept of sustainability has been there even before the 20 century, this concept came in to existence formally consequent to the publication of Brundtland Commission Report of the World Commission on Environment and Development (Jiboye, 2011). Sustainable development has been defined by the Brundtland Commission as “development that meets the needs of the present generation without compromising future generations to meet their own needs” (WCED, 1987; Jiboye, 2011). Even though different scholars, organisations and reports define and explain the concept of sustainable development it connotes the same meaning. It means that better quality or standard of life should be ensured for everyone including future generations (Jiboye, 2011) when the development is achieved.

Sustainable development can be subdivided into three categories namely; social sustainability, economic sustainability and environmental sustainability (William, 2002). Mary Robinson, the United Nations High Commissioner for Human Rights states that people are the paramount consideration of sustainable development (UNAC Insight series, p.1). Social sustainability means that upgrading and maintaining a sound quality of life of public. This includes physical and psychological health of people, considering all humans fairly in providing essential and basic facilities such as housing and education. Economic or financial sustainability does not mean merely to increase in production, but it means to upgrade various indicators like poverty rate, life expectancy rate and literacy rate. Environmental sustainability indicates that keeping the environment in an unpolluted, original and in a natural condition.

The high pace of social and economic development in Asia results in lack of infrastructure, congested traffic, environmental degradation and a housing shortage (The Asia-Pacific Forum for Environment and Development (APFED), 2001 cited Ichimura, 2003). A statement made by the Chinese government in the Annual General Meeting emphasised the issues caused due to urbanisation (China Council for International Corporation for Environment and Development (CCICED), 2006);

> Urbanization has increased the living standard of urban as well as rural residents. However, serious problems resulting from rapid urbanization have emerged. Natural resources are increasingly in short supply. Problems such as pollution, excessive use of groundwater and waste have worsened the environmental situation and led to shortage of water resources. [...] Authorities have not done enough to raise efficiency standards. [...] Rapid growth in private vehicles will further exacerbate this situation. Air and water quality in cities is a major problem, with many negative regional effects. Industrial resource efficiency is still very low by comparison to international standards.

This statement reflects that urbanization is a significant challenge to the living standard of human and sustainable urbanisation is vital.

a. What are Human Rights?

Human rights are inherent rights of all human beings irrespective of their colour, nationality, sex, language or any other status (OHCHR, 2015). In other words every human being is entitled to enjoy human rights without any discrimination. Human rights can be broadly categorized into two main categories namely, civil and political rights and economic, social and cultural rights (Sen, 2005). These rights are enshrined in two main international instruments. According to (United Nations, 1976), Civil and Political rights are included in International Covenant on Civil and Political Rights (ICCPR) whereas economic, social and cultural rights are included in International Covenant on Economic, Social and Cultural rights (United Nations Human Rights, 2015). All these rights are universal, interrelated, indivisible and interdependent. Sri Lanka has ratified both convention and even enabling legislation has been enacted namely, the International Covenant on Civil and Political Rights Act No.56 of 2007 to give effect to ICCPR.

b. Whether human rights is the end or means of sustainable urbanization?

As far as economic, social and cultural rights are concerned all people have the right of self-determination. By virtue of that right they freely determine their political status and freely pursue their economic, social and cultural development (United Nations Human Rights, 2015, Art 1(1)). Also the right of everyone to education (United Nations Human Rights, 2015, Art 13) and the right of everyone to take part in cultural life, to enjoy the benefits of scientific progress and its applications are recognized (United Nations Human Rights, 2015, Art 15) under this category of rights. Also everyone has the right to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions (United Nations Human Rights, 2015, Art 11 (1)). Furthermore, all human beings are able to enjoy these rights without discrimination of any kind as to race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth or other status (United Nations Human Rights, 2015, Art 2(2)).This category of rights recognizes, on the one hand the right to development including social, economic and cultural upgrading. Therefore, it is evident that people can pursue development and they can migrate from rural areas seeking development as of their right. Also it can be argued that on the other hand, if the three pillars of sustainability, namely, social, economic and environmental sustainability are achieved in development process all these economic, social and cultural rights can be enjoyed.

Moreover, the right of everyone to the enjoyment of the highest attainable standard of physical and mental health (United Nations Human Rights, 2015, Art 12(1)) and the improvement of all aspects of environmental and industrial hygiene (United Nations Human Rights, 2015, Art 12(2)(b)) are recognized as human rights. Hence, it can also be argued that although people have the right to development it should not undermine the right to have an unpolluted environment and the right to health.

In addition to these aforementioned economic, social and cultural rights, sustainable development focuses on civil and political rights too. Every human being has the inherent right to life (United Nations, 1976, Art 6). If a decent environment suitable for human living is ensured, it is deemed as protection of right to life. Also if the right to life or right to health or right to an unpolluted environment is challenged people should have the ability to seek remedy without any discrimination as all persons shall be equal before the courts and tribunals (United Nations, 1976, Art 14).

Furthermore, everyone shall have the right to hold opinions without interference and everyone shall have the right to freedom of expression which shall include freedom to seek, receive and impart information and ideas of all kinds, regardless of frontiers, either orally, in writing or in print, in the form of art, or through any other media of his choice (United Nations, 1976, Art19).If the authorities enable public to get to know information with regard to development projects which will affect the environment it can be perceived as protection of aforementioned rights. Article 21 of the ICCPR recognizes the right of peaceful assembly and Article 22 recognizes the right to freedom of association. It is apparent that three pillars of sustainable development are indivisible and it is wise to discuss them by way of holistic approach.

As far as environmental sustainability or in simple terms protection of environment is concerned it is worth noting to analyse further whether human rights can be protected through environmental sustainability or protection of environment. Some scholars perceive that environmental protection is pre requisite for fulfilment of human rights whereas some state that it is an integral part of human rights (Dias, 2000). However, it should be noted that both arguments lead to one single norm that there is a relationship between environmental protection and human rights. In other words it can be argued that issues with respect to environment and human rights are interdependent. Also it is evident that some international instrument even way back in the 19th century has recognized the interconnection between environment and human rights. For instance Stockholm Declaration on Human Environment, (1972) states that ‘man has the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being’, identifying the relationship between human rights and environmental protection.

In addition to international conventions and covenants many constitutions all over the world explicitly recognizes the right to environment. The right to environment is enshrined in many national constitutions. The Argentina Constitution provides "all residents enjoy the right to a healthy, balanced environment” (Human rights constitutional documents, 1994, Art 31). The constitution of the Congo states that "each citizen shall have the right to healthy, satisfactory and enduring environment" (The constitution of the Congo, Art. 46).The Article 35 of the Korean Constitution states “all citizens shall have the right to a healthy and pleasant environment”. Even though Sri Lankan Constitution, 1978 does not recognize the right to environment, Article 27(14) mentions that “the State shall protect, preserve and improve the environment for the benefit of the community” and Article 28(f) mentions that “the exercise and enjoyment of rights and freedoms is inseparable from the performance of duties and obligations, and accordingly it is the duty of every person in Sri Lanka to protect nature and conserve riches.” Therefore it is clear that the 1978 Sri Lankan Constitution includes principle of sustainable development under its Directive Principles of State Policy and Fundamental Duties.

Three approaches are suggested to achieve environmental sustainability through which human rights can be ensured. Firstly deploying existing right to achieve environmental goals, secondly, reinterpreting existing rights in order to include environmental issues and thirdly creating new rights which explicitly address right to environment. When the existing human rights including right to environment or right to health that are enshrined in international and national laws are preserved and mobilized sustainable urbanization can be achieved.

It is apparent that at the time of some of the national and international laws were drafted current environmental concerns did not exist. Thus, it is wise to reinterpret those laws to include environmental concerns which are important today. For instance Indian judiciary reinterpreted right to life so as to include right to an unpolluted and a decent environment, *Vellore Citizens Welfare Forum Vs Union of India* (AIR (1996) SC 2715)Petitioners filed a petition under Article 32, right to life of the Indian Constitution. This petition was filed against the pollution occurred due to enormous discharge of sewage from industries in Tamil Nadu. There the Court interpreted right to life widely so as to include right to healthy environment, pollution free environment and ecological balance. It is evident that there, court held in favour of the petitioners interpreting the right to life broadly.

Furthermore, it is evident that many domestic and international laws are emerging in addressing environmental issues from human rights perspective. African Charter on Human and People' Right is the first human right treaty which explicitly identifies the 'right to a satisfactory environment favourable to human development'. Also Organisation of Economic and Development (OECD) has recognized decent environment as one of the basic human rights. Moreover, Charter on Environmental Rights and Obligations drafted by the United Nations Economic Commission for Europe (UNECE) highlights that every human being has the right to an unpolluted environment which ensures general health and well-being.

Mary Robinson-United Nations High Commissioner for Human Rights states that "Poverty eradication without empowerment is unsustainable. Social integration without minority rights is unimaginable. Gender equality without women's rights is illusory. Full employment without worker's rights may be no more than a promise of sweatshops, exploitation and slavery. The logic of human rights in development is inescapable" (UNAC Insight Series). Therefore it is stated that though the development should be pursued protection of social, economic, cultural, civil and political rights of human should not be undermined. In other words 'preservation of human rights' should be the end of sustainability.

On the other hand to achieve sustainability, human rights concerns are the best approach. In other words Human Rights activists and organisations across the world argue that right-based approach should be followed to achieve sustainability. Proponents of this argument further state that there should be three main fields that should be focused in order to achieve right-based approach to sustainable development. They are, right to clean and unpolluted environment, right to access information and right to active and meaningful participation of public in decision making processes and right to preserve and defend environmental protection and human rights.

Right to healthy environment cannot be achieved only having national and international substantial laws mentioned above. It can only be achieved by linking substantive rights with procedural rights. Procedural rights include right to information, right to participation and right to obtain suitable remedies. Right to information means that national states should provide information in relation to activities carried out by them in development projects including potential environment impacts. Also governments should give notice to public who are likely to be affected by the development projects.

Public who will be affected by any project should have to have the right to participate in decision making processes. Some international as well as national laws have already recognized this as an important right. For instance The Espoo Convention on Environmental Impact Assessment (EIA) in a Trans boundary Context states that public will be notified and they should be provided with an opportunity to participate in environmental impact assessment procedures. Also National Environment Act of Sri Lanka as amended, recognizes public participation in EIA process.

There are plenty of examples to state that if the right-based approach is not followed then it will create unsustainable development and unplanned urbanization. Colombo Port City Project initiated by China Communications Construction Company Limited can be taken as an example. This is intended to cover 5.2 million square meters and it will have a capacity to hold 160,000 people (Wijenayake, 2015). However, there are lots of oppositions raised with regard to the project questioning the validity of the Environmental Impact Assessment (EIA) obtained in relation to the project. EIA Process is laid down in the National Environment Act No.56 of 1998 as amended in 2000 by the Act No.53. This EIA procedure is also mentioned in the Gazette No.772/22 dated 24th June 1993 (Wijenayake, 2015). EIA process includes several steps such as submitting preliminary information to the Central Environment Authority (CEA) by the project proponent and 30 days for public consultations. It is questioned by many environmental activists and organisations whether the steps to be followed are properly adhered to with respect to Port City Project (Wijenayake, 2015).

Also it is argued that the project will adversely affect the western coastal line and as it has been planned to filling the sea it would cause coastal erosion and will vary the marine bio diversity. Also sand and other debris disposed to the sea will have adverse impact on corals, grass habitats, weeds in the seabed and mangrove in the coast. Furthermore, it is argued that the air in Colombo City will be polluted by the project and natural water resources will be under threat as great quantity of water is needed for the construction (Wijenayake, 2015). Here it can be seen that right to participation and right to information which are the key factors in right–based approach is violated and thus, sustainable urbanization is at stake.

Furthermore, Gampaha - Rathupaswala incident is another good example. There is a rapid urbanization of the Gampaha District and people live in Gampaha District welcome good outcome of the urbanization and protest against the adverse effect of the same. In August 2013, a very large crowd gathered and protested against water pollution caused by Venigros (Pvt) Ltd, a latex glove manufacturing factory. Three civilians were killed and many were injured in this protest. (Rajasingham, 2014) This incident can be viewed as one of the major human rights violations occurred in the recent past. Chemical effluents dumped from the factory contaminated the water and it directly violated the right to have healthy life (United Nations Human Rights, 2015, Art 12(2) (b)), right to water and right to an adequate standard of living. On the other hand using excessive power to control the protest by killing people is a gross violation of right to life (United Nations, 1976, Art 6), right to assembly (United Nations, 1976, Art 21) , freedom of association (United Nations, 1976, Art 22) and right to freedom of expression (United Nations, 1976, Art 19).

If the right based approach to development is adhered this type of situation can be prevented. Right-based approach to development requires the State to act in a way so as to obtain active, free, meaningful participation of all stakeholders (Rajasingham, 2014) involved in the development projects. Here it is evident that public in Rathupaswala was not consulted properly before setting up the factory and that created a huge social unrest.

3. CONCLUSIONS

The Preamble to the Draft Declaration of Principles on Human Rights and the Environment stresses the connection between human rights and environment “human rights violations lead to environmental degradation and environmental degradation leads to human right violations" (Dias, 2000). In the same vein, it can be concluded that sustainable urbanization leads to preserve human rights and when the right-based approach is followed to achieve development it will pave the way towards sustainable development and sustainable urbanization. Therefore it can be concluded that “Human Rights are the end as well as the mean so of achieving sustainable urbanization.”

4. REFERENCES

China Council for International Corporation for Environment and Development (CCICED), 2006. *Work Report of CCICED* [online]. Available from: http://www.cciced.net/encciced/event/AGM_1/Pub06AGM/meetingdoc06/201205/t20120515_229003.html [Accessed 3 March 2015].

Cohen, B., 2006. Urbanization in Developing Countries: Current Trends, Future Projections and Key Challenges for Sustainability. *Technology in Society*, 28, 63–80.

Dias, A., 2000. *Human Rights, Environments and Development: with special emphasis on Corporate Accountability* [online]. Human Development Report, Background Paper. Available from: http://hdr.undp.org/sites/default/files/ayesha-dias.pdf [Accessed 21 March 2015].

Ichimura, M., 2003. *Urbanization, Urban Environment and Land Use: Challenges and Opportunities.* In: *Asia-Pacific Forum for Environment and Development Expert Meeting*, Guilin: People's Republic of China.

Initiative of the United Nations Association in Canada with the Support of IDRC, Insight Series 2, 2013. *The Human Rights Approach to Sustainable Development: Environmental Rights, Public Participation and Human Security* [online]. Available from: http://unac.org/wp-content/uploads/2013/07/HRandSD-EN-PDF.pdf [Accessed 11 March 2015]

Jiboye, A. D., 2011. Sustainable Urbanization: Issues and Challenges for Effective Urban Governance in Nigeria. *Journal of Sustainable Development*, 4, 56-63.

Human Rights Constitutional Documents, 1994. *Constitution of the Argentine Nation* [online]. Available from: http://www.hrcr.org/docs/Argentine_Const/First_Part.html [Accessed 3 March 2015].

Levy, C., 2009. Urbanization without Social Justice is not Sustainable. *Journal of Sustainable Cities*, 12, 45-56.

McGranahan, G. and Satterthwaite, D., 2014. *Urbanisation Concepts and Trends* [online]. IIED Working Paper. IIED, London. Available from: http://pubs.iied.org/pdfs/10709IIED.pdf [Accessed 5 March 2015].

Mihr, A., 2009. *Urbanization and Human Rights.* In: Amsterdam Conference on the Human Dimensions of Global Environmental Change, Volendam: Netherlands.

Peng, X., Chen, X. and Cheng, Y., 2012. *Urbanization and Its Consequences* [online]. Available from: https://www.google.lk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CBwQFjAAahUKEwicpa2RjbFAhWCwBQKHblVANk&url=http%3A%2F%2Fpeople.duke.edu%2F~zengyi%2Funesco-eolss%2520demography-%2520revised-final-manuscripts%2FCh%252018-Urbanization%2FCh%252018-Xizhe%2520Peng%25202009-06.doc&ei=kOtnVZydFYKBU7mrgcgN&usg= AFQjCNHU6lWbPUHjhIRl8mCwafMKO3sqYA&sig2=mJfyzD3kdQaBvj_sBnN3SQ&bvm=bv.94455598,d.d24 [Accessed 3 March 2015].

Rajasingham, D. S., 2014. *Human Right, Development and Rathupaswala, Faculty of Law: Sri Lanka* [online]. Available from: http://www.lawandsocietytrust.org/PDF/resource/Winning%20Submission%20Call%20for%20Papers%20-%20Ratupaswala.pdf [Accessed 23rd March 2015]

Sen, A., 2005. Human Rights and Capabilities, *Journal of Human Development, 6*(2), 151-166.

Soja, E. and Kanai, M., 2007. The Urbanization of the World, In: R. Burdett and D. Sudjic, ed. *The Endless City*, Phaidon: London.

Stockholm Declaration on Human Environment, 1972. *Declaration of the United Nations Conference on the Human Environment, United Nations Environment Programme* [online]. Available from: http://www.unep.org/Documents.Multilingual/Default.Print.asp?documentid=97&articleid=1503 [Accessed 23 March 2015].

The Constitution of the Democratic Republic of the Congo, 2005. *The Constitution of the Democratic Republic of the Congo* [online]. Available from: http://www.constitutionnet.org/files/DRC%20-%20Congo%20Constitution.pdf [Accessed 3March 2015].

UN HABITAT, 2012. *UN System Task Team on the Post-2015 UN Development Agenda: Sustainable Urbanization Thematic Think Piece* [online]. Available from: http://www.un.org/millenniumgoals/pdf/Think%20Pieces/18_urbanization.pdf [Accessed 5 March 2015].

United Nations, 1976. *International Covenant on Civil and Political Rights (ICCPR)* [online]. Available from: https://treaties.un.org/doc/Publication/UNTS/Volume%20999/volume-999-I-14668-English.pdf [Accessed 3 March 2015].

United Nations Human Rights, 2015.International Covenant on Economic, Social and Cultural rights (ICESCR) [online]. Available from: http://www.ohchr.org/EN/ProfessionalInterest/Pages/CESCR.aspx [Accessed 3 March 2015].

Vellore Citizens Welfare Forum Union of India AIR, 1996. *SC 2715* [online]. Available from: http://indiankanoon.org/doc/1934103/ [Accessed 3 March 2015].

WCED, 1987. *Our Common Future. World Commission on Environment and Development*. Oxford: University Press.

Wijenayake, V., 2015. *Colombo Port City Project: A Threat to Sustainable Development?*. Daily Mirror: Sri Lanka [online]. Available from: http://www.dailymirror.lk/65601/colombo-port-city-project-a-threat-to-sustainable-development#sthash.IAlX8uEv.dpuf [Accessed 3 March 2015]

ISSUES IN SUBMISSION AND CERTIFICATION OF VARIATIONS

Thuritha M. Karunathilake* , L.D. Indunil P. Seneviratne and Kaushalya Weththasinghe
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The valuation of variation is a critical aspect in the post contract stage. The Contractor has to carry out the works according to issued variation order or on the instructions given by the Engineer even without having the approval. The Contractor might be paid a percentage on the submitted price until cost proposal is certified by the Engineer. The submission and certification process is delayed on most of the projects and this will lead the Contractor to suffer losses from the project.

The researcher attempted to review the time gap between variation submission and certification, using a documentary survey of completed building projects. Content analysis of the documents exposed delay in certification period of several variations, those had generated payment delay to Contractor, and identified the loss of opportunity cost as the ultimate effect. Further, the author identified the issues which caused delays in submission and certification of cost variations, and probable solutions to mitigate those issues. In order to achieve above facts, interview survey was carried out with professionals, who had experience in variation management of building construction field. The issues of delay in variation submission and certification procedure in Sri Lankan industry, and solutions for those issues were derived via analysis of the content of conducted interviews. Finally "Variation Procedure Guideline" was proposed and validated with the participation of experts.

Author recommended that a proper variation procedure is required to control and certify the value of variation according to the proposed guideline to manage the situation without conflicts. Further, maintain the positive relationship between project stakeholders and contribution of government as the regulatory body will be essential to overcome from mentioned issues.

Keywords: *Certification; Conflicts; Submission; Variation Management; Variation Procedure.*

1. INTRODUCTION

Construction industry is one of the important contributors to growth of national economy in any country and a significant supplier to national economy (Ocal *et al*., 2007). Arditi and Mochtar (2000) contented that, "The output of the construction industry constitutes one-half of the gross capital and is 3% - 8% of the Gross Domestic Product (GDP) in most countries" (p.15). Moreover Ocal *et al.* (2007) explained that, construction industry directly affects about 200 other sectors in a country, which also provide essential support to growth of economy.

Zhao *et al.* (2010) summarised that complexity and dynamic nature of construction projects lead to uncertainties and risks. "Changes in projects are common and may be deleterious or beneficial" (Ibbs *et al.*, 2001, p.159). The authors defined, that change in projects as, any additions, deletions or revision to project goals and scope. According to Baloi and Price (2003) there are various factors, those significantly influence construction cost from the estimating stage to project completion stage. Furthermore, Love *et al.* (2002) stated, both internal and external environments of construction projects are dynamic and relatively unstable. Therefore changes those are occurred during a project may have significant and often unpredictable effects on its organisation and management. Thus disputes over variation orders are inevitable in all construction projects (Cox, 1997).

Jayalath (2013) illustrated that a variation in a construction project is a change in form, character, kind, quality, quantity, line, level, position, alignment, or dimension of existing work or an additional work that

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

is necessary, appropriate or desirable to complete works. Correspondingly, Turner (1984) elucidated that variations are 'changes within a contract' and not 'changes of the contract'. The latter will require that the contract be rescinded in favour of writing another one if both parties are still interested. Furthermore, the author stated that variations relate to firstly, changes to the work itself and secondly, to the means of getting the work done. Similarly, Baxendale and Schofield (1986) defined variation simply as any change to the basis on which the contract was signed. This includes not only changes to the work or matters relating to the work in accordance with the provision of the contract, but also changes to the working conditions themselves. In the condition of the contract in Standard Bidding Document (SBD) by Institute for Construction Training and Development (ICTAD) in Sri Lanka, Joint Contract Tribunal (JCT), Federation Internationale des Ingenieurs Consils (FIDIC) and other bidding documents define variations and variation procedure for variation orders. All those definitions explain that a variation is an addition, omission, substitutions to the original work agreed in a contract. This can be an alteration of design, quality, quantity and kind or standard of material.

Ibbs *et al.* (2001) discovered that project changes affect to the cost, the scheduling and the duration of projects. This can be direct or indirect effect. Moreover, Jayalath (2013) stated that contractor cannot be compelled without an express provision allowing for those alterations and those must be additional works. Furthermore, the author demonstrated several methods of valuing variations such as using existing bill rates as long as they are suitable, using contract rates and prices as the basis for preparing new rates and prices and using new rates and prices with the settlement between both of the contractor and the employer. Turner (1983) identified that preparing new rates is the available option for additional works where neither bill rates nor adjusted bill rates can be applied. The author recognised this is termed as “fair rates and prices” by the contract, which would appear to mean a level of pricing that affords at least some profit margin. According to Jayalath (2013), engineer can prepare a new rate by breaking down the quoted rates into the elements of plant, materials, labour and overheads, or by using notional build up using any contemporary records.

Avlonitis and Indounas (2005) discovered that out of different pricing methods, cost plus method and pricing according to the market’s average prices are the most popular methods. According to Levin (1998) contractor is entitled to a reasonable allowance for overhead and profit, in addition to the direct cost of performing the extra work.

Giving approval for variation order can be done by the employer, architect or project manager (Hao *et al*., 2008). FIDIC (1999) and ICTAD (2007) forms of contracts state approval must be given as soon as practicable time period after receiving the cost proposal from the contractor. But neither of contract forms state certain time period to give approval for the variation except determining a provisional rate or price for Interim Payment Certificates (IPC) until approving cost and time for the variation.

Forms of contract do not allocate specific time period to give approval to contractor’s cost proposal of variation. Consequently the party, who gives approval to the cost proposal is not bounded to do it within a certain period. Thus in most of projects cost proposals may not approved on time and this leads to delay payment for the contractor for works, which he already completed. Delaying payments for completed works create an opportunity cost for the contractor. Nevertheless contractor is not eligible to claim for that opportunity cost according to standard contract forms for this situation.

Contractor is not entitled to suffer loss for that type of circumstances unless variation is arouse because of his fault. Also there is not any provision to claim this kind of cost and contractor has to suffer.

The aim of the research is to identify the issues and probable solutions to delay in variation submission and certification procedure and to develop a guideline to finalise the variation management procedure within specific time period for an identified variation. The paper provides a comprehensive literature review to identify the prevailing knowledge about variation management. Then findings of documentary survey and interview survey are presented and further subjected to discussion. Finally conclusions are drawn from the findings.

2. VARIATION MANAGEMENT IN CONSTRUCTION PROJECTS

2.1. VARIATIONS

Variation or change is any type of deviation from a work, which is agreed upon, well defined scope or scheduled (Keane *et al*., 2010). According to Hao *et al.* (2008) change orders are common in most projects and it is growing more while the project is getting larger. Those have to be negotiated separately and require a common agreement among all the stakeholders of the project. Anees *et al.* (2013) stated that written approval is the only way to proceed with the change order.

Jayalath (2013) clarified a variation in a construction project is a change in form, character, kind, quality, quantity, line, level, position, alignment, or dimension of existing work or an additional work that is necessary, appropriate or desirable to complete works. According to ICTAD (2007) and FIDIC (1999) variation may aroused in following situations as change to quantity of any item of work, quality and other characteristics of any item of work, levels, positions and dimensions of any part of work or omission of any agreed work, additional work except agreed as in the contract or changes to the sequence or timing of the execution of the works. Ramus and Birchall (1996) stated variation arises when architect needs to modify the design or specification, when a conflict is discovered between two or more of contract documents, when a conflict is discovered between any statutory requirement and any of the contract documents, when an error in or omission from the contract bills is discovered and/or when the description of a provisional sum for defined work in the contract bills does not provide the necessary information.

2.2. CAUSES OF VARIATION

Employer and the consultant are the first and second major contributors to changes in a project (Anees *et al*., 2013). Furthermore authors stated that major causes to the changes are lack of coordination between contractor and consultant, errors and omissions in the design, value engineering exercises, changes of the design and change of plans by the owner. Moreover, Hao *et al.* (2008) clarified that change orders are results of unanticipated causes such as scope changes by the employer, design or technological changes from the architect, cost and/or time changes caused because of supplier problems, design errors, material and operational failures, unsatisfactory site conditions. Also Isaac and Navon (2008) discovered the primary causes of change orders are employer initiated changes and designer's or consultant's errors and omissions. Most frequent and most costly changes are design changes and design errors (Isaac and Navon, 2008).

Keane *et al.* (2010) categorised three types of variation according to the contracting parties in the project. Those are owner related variations, consultant related variations and contractor related variations. Additionally authors added another type of variation as other variations for variations those are arouse by the influences of other parties. According to the author, owner related variations are emerged because of changes of the scope, owner's financial difficulties, inadequate project objectives, changes of materials and working procedures, conflicts arising of sudden decision making process, change the design by the owner and change the specifications by the owner. Consultant related variations are changes to the design by the consultant, errors or omissions in design, conflicts arise in contract documents, changes in the technology, value engineering exercises, lack of coordination between other parties, complexity of design, insufficient details of working drawings, less awareness of available material and equipment, shortage of required data for consultant, ambiguous design details and specification changes which are done by the consultant. Authors identified contractor related variations as lack of involvement with the design, unavailability of plants and equipment, unavailability of skills, financial difficulties of contractor, expected profit of the contractor, variance of site conditions, less workmanship, unfamiliarity with local conditions, fast track construction processes without organised system, poor procurement process, lack of communication with other parties, procurement delays, complexity of design and technology, poor planning process. Other variations are identified such as adverse weather conditions, noncompliance with health and safety regulations, changes in economic conditions, social factors and unforeseen problems.

2.3. EFFECTS OF VARIATION

Variations can be effected to a project by project delay, cost overruns, defects and it may cause to project failure also (Hao *et al*., 2008). Anees *et al*. (2013) identified that the top effects of change orders as cost overrun, time overrun, disputes among the stakeholders of project, enhance quality standards and complaints of one or more parties to the contract. Arain and Pheng (2007) stated that variation in a project is one of the most important causes to project delay. Table 1 explains the effect of change orders to stakeholders of a project.

Table 1: Effects of Change Orders

Effects	Developer	Consultant	Contractor
Increase in project cost	x		
Additional payment for contractor	x		
Progress is affected but without any delay			x
Completion schedule delay	x		x
Increase in overhead expenses		x	x
Rework and demolition		x	x

Source: Arain and Pheng (2007)

2.4. VALUING VARIATIONS

The most significant section of a change order is cost (Anees *et al*., 2013). Also authors stated one of the most important factors for successive change order implementation is discussion of change order calculations.

FIDIC (1999) and ICTAD (2007) defined the methods of valuing variations as,

- When there is a price specified in the contract for a work with similar character and executed under similar conditions, use it as the unit rate,
- When there is a price specified in the contract for a work with similar character and is not executed under similar condition, that price can be used to derive the new rate of variation,
- When the item of work has not a similar character, or is not executed under similar conditions, as any item in the contract, prepare a new rate or price for the variation item,
- For a work of a minor or incidental nature, work can be valued accordance with the daywork schedule.

Pricing of change orders is barely considered on the indirect effects and generally the methods of work break down structure or any other technique is used to track the cost changes (Anees *et al*, 2013). Furthermore ICTAD (2007) and FIDIC (1999) explained that prepared of new rate must be included with a reasonable cost of executing the work and reasonable profit. Additionally, Saunders (1996) summarised that the cost of changes is comprised with direct cost and mark-up.

2.5. VARIATION MANAGEMENT PROCESS

Managing change orders is a huge burden in project management and people in construction industry do not wish to face such processes (Hao *et al*., 2008). Arain and Pheng (2007) introduced a process oriented model for managing variations, which is based on principles of effectiveness, decision making and controls. Those are identify variation, recognise variation, diagnose variation, implement variation, implementation of controlling strategies and learn from past experience.

Engineer can initiate variations at any time before issuing the “Taking-Over Certificate” to the contactor (ICTAD, 2007; FIDIC 1999). Furthermore the documents mention that initiation can be done by either an instruction or request for the contractor to submit a proposal. ICTAD (2007) stated that engineer has the authority to do minor changes to the design if it is necessary or expedient. Engineer will have to get the approval from the client for modification of the design and cost of the relevant work, if it is a major variation. In spite of approval, engineer would have permission issue instruction for major variations without approval of the client if the variation required immediate action.

2.6. PROCESS OF EVALUATION

According to Hao *et al.* (2008) authorisation of finalising change orders is kept with the either owner, his delegated architect or project manager. Additionally, authors explained that change order become a part of the contract after it is submitted and approved. ICTAD (2007) and FIDIC (1999) stated the documents which must be submitted to get approval for variation order as, a description of proposed work and a programme of it execution, contractor's proposal for any necessary modification to the construction programme and contractor's cost proposal for evaluation. Process of variation application and approval according to ICTAD (2007) and FIDIC (1999) is shown in Figure 1.

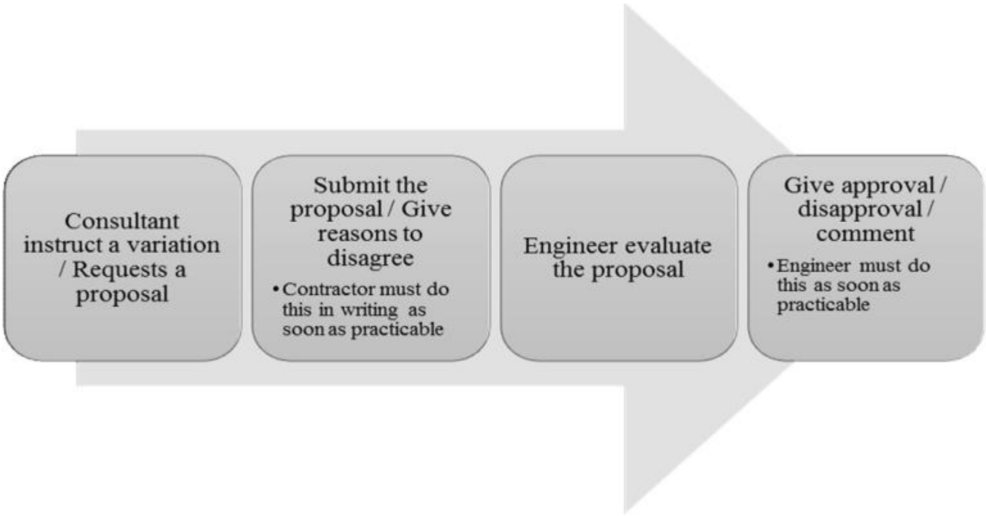


Figure 1: Variation Procedure
Source: FIDIC (1999); ICTAD (2007)

2.7. TIME ALLOCATION TO EVALUATE VARIATIONS

Engineer must respond to the submitted proposal of variation in either the manner of approval, disapproval or comments as soon as practicable (ICTAD, 2007; FIDIC, 1999). But the necessity of approving the change order in certain time period is not considered in the change order handling procedure (Anees *et al*., 2013).

2.8. PAYMENT FOR COMPLETED WORKS

Contractor is paid by the employer in three situations except advance payment as described in ICTAD (2007) and FIDIC (1999). Payment application and certification procedure is summarised in Table 2.

Table 2: Summary of Payment Methods to Contractor

Payment Certificate	ICTAD 2007 Provisions			FIDIC 1999 Provisions		
	Application by Contractor	**Certified by Engineer**	**Payment by Employer**	**Application by Contractor**	**Certified by Engineer**	**Payment by Employer**
Interim Payment Certificate	End of each month	Within 21 days after receiving the statement	Within 14 days after the employer receives certificate	End of each month	Within 28 days after engineer receives statement	Within 56 days after engineer receives statement
Statement at Completion	Within 84 days after receiving Taking Over Certificate	Within 21 days after receiving the statement	Within 14 days after the employer receives certificate	Within 84 days after receiving Taking Over Certificate	Within 28 days after engineer receives statement	Within 56 days after engineer receives statement
Final Payment Certificate	Within 56 days after receiving Performance certificate	Within 28 days after receiving final statement	Within 56 days after the employer receives certificate	Within 56 days after receiving Performance certificate	Within 28 days after receiving final statement	Within 56 days after employer receives the certificate

Source: FIDIC (1999) and ICTAD (2007)

2.9. DELAYED PAYMENTS

Mohamad, Nekooie and Kamaruddin (2012) identified miscommunication on variation leads to disagreement on valuation and finally the payment to the contractor will be delayed. Furthermore, misrepresentation of client's requirement of variation order and disagreement between the parties on payment amount, generate conflicts among the project stakeholders (Rahman *et al*., 2009). Subsequently the author mentioned that those conflicts also effect to the delay of payment to the contractor.

Contractor will be entitled to demand for interest payment if he is not received certified payments until specified date (ICTAD, 2007; FIDIC, 1999). However, the payment must be certified for demanding the interest claim.

3. RESEARCH METHODOLOGY

Survey approach was used to achieve the aims and objectives of the research. Literature survey was carried out to acquire definitions and procedures related to variations in construction industry. Documentary review was adopted for collecting data on, duration those had spent to approve variation applications and variation valuation methods in current practice. Semi-structured face to face interviews were conducted with professionals who had experience on variations in building construction projects. Content analysis was used as the technique of data analysis to analyse collected data. Finally validity and reliability of the research design is ensured by following proper measures.

4. DATA ANALYSIS

Based on the findings of documentary survey, researcher identified all the projects, those had delays in certification variations as per Figures 2, 3 and 4. Average period of time which consumes to certify variations, were varied according to particular characteristics of the project. The delays in certification of variations affect to delays in certification of statement at completion. Thus, payments of completed works of contractor was also delayed without providing a claim for opportunity cost. There were three methods which are used to determine the price of each variation as using a rate of similar item in BOQ, using pro-rata basis for an existing rate in BOQ and calculating a new rate from rate breakdowns. All the methods were used in a projects where in appropriate situation and the portion of each method is also varied according to the characteristics of the project. There are number of reasons for the extensive processing time of variations as, caused by faults from contractor, engineer and employer, errors on proceedings which are practiced, and characteristics of each project. Necessary steps to be taken to mitigate those issues were also identified using the comments those had been gained from interviews. Moreover the most optimum duration for evaluating variations is identified as 14 days as per the Figure 5. Furthermore, the variation procedure guideline was prepared according to the collected data and validated through interviews from professionals who had experience in variations. Finally, the variation procedure guideline was modified according to the comments from validation interviews, to be more feasible to the construction industry and procedures.

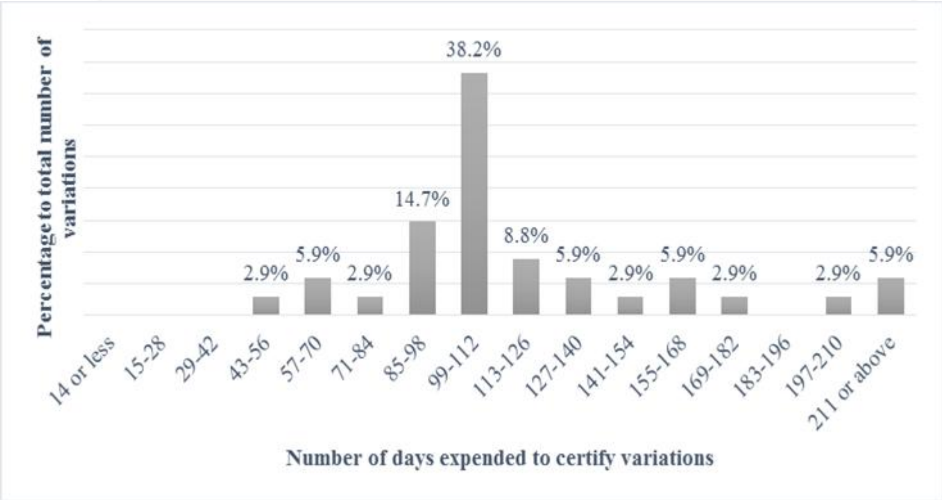


Figure 2: Durations Taken to Certify Cost Proposal of Project A

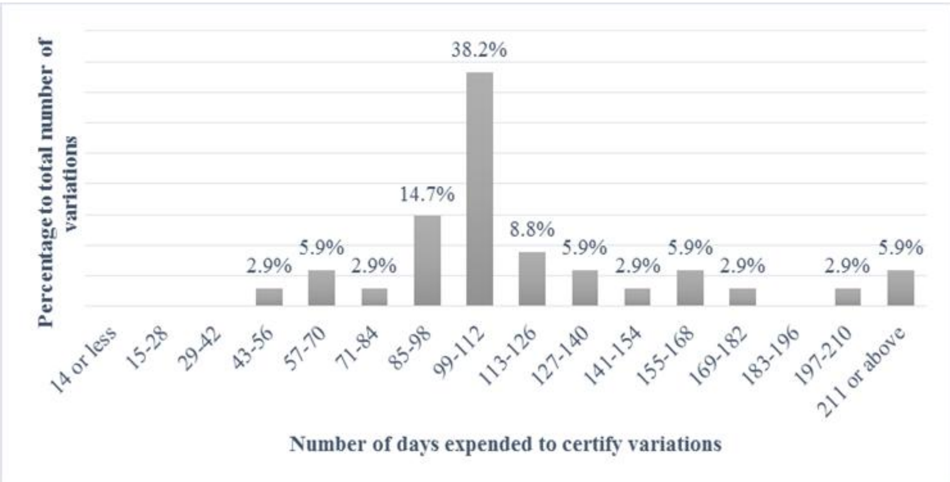


Figure 3: Durations Taken to Certify Cost Proposal of Project B

Figure 4: Durations Taken to Certify Cost Proposal of Project C

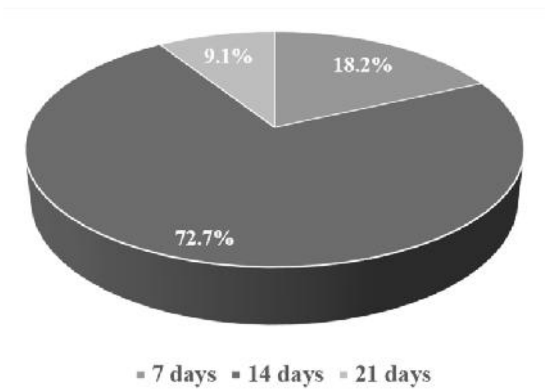


Figure 5: Optimum Duration for Evaluating Variations

5. CONCLUSION

Changes in construction projects are inevitable due to unique characteristics as uncertainties and risks. There are number of divergent construction changes, those occurred in several stages until the completion and alter the project. Proper change management procedure must be followed to approach and implement the change in an efficient manner.

Variation is one of the major type of changes in construction projects, which presents significant influences to the cost until the completion. Variation can arise in numerous ways and can be categorised, according to the relating party to each type of variation. Furthermore, each variation effects to either one or more direct stakeholders of the project. Valuing a variation is one of the major elements in variation management process. Evaluation and certification of the value of variation may create critical and conflict circumstances in the variation management process and generate payment delay to contractor, despite of included provisions in standard documents and contracts.

Documentary survey discovered that the projects had experienced delay in certification of variations in spite of the contract document, payment method and scope of the project. Furthermore, the identified delays had affected as delay the payments to the contractor and had created a loss to the contractor. Three important methods of valuing variations were exposed through the information of the analysed projects.

Interviews verified the delay in current procedure of variations, identified loss of opportunity cost to the contractor due to the delay, and revealed number of reasons for the extensive processing time of variations. The issues were categorised by way of aroused due to negligence of direct stakeholders of the project, errors of standard proceedings and unique characteristics of the projects as shown in Appendix A.

Necessary steps those must be taken to mitigate those issues were recognised in the interview survey. All the solutions were arranged in to four groups by considering the engaging party to each solution as Contractor, Engineer, Employer and government authorities. Next step was preparation of the "Variation Procedure Guideline" using the arranged responsibilities, identified additional solutions and received recommendations of guideline. Guideline was included with three sections such as allocation of responsibility to each stakeholder, variation procedure and cost proposal checklist. Finally the guideline was validated with the positive responses from experts in variation management and thereafter the prepared guideline was modified according to the comments those had given in the validation interviews. Thus the full guideline can be considered as defects free document. This attempt achieved the forth objective of this research.

6. RECOMMENDATIONS

The analysis of the interview survey derived essential recommendations for the variation procedure and documentation process for Sri Lankan construction industry. The author recommends that the "Variation Procedure Guideline" must practice for variation management procedure to improve the efficiency of procedures.

Further, attitude of the stakeholders of the project must be improved to finish the project in a win-win situation. All the parties must maintain a good relationship between each other and arguments of each party must be reasonable to other partners where in a conflict situation, especially in valuation of variations.

Additionally, both Contractor and Engineer must prepare databases for the cost of each item and those must be updated periodically. This will lead the determination process of value to be efficient.

Moreover, new technology must use in presentation and documentation methods. Using new technology to presentation and documentation procedure will diminish most of conflicts in construction industry, because of the efficiency and realism of those methods are more convenient than traditional methods.

Government authorities must publish standard documents of BSR and variation procedure. Consequently, each party in a construction project can refer those documents to get clarifications in a conflict and justify the decision to other parties in a reasonable way, because of government is considered as the regulatory body for construction standards in Sri Lanka.

In conclusion it is necessary to emphasise that, "Variation Procedure Guideline" must be used in Sri Lankan construction industry to diminish the conflicts and achieve benefit in a win-win situation to the project stakeholders.

7. REFERENCES

Anees, M.M., Mohamed, H.E. and Razek, M.E.A., 2013. Evaluation of Change Management Efficiency of Construction Contractors. *Housing and Building National Research Centre Journal* [online], 9(1), 77-85. Available from: http://www.sciencedirect.com/science/article/pii/S1687404813000060 [Accessed 3 May 2014].

Arain, F.M. and Pheng, L.S., 2007. Modelling for Management of Variations in Building Projects. *Engineering, Construction and Architectural Management* [online], 14(5), 420-433. Available from: http://www.emeraldinsight.com/doi/abs/10.1108/09699980710780737 [Accessed 3 May 2014].

Arditi, D. and Mochtar K., 2000. Trends in Productivity Improvement in the US Construction Industry. *Construction Management and Economics* [online], 18(1), 15-27. Available from: https://ideas.repec.org/a/taf/conmgt/v18y2000i1p15-27.html [Accessed 3 May 2014].

Avlonitis, G.F. and Indounas, K.A., 2005. Pricing Objectives and Pricing Methods in the Service Sector. *Journal of Services Marketing* [online], 19(1), 47-57. Available from: http://www.emeraldinsight.com/doi/abs/10.1108/08876040510579398 [Accessed 5 May 2014].

Baxendale, A.T. and Schofield, T.J., 1986. Planning and Progressing Project Variations. In: Langford, D.A. and Retik A., eds. *The Organisation and Management of Construction: Shaping Theory and Practice Volume 2*. Britain: E and FN SPON.

Baloi, D. and Price, A.D.F., 2003. Modelling Global Risk Factors Affecting Construction Cost Performance. *International Journal of Project Management* [online], 21(1), 261-269. Available from: http://www.researchgate.net/publication/222125676_Modelling_global_risk_factors_affecting_construction_cost_performance [Accessed 5 May 2014].

Cox, R.K., 1997. Managing Change Orders and Claims. *Journal of Management in Engineering* [online], 13(1), 24-29. Available from: http://ascelibrary.org/doi/abs/10.1061/(ASCE)0742-597X(1997)13%3A1(24) [Accessed 5 May 2014].

Federation Internationale des Ingenieurs Consils (FIDIC), 1999. *Conditions of Contracts for Construction*. Switzerland: FIDIC.

Hao, Q., Shen, W., Neelamkavil, J. and Thomas, R., 2008. Change Management in Construction Projects. In: *The International Conference on Information Technology in Construction* [online], Chile: Santiago, 1-11. Available from: http://itc.scix.net/data/works/att/w78-2008-3-07.pdf [Accessed 5 May 2014].

Ibbs, C.W., Wong, C.K. and Kwak, Y.H., 2001. Project Change Management System. *Journal of Management in Engineering* [online], 17(3), 159-165. Available from: http://ascelibrary.org/doi/abs/10.1061/(ASCE)0742-597X(2001)17%3A3(159) [Accessed 5 May 2014].

Institute for Construction Training and Development (ICTAD), 2007. *Standard Bidding Document, Procurement of Works, Major Contracts.* 2nd ed. Colombo: ICTAD.

Isaac, S. and Navon., R., 2008. Feasibility Study of an Automated Tool for Identifying the Implications of Changes in Construction Projects. *Journal of Construction Engineering and Management* [online], 134(2), 139-145. Available from: http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9364(2008)134%3A2(139) [Accessed 5 May 2014].

Jayalath, C., 2013. *Arguing Construction Claims*. Colombo: S. Godage and Brothers.

Keane, P., Sertyesilisik, B. and Ross, A., 2010. Variations and Change Orders on Construction Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, 2(2), 89-96.

Levin, P., 1998. Construction Contract Claims, Changes and Dispute Resolution. 2nd ed. United States: ASCE Press.

Love, P.E.D., Holt, G.D., Shen, L.Y., Li, H. and Irani, Z., 2002. Using Systems Dynamics to Better Understand Change and Rework in Construction Project Management Systems. *International Journal of Project Management*, 20(1), 425-436.

Mohamad, M.I., Nekooie, M.A. and Kamaruddin, N.B.C., 2012. The Adequacy of Contractual Provisions in Managing Construction Failure in Malaysia. *European Journal of Business and Management* [online], 4(1), 22-37. Available from: www.iiste.org/Journals/index.php/EJBM/article/download/1023/943 [Accessed 6 May 2014].

Ocal, M.E., Oral, E.L., Erdis, E. and Vural, G., 2007. Industry Financial Ratios-Application of Factor Analysis in Turkish Construction Industry. *Building and Environment* [online], 42(1), 385-392. Available from: http://www.ccsenet.org/journal/index.php/ijbm/article/viewFile/24767/16350 [Accessed 6 May 2014].

Rahman, H.A., Takim, R. and Min, W.S., 2009. Financial-Related Causes Contributing to Project Delays. *Journal of Retail & Leisure Property* [online], 8(3), 225-238. Available from: http://www.palgrave-journals.com/rlp/journal/v8/n3/full/rlp200911a.html [Accessed 6 May 2014].

Ramus, J. and Birchall, S. 1996. *Contract Practice for Quantity Surveyors.* 3rd ed. Oxford: Laxtons.

Saunders, H., 1996. Survey of Change Order Markups. *Practice Periodical on Structural Design and Construction* [online], 1(1), 15-19. Available from: http://ascelibrary.org/doi/abs/10.1061/(ASCE)1084-0680(1996)1%3A1(15) [Accessed 6 May 2014].

Turner, D.F., 1983. *Quantity Surveying Practice and Administration*, London: George Godwin.

Turner, D.F., 1984. *Standard Contracts for Building*, London: George Godwin.

Zhao, Z.Y., Lv, Q., Zuo, J. and Zillante, G., 2010. Prediction System for Change Management in Construction Project. *Journal of Construction Engineering and Management* [online], 136(6), 659-669. Available from: http://ascelibrary.org/doi/abs/10.1061/(ASCE)CO.1943-7862.0000168 [Accessed 6 May 2014].

KNOWLEDGE MANAGEMENT STRATEGIES FOR SUSTAINABLE FACILITIES MANAGEMENT IN SRI LANKA

Sepani Senaratne*
School of Computing, Engineering and Mathematics, University of Western Sydney, Australia

N.S.D Abeysinghe and A.K Andaraweera
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

The profession of facilities management (FM) is becoming knowledge driven. In this regard, managing facilities managers' knowledge helps for sustainable outputs through the creation of supportive and cost effective physical environment that strongly supports the primary objectives of office buildings sector. This study attempts to bring in knowledge management insights into facilities management and explores strategies of managing facilities manger's knowledge. Case studies of three in-house FM teams occupied in three leading office buildings in Sri Lanka were used to approach the research problem. Data was collected using semi-structured interviews with three individuals from each case. The findings revealed that a wealth of knowledge is accumulated within a handful of FM practitioners as tacit knowledge in the form of experiences, intuitions and insights. Hence, a personalisation approach is preferred to a codification approach in managing FM knowledge within individual organisations and the profession as a whole. However, codification strategies are also suggested to complement the process in the long term due to the emerging nature of the profession and the need for transferring knowledge to future FM professionals. This research is of exploratory nature, which explored an emerging FM profession in Sri Lanka. Further research is required to fully understand how knowledge management concepts could be incorporated within FM professions worldwide for sustainable FM.

Keywords: *Case Studies; Codification Strategies; Facilities Management; Knowledge Management; Personalisation Strategies;*

1. INTRODUCTION

It is obvious that the secret behind returns on invested facilities lies upon proper and effective management of the built environment. Thus, the attraction of facilities management (FM) has become increasingly common as forward-looking organisations are beginning to realise FM as a function with clearly defined objectives and a strategic and commercially-oriented discipline (Pathirage *et al.*, 2008). Facilities Management is frequently described as "an integrated approach to operating, maintaining, improving and adapting the buildings and infrastructure of an organisation in order to create an environment that strongly supports primary objectives of that organisation" (Then, 1999. P.22). According to Atkin and Brooks (2000), FM services encompass broad and a large number of functions and roles towards a strategic concern. Nutt (2000) classifies these FM areas into four basic trails, in which one is identified as 'knowledge resource trail.' This trail reflects the growing importance placed on managing facilities knowledge as a strategic resource (Pathirage *et al.*, 2008). Bainbridge and Finch (2009) affirm this when they state that KM is permeating every aspect of FM role.

As far as KM is concerned, it is a process comprising of number of sub-processes such as knowledge sharing, capture, store and reuse. Robinson *et al.* (2004, p.735) provide a commonly cited definition for KM as, "any process of creating, acquiring, capturing, sharing and using knowledge wherever it resides, to enhance learning and performance in organisations." When applying this definition to FM, managing

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

FM knowledge could be seen as creation of FM knowledge; acquiring and sharing it; and, capturing and storing it for future reuse in the FM organisation. Hansen *et al.* (1999) identifies that organisations should focus on particular KM processes based on the nature of knowledge and mainly use two KM strategies namely codification and personalisation strategies to manage organisational knowledge resources. Since nature of knowledge is not well defined in FM context, what KM strategies are more applicable for FM is not well understood. This created the knowledge gap for this research and emerged the research question for the study. Accordingly, the research question that was developed for the study is 'what KM strategies would be applicable to KM considering the nature of FM knowledge?' Due to the evolving nature of FM profession in Sri Lanka, exploratory case studies were carried out to explore answerers to the research question. The key findings from the literature review are discussed next in this paper. BIM and its development

2. KEY FINDINGS FROM THE LITERATURE

FM is relatively a new profession in the built environment. There are very few FM experts in developing countries like Sri Lanka who has extensive knowledge and experience in the field of facilities management (De Silva, 2011). FM is a multidisciplinary profession, which demands to link various types of knowledge that is borrowed from various professional fields (Nutt, 2000). As FM matures, it needs to think more for itself, to develop its own contribution to management expertise, with less reliance on borrowed concepts and imported expertise from other professional fields of activity. To achieve this, all working in the FM field need to be collaborating to build an expert FM knowledge base with supporting methods, techniques and data structures (Nutt, 2000). These reasons trigger out the critical need and the importance of managing facilities manager's knowledge for the establishment and the development of the FM profession.

Knowledge is typically classified as either tacit or explicit. Tacit knowledge is highly personalised, which draws on the accumulated experience and learning of a person (Debowski, 2006). Explicit knowledge, on the other hand, is transmittable in formal, systematic language; and can be conceptualised and stored in information systems (Nonaka and Takeuchi, 1995). Approaches to manage these types of knowledge vary from organisation to organisation. Such approaches require the organisational optimisation of knowledge resources, such as human power, capital, and managerial efforts, to achieve enhanced performance through the use of various methods and techniques (Davenport and Prusak, 1998; Kamara*et al.*, 2002). Hansen *et al.* (1999) argued that there are basically two strategies for managing knowledge in organisational level. They term these strategies as "codification" and "personalisation." To Choi and Lee's (2003), these are either system-oriented or human-oriented approaches.

System orientation emphasises on codified knowledge, which focuses on codifying and storing knowledge via information technology where attempts are made to share knowledge formally. When knowledge is seen as a 'thing', codification strategies, which especially disseminate explicit knowledge through person-to-document approaches, are considered. On the contrary, human orientation emphasises on dialogue through social networks and person-to-person contacts, which focus on acquiring knowledge via experienced and skilled people and where attempts are made to share knowledge informally. Hansen *et al.* (1999) state that in certain companies, knowledge is closely tied to the person, who developed it and is shared mainly through direct person-to-person contacts. They viewed this as personalisation strategy. This strategy refers to personal development of tacit knowledge that is based on insights, intuition and personal skills for solving complex problems.

The codification knowledge management strategy in the context of facilities management should start with understanding critical knowledge management areas and then capturing and storing such knowledge for future reuse. Nutt (2000) emphasises that understanding what knowledge that facilities managers may need, use and create in the future is an important area for investigation for FM organisations to remain competitive. Kincaid (1994) describes that FM requires knowledge of both management and facilities in order to perform two roles as management role and operational role. These management concepts and operational expertise, closely link with management and the operational level knowledge explained by Chotipanich (2004).

FM knowledge that is critical for the successful operation of the two identified levels need be considered for codification. Nutt (2000) states that capturing knowledge from experts and feeding forward their experiences is vital to the future success of FM. However, capturing all FM knowledge is not worthwhile and possible. Therefore, consideration has to be given to identify most critical knowledge that is crucial for effective FM performance. On the other hand, knowledge that is captured and stored will be of no use if it is not re-used in future situations. Nonaka and Takeuchi (1995) define knowledge reuse as adaptation of explicit knowledge of successful practices to generate new and useful ideas. According to Markus (2001), reusing knowledge involves both recall (that information has been stored, in what location, under what index or classification scheme) and recognition (that the information meets the users' needs, as well as actually applying the knowledge). According to Nutt (2000), the areas where FM knowledge reuse will give its highest contribution are in managing facility operations and support services; managing facility use and performance; and, managing facility procurement and adaptation. Hence, codification strategies should be appropriately adopted to identify, capture and store FM knowledge.

However, Puddy *et al.* (2001), through their research that applied knowledge conversion theory in KM to FM, found that codified FM polices and standards are not helpful if they do not incorporate FM tacit knowledge. Hansen *et al.* (1999) show that tacit knowledge is best transferred through personalisation strategies than codification. Through effective personalisation strategies, it is believed that tacit knowledge embedded in FM experts could be transferred and shared within the profession. Egbu *et al.* (2003) describe several knowledge management techniques that facilitate personalisation strategy such as communities of practices (CoP), face-to-face interaction, discussion forums, post project reviews, seminars, apprenticeship, mentoring and training. Egbu (2012) mentions that for KM, the term ‘tools’ is used loosely and too often, KM ‘tools’ is used to mean only IT tools and ignore those tools mentioned under KM techniques that help in tacit knowledge sharing. It is clear that these techniques would facilitate the exchange of FM expertise. However, little is known on how above KM strategies could be effectively applied to facilities management. Hence, this research aimed to explore how KM strategies such as codification and personalisation could be effectively used to manage facilities management knowledge. The research method is explained next.

3. RESEARCH METHODOLOGY

This research took an exploratory nature and it required access to FM professionals, who could explain their views and experience. As such, case study has been selected for this research. In Sri Lankan office building sector, there are very few in-house divisions for facilities management, who are practicing FM in its full sense. Three such FM divisions in office buildings were selected for these case studies. Within one organisation, three professionals from the FM division were interviewed. The description of cases and professionals interviewed are given below.

Case A

With over 750,000 square feet of prime office and retail space, this organisation is an international business complex on par with premium grade buildings in major cities around the world. Built to the highest standards, this impressive landmark comprises two 39 storey towers connected by a 4 storey retail block. It has attracted prestigious local, international and multinational companies as tenants, making it the most sought after business address in Sri Lanka. With its prime location in the heart of the city in the Central Business District (CBD) and easy access to all main banks, major five star hotels, government offices, shops and the headquarters of some of the largest businesses, this towering business complex is Sri Lanka’s tallest and most impressive commercial landmark. Within this organisation, interviews were conducted with the facilities manager, assistant facilities manager and electronic engineer.

Case B

This organisation is a largest banking and financial services organisation. It has more than 32,000 skilled professionals operating out of 15 Group Service Centers present in five countries in Asia, including India, China, Malaysia, Philippines, and Sri Lanka. The service centre in Sri Lanka is managed by the business process outsourcing arm of the Group and it is occupied by the bank’s back offices service providing professionals within over 350,000 square feet. Interviews were made with the facilities manager, assistant facilities manager and the outsourced facilities manager in this organsiation.

Case C

This organisation is one of the leading government banks in Sri Lanka. This building is a 32 storied head office building with a total built up area of 600,000 square feet. It was constructed in 1987 to house all administrative offices, international division and corporate branch of the bank. Managing this building is done with the involvement of well qualified and experienced FM related professionals. Therefore, data has been collected from three key FM related professionals namely maintenance manager, human resource manager and the electrical and plumbing engineer.

While interviewing, note taking and tape recording (with permission of the interviewee) were performed to maintain the accuracy of data collection. The data gathered from the interviews were analysed by manual code-based content analysis. Finally, conclusions about the overall research problem were drawn by analysing the findings as described next.

4. RESEARCH FINDINGS

4. 1. FM KNOWLEDGE AREAS

Case studies highlighted that facilities, standards and culture of the organisation can significantly influence the FM practice. Therefore, only basic areas of knowledge can be identified common to any facility manager. Within these, the respondents in all cases highlighted the importance of Property management. Under property management, a respondent in Case A revealed importance of knowledge such as strategic property management, property acquisition, disposal of real property, risk management and lease management. Other critical knowledge areas as identified the interviewees include energy management, facilities maintenance along with conditions assessments, building services management and financial management. Overall, interviewees mentioned that a typical facility manager should possess knowledge on corporate objectives, support infrastructure, human resource management and skills such as communication skills, interpersonal skills and business skills (see Figure 1).

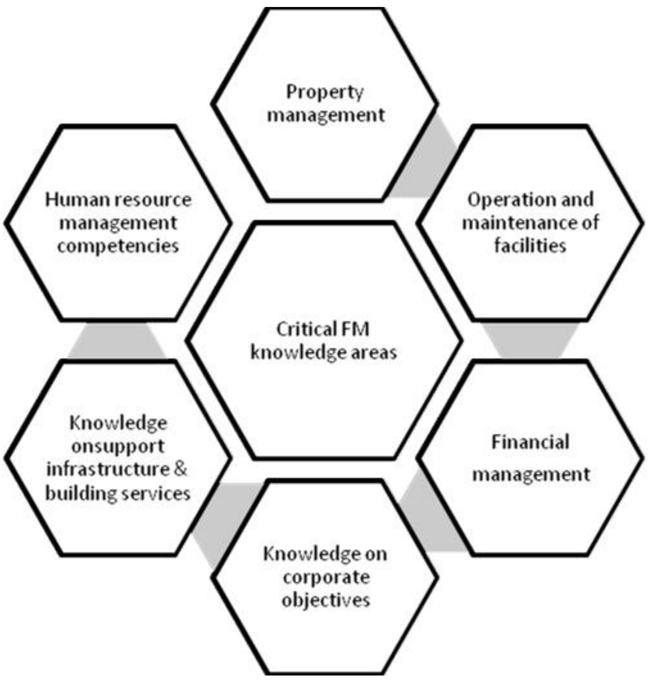


Figure 1: Critical Knowledge Areas of FM from Case Studies

Being consistent with the literature, case study findings revealed that generally, the facilities managers were performing two main integrated roles within their organisations as 'strategic role' and 'operational role'. The strategic role of the facilities managers was highly interrelated with the activities with the top-level management of the organisation while the operational role was highly associated with their own subordinates within the FM team. For each of these two roles, there were specific knowledge areas equipped by the facilities managers. Generally, the strategic role required more knowledge on management subjects than other knowledge areas for which they were expected to participate in making and implementing critical decisions to shape the future in relation to the goals achievement of the organisation. The operational role required more knowledge on technical, operational, regulations and legal aspects for which they participated in optimising workflows and usage while keeping down the operating cost of the building.

4 .2. USE OF CODIFICATION STRATEGIES

In terms of the requirement for codification, most of the respondents agreed that with time, FM would be challenged to build its own distinctive knowledge-base with supporting methods, techniques and data structures to underpin best practice (see Figure 2). For example, a respondent in case A stated, "*it is critical to have a knowledge base for the further development of the FM profession. However, entire knowledge cannot be stored, there is certain knowledge that is unique to a person and will die down with the person*." According to a respondent in case B, the good practices should be stored. A respondent in case C further elaborated these good practices such as reusing knowledge about what was done, how and why things were done and how this knowledge can be applied in other settings.

In the view of a respondent in case A, "*FM organisations have knowledge- intensive working environments, so it requires critically relevant knowledge to find flexible solutions and solve problems under tight deadlines*." A respondent in case C agreed on this when he mentioned the need for storing standards for the decision making of a facilities manager. At the moment, the documents both in hard and soft copies in the forms of manuals and service agreements provided them with a common FM knowledge. The individuals were reluctant to use IT based methods although the organisations provided them such methods. Intranet was used in certain situations while company websites with online forums were rarely used. It was noted that specific knowledge bases were not used by FMs. All the respondents in case studies highlighted that using knowledge as it is to achieve day-to-day FM functions will not be successful, because FM is a profession which involves facing different and novel situations in each and every day. Hence, they preferred personalisation strategies compared to codification.

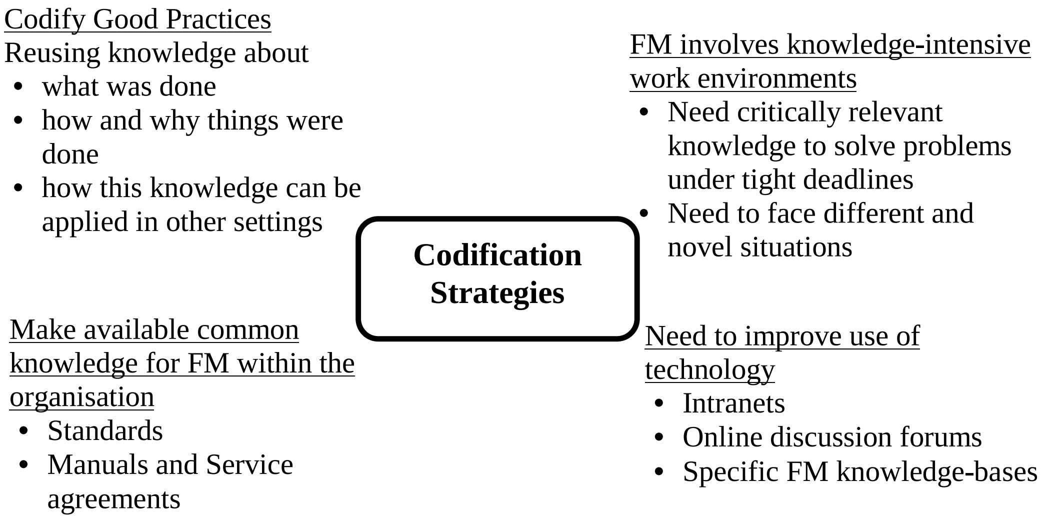


Figure 2: Codification Strategies for FM

4.3. USE OF PERSONALISATION STRATEGIES

Case studies revealed that a facility manager generally seek personal assistant from their peers or subordinates within their organisation favouring personalisation knowledge management strategies. See Figure 3 for a summary of the case studies' findings related to this. Face-to-face interaction with other members in the FM department was very common. Among formal sharing methods, the individuals' priority was given to meetings. Ad-hoc meetings were very common, which brought the team members together to discuss about FM subject matters. Post project reviews were another form where knowledge sharing took place between facilities managers. The organisations' investments in providing infrastructure for close interaction were at a good level. The formal and informal places and methods provided by the organisations were highlighted by the respondents. It was observed that these places and methods significantly contributed to promote personalisation strategies. As the individuals' workstations were arranged in a way that they exposed to each other, the physical work environment and the layout of work areas were encouraging this process.

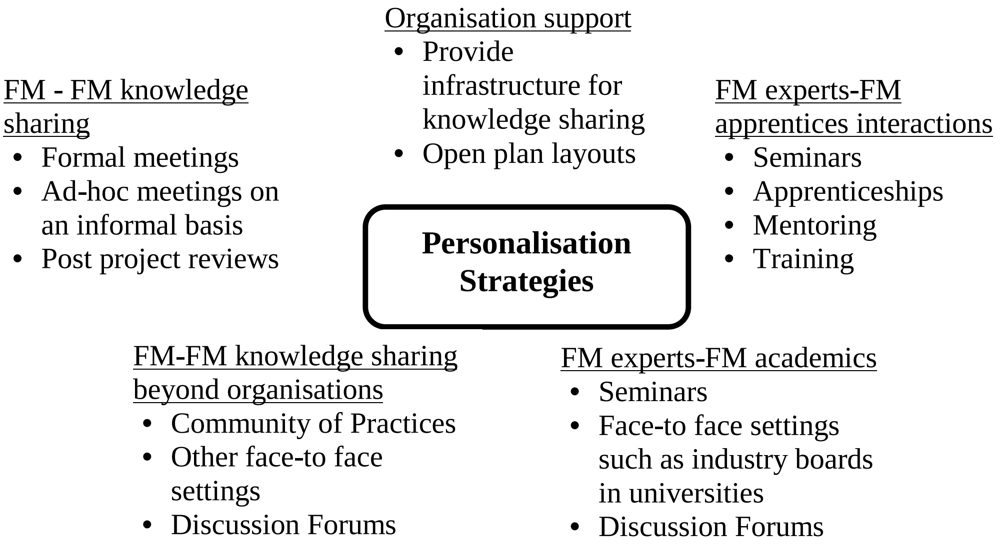


Figure 3: Personalisation Strategies for FM

In order to share FM expert knowledge through personalisation to other FM experts from different organisational settings Community of Practices (CoP), face-to-face interaction, and discussion forums were identified as more important than other techniques by the interviewees. For enhancing interaction between FM experts and apprentices, most suitable techniques mentioned were seminars, apprenticeship, mentoring and training. Similarly, to encourage the interaction between academics and FM experts, techniques such as face-to-face interaction, discussion forums and seminars were identified as the best techniques.

On the whole, the findings established that pioneer FM professionals hold a unique set of knowledge, which has been gained through facing new challenges and personal experience such as work practices, operational know-how, own opinions about the profession, success stories, best practices and insight about the industry. This unique knowledge is much critical to FM community in order to spread the profession in Sri Lankan context. The case study participants viewed the importance of having a collective body that could attend to FM knowledge development process. The areas that they highlighted in specific are listed below:

- Identify new strategic directions: exploring the changing priorities, potential scope, future functions and impact of FM
- Identify future performance imperatives: developing the basis for the next generation of property and facility performance criteria, management methods, operational procedures and decision techniques

- For policy and investment development: investigating the key property and FM issues for the future and the development of radically new approaches to investment and risk.

Overall, personalisation strategy is found more effective at present. However, codification strategies should also be in place towards the development of an ultimate FM knowledge base. Next section concludes the findings of this exploratory study.

5. CONCLUSIONS

The research findings confirmed that there is relatively a small number of facilities managers who operate in the local industry and most of their knowledge is almost locked in their heads. In fact, the existing knowledge management practices of a facilities manager in the building sector were unnoticed, unfamiliar and inefficient in its implementation. Hence, it would be important to use some codification strategies to mainly capture FM best practices, while it would be critical for organisations to store such FM knowledge, and provide access for future re-use. This will ease the heavy reliance on specific individuals and the possible knowledge loss when they leave the organisation. Overall, it is recommended that appropriate codification will be required for FM organisations possibly to initiate a knowledgebase that incorporates advanced FM practice experience; cross-sector benchmarking criteria; forecasts of key future FM issues and possible solutions; and, the distinctive features and functions of the facilities management.

More importantly, case study findings revealed the importance of people-to-people interaction in managing FM knowledge. KM techniques, which supports for people-to-people interaction should be carefully chosen and applied to gain benefits for the collective level FM parties. Since there are very few FM experts in Sri Lanka, absence of them would create a knowledge gap in the field of FM. Therefore, it is essential to disseminate knowledge that resides within FM experts to a wider community in order to maintain the consistency of the profession. It is recommended that this wider community should go beyond a single organisation to the industry level and connect three parties: FM experts, apprentices and academics. The interaction could be provided by an organised body such as an institution. Determining the knowledge requirements of the FM community and taking appropriate steps to manage FM knowledge within the FM community would be the key responsibilities of such an institution, in terms of managing FM knowledge industry-wide. Finally, Figure 4 captures the key findings of this study and their implications to sustainable facilities management in Sri Lanka.

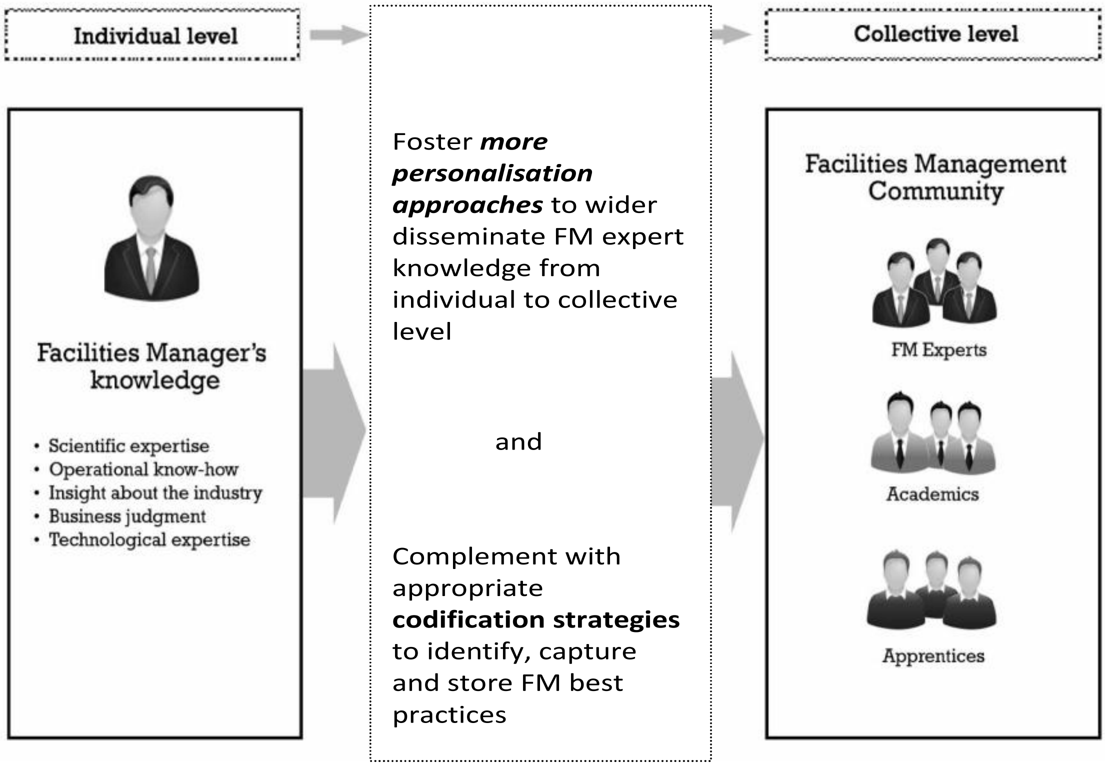


Figure 4: KM Strategies for FM

Further research is required to identify above aspects and to fully understand how knowledge management concepts could be incorporated within FM professions worldwide.

6. REFERENCES

Atkin, B. and Brooks, A., 2000. *Total facilities management.* Chichester: Blackwell Publishing.

Bainbridge, M. and Finch, E. F., 2009. Getting the attention the facilities manger deserves. *Facilities*, 27(7/8), 277-290.

Choi, B. and Lee, H., 2003. An empirical investigation of KM styles and their effect on corporate performance.*Information and management*, 40(5), 403-417.

Chotipanich, S., 2004. Positioning facility management.*Facilities*, 22(13/14), 364-372.

Davenport, T. and Prusak, L., 1998.*Working knowledge: How organisations manage what they know*. Boston: Harvard Business School Press.

Debowski, S., 2006. *Knowledge Management*.Sydney: Wiley.

De Silva, N., 2011. Promoting the facilities management profession in the project development phase of high-rise buildings in Sri Lanka.*Built - Environment - Sri Lanka,* 9(10), 37-44.

Egbu, C., Quintas, P., Anumba, C., Kurul, E., Hutchinson, V. and Ruikar, K., 2003. *Knowledge Production Resources and Capabilities in the Construction Industry –Work Package 3–Final Report* [online]. Available from: http://www.knowledgemanagement.uk.net/resources/kmfinalwp1.pdf [Accessed 20April 2014].

Egbu, C., 2012. Construction Innovation through Knowledge Management, in *Construction Innovation and Process Improvement.* Uk:Wiley Balckwell.

Hansen, M., Nohria, N. and Tierney, T., 1999. What's your strategy for managing knowledge?.*Harvard business review*, 77 (2), 106-116.

Kamara, J., Anumba, C. and Carrillo, P., 2002. A clever approach to selecting a knowledge management strategy.*International journal of project management*, 20(3), 205-211.

Kincaid, D., 1994. Integrated facility management.*Facilities*, 12(8), 20-23.

Markus, M., 2001. Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success. *Journal of Management Information System*, 18(1), 57- 93.

Nonaka, I. and Takeuchi, H., 1995. *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation*. New York: Oxford University Press.

Nutt, B., 2000. Four competing futures for facility management. *Facilities*, 18(3), 124-32.

Pathirage, C., Haigh, R., Amaratunga, D. and Baldry, D., 2008. Knowledge management practices in facilities organisations: a case study. *Journal of Knowledge Management*, 6(1), 5-22.

Puddy, F.R., Price, I. and Smith, L., 2001. FM policies and standards as a knowledge management system. *Facilities*, 19(14), 504-14.

Robinson, H. S., Carrillo, P. M., Anumbe, C. J. and Al-Ghassani, A. M., 2004. *Designing a business case for knowledge management: the IMPaKT approach*, 22, 733-743.

Then, D.S.S., 1999. An integrated resource management view of facilities management. *Facilities*, 17(12/13), 462-469.

LABOUR PRODUCTIVITY NORMS FOR ALUMINIUM SYSTEM FORMWORK IN LOW-COST HOUSING CONSTRUCTION PROJECTS IN SRI LANKA

S.J.A.R.S. Jayasinghe* and Nirodha Gayani Fernando
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In enhancing the living standards of the society advanced technologies can be used in gaining the labour productivity and competitive advantage. There the low-cost housing projects are facilitating a proper labour productivity adhering the effect of labour productivity factors. Thereby, Aluminium system formwork is a use of advanced methodology which enhance the labour productivity in low-cost housing projects while highlighting the significance and domain created within the industry.

Meanwhile, tendency of poor performance in Aluminium System Formwork is observed due to improper planning in high rise building construction. Consequently when maintaining productive advantage, productivity norms are number of labour hours required to complete a particular task while facilitating the efficient evaluation of labour performance in enhancing the merits of the Aluminium System Formwork. Hence, deficiency of researches have been done to establish particular standards or norms, this research aims at investigating the realistic measure of the labour performance for Aluminium System Formwork in low cost housing projects.

Accordingly, a case study was conducted using direct observations to prepare the labour productivity norms and collected data were analysed based on labour productivity factors. Finally conclusions were drawn and recommendations were put forward.

Findings proved the combination and varying effect of weather factors, crew factors, management and projects factors, site conditions represent different labour productivity norms in each four different occasions. Meanwhile within each occasion the effect of structural elements towards the norms is highlighted and facilities the realistic measurement of the labour performance in Aluminium system formwork while embossing low cast housing concept.

Keywords: *Aluminium System Formwork; Labour Productivity; Labour Productivity Factors; Labour Productivity Norms; Low Cost Housing Projects.*

1. INTRODUCTION

The construction industry plays a significant role in any developing country, promoting main human needs required in socio-economic development (Karim *et al.*, 2012). Meanwhile, in order to fulfil that Tam *et al.* (2004) suggested that, advance technological improvements play a vital role in achieving the speedy construction. Further, Durdyev and Mbachu (2011) pointed out that, in the industry level, the productivity enables the sector to maintain satisfied clients, attract investment, remain viable and contribute to the economic growth and well-being of the nation. Meanwhile, Cheetham and Lewis (2001) emphasized that, productivity can be increased by ensuring proper and efficient use resources such as, material, labour management expertise and capital. Among them labour productivity stands as a foremost measuring tool, since almost all the aspects of the construction industry are labour oriented (Mar, 1985). Furthermore, Moselhi and Khan, (2009) emphasized that, when focusing on formwork technology it has a direct impact on labour productivity. Additionally, Tam *et al.* (2004) declares that, formwork represents a significant part of the cost of concrete structure and following that concept, Urban Development

*Corresponding Author: E-mail - jruchini@yahoo.com

Authority of Sri Lanka has started urban regeneration projects in Colombo to eliminate shanties, slums and other dilapidated. Accordingly, Aluminium System Formwork has become the ideal cost effective tool for the mega housing projects with intension of obtaining the higher reputation and higher productivity (Mivan Aluminium formwork, 2012). Ultimately, by considering different factors, it is essential to have realistic estimates of expected labour productivity to plan and carry out labour-based work effectively (Stiedl, 1998). Therefore, AbouRizk and Dozzi (1993) stressed, labour norms are essential and act as a guideline for cost estimating and provide a logical and reliable consistent values which facilitate the planning and scheduling, resource planning, and risk assessment in the construction Therefore, the author further stressed that when determining a realistic norm productivity is very much critical .

When Aluminium System Formwork is concerned, it is one of the most economical, new technological approaches to maintain the site labour productivity, norms can be considered as an ideal yardstick to prove the effectiveness of the new system. Even though deficiency of researches have been done to establish particular standards or the norms to measure the labour productivity of the Aluminium System Formwork. Therefore a gap is found that, there was no standard to generate a clear idea about the actual and realistic measure of the site labour and their efficiency of using this system in the industry. Hence, the research problem has been identified as the necessity of appropriate norms for new formwork system related to Sri Lankan context, in providing the maximum out of this new technology and archiving a value for money

2. LITERATURE SYNTHESIS

In Sri Lanka, according to Samarathunge (2012), over $700 million worth of building construction is expected in next 5 years, driven by urban development and among them 40,000 low-income housing units project. Further, Ministry of Defence and Urban Development (2013) and Samaratunga, (2012) reported, government is targeting nearly 66000 housing units remarking the biggest relocation program for ever. CICRA Lanka (2011) and Wijesundara (n.d.) reported that, number of relocation of underserved settlement programs have been conducted by Urban Development Authority (UDA), to provide comfortable housing with relevant common amenities. Therefore, a great necessity has been arrived under the urban development plans in Sri Lanka to consider about the rehabilitation of low income populace in Colombo city and there, low cost housing projects play a significant role within the economical scope of poor majority.

2.1. CONSTRUCTION LABOUR PRODUCTIVITY

Wilcox *et al.* (2000, cited Enshassi *et al.*, 2007) has successfully elaborated that, for any profit oriented organisation improving productivity is a major apprehension with respect to effective and efficient conversion of resources into marketable products. Therefore the endeavour for defining, measuring and comparing the productivity has become a critical task. According to Chia *et al.* (2012), construction industry is an industry which depicts a core strategic importance due to its significant effect of level of productivity on national economic growth. Furthermore, CICRA Lanka (2011) supported as, in 2010 Sri Lanka`s Gross Domestic Product (GDP) growth was 8% when compared to 3.5% in 2009 and among that figure higher construction activity resulted in 12% growth in domestic production of building materials. Therefore, above statistical data emphasized that the economic boom in Sri Lanka has been significantly powered by the construction industry while gaining similar advances in accelerating the productivity growth. In achieving the economic growth, Karunatilake (2009) and Kazaz and Ulubeyli (2007) have emphasized, human resource can be identified as a key strategic resource in ensuring improved productivity. With the intention of that significance, Nasira *et al.* (2013) has figure out, the labour productivity as; ***Labour productivity = Actual work hours/Installed quantity*.** Therefore the labour productivity in the construction industry can be generalized as the physical progress achieved per unit of time period and the investigation about the factors in order to enjoy comparative advantages in international markets, which is domineering in a rapid changing nature in global environment.

2.2. *LABOUR PRODUCTIVITY NORMS*

Meanwhile Vliet (2011), has introduced a mathematical equations for labour productivity norm (LPN) as, ***"Number of labour hours (work effort) required to complete a defined construction activity, given the specific qualifications associated with each individual labour"***. Moreover according to Nes (n.d.) and Bastraw (2015) the LPN can be considered under the category of the Key Performance Indicator (KPI) which is typically used to measure individual and group performance and it is the amount of output per the number of hours worked per day, week or month while creating a time frame on which to base the inputs of the measurement. Therefore, estimating the correct productivity of the labour is critical and International Labour Organisation, Advisory Support, Information Services, and Training (ASIST) (1998), it is beneficial in re-measurement, for easy rectification of the employees, leads to maintain the required labour force, undergone the best work practice, using correct tool having minimum disturbances and mainly as a benchmark to facilitate standardization and efficient evaluation. Association for the Advanced Cost Engineering (AACE) International Recommended Practice (2004) has recommended, some methods of estimating the labour productivity by work study or the work sampling method where the number of direct observations are possible. Therefore, by using an appropriate measurement technique, and building up the suitable norms would become the dynamic measure of labour productivity and it drives towards the economic growth and living standards.

2.3. *FACTORS AFFECTING LABOUR PRODUCTIVITY*

Meanwhile Doloi (2008), also was able to build up a strong relationship between labour productivity and its changes, as changes or the variations are essential in the construction industry to improve the labour productivity and to build up accurate norms. Further to author, a single factor cannot affect the status of productivity to be high or low, but set variables or factors such as management, design, economic, social-psychological, labour, material, technological, environmental, administrative and organisational related factors and etc. which are interacting each other generate the final result. Hence, the necessity has been occurred to conduct a critical evaluation of the factors affecting the productivity in analysing and developing critical evaluation standards.

2.4. *NECESSITY OF LABOUR PRODUCTIVITY FOR LOW COST HOUSING PROJECTS*

Mainly the variations of the labour productivity have ability to generate a greater impact on national economy (Jayaweera, 1997). Moreover, Olotuath (2002) emphasised labour productivity has become the underlying goal of low cost housing projects. Better productivity can increase affordability by improving the quality of building work, and by reducing residential construction costs. When referring to residential construction costs especially for low income, materials, labour, subcontracted work, and other costs such as overheads and profit margins are concerned and the usage of prefabrication or modular components has been suggested as an effective mechanism to uplift building productivity and then facilities the reduction of cost for the housing projects (Olotuath, 2002). According to, Ministry of Federal Affairs (n.d.) and Richard (2014), cost efficiency is achieved through prefabricated standardized materials and tools, as reusable metal formwork. Consequently, through number of urban renewal programs Sri Lanka is attempting to empower the labour productivity, moving from the conventional building materials especially with respect to formwork systems in order to make the concept of "low-cost housing" a reality.

2.5. *DIFFERENT TYPES OF FORMWORK SYSTEMS USED IN LOW COST HOUSING PROJECTS*

Innovation in the building system and the techniques are required, towards better productivity in low cost housing projects (Richard, 2014). According to Huanga and Chenb(2004), since Concrete formwork is a labour-intensive and time-consuming operation, to facilities productivity and cost effectiveness, many modular formwork systems have been developed. According to Tam *et al.* (2005), and Construction Industry South Australia (2012), selection of appropriate formwork system facilitates speedy construction, maintain the smooth flow, and on the other hand Suryakant (n.d) emphasized, delivering good quality, cost effective, durable structure and good speed is highly demanded in housing sector. Therefore Elbeltagi *et al.*(2011), Common formwork system (n.d.), and Lyngcoln (1991) highlight that, suitable formwork system would dominate the success of the housing projects in terms of time, cost and quality. Meanwhile Rubaratuka (2013), Johnston (n.d.) and Smith and Hanna (1993) stressed that, the selection of formwork based on quality, safety, economy compatibility with architectural, structural and mechanical and maximum reusability is essentials. According to Formwork (n.d.), general classification based on materials such as timber, hardboard, steel aluminium, plywood used in low-cost housing projects in Sri Lanka depending on the required quality, cost and time.

2.6. THE EFFECT OF LABOUR PRODUCTIVITY FACTORS ON FORMWORK SYSTEMS

Baxi (2011) and Nemati (2007) describe that, cost of formwork is higher than the total cost of reinforcement and concrete material and labour and among formwork, greater portion of cost more towards labour. Further Smith and Hanna (1993), also proved that labour productivity has a higher influence on the formwork productivity and factors affecting the labour productivity have been used to examine their impact on formwork in Sri Lankan construction industry and it can be elaborated though Table 1 that the co-relationship with the labour productivity factors and the formwork types, while highlighting the requirements to be fulfilled to enhance the labour productivity through a proper formwork system.

Table 1: The Effect of Labour Productivity Factors on Formwork in Sri Lankan Construction Industry

Labour Productivity Factor	Effect on Formwork	Requirement for a Good Formwork System to Enhance Labour Productivity
Design Factors	It increase or decrease the time required for fabrication, erection and dismantling the forms. Further dimensions of walls jointing pattern, length of wall, surface finish, floor height and etc., highly concerns the quality of work	Time Saving and good quality output
Management Factors and Project factors	Site planning, construction process and site supervision and the interpretation ability of site supervisor for an effective communication with the labourers to reduce rework	Well documented instructions thereby time and cost saving
Buildability Factors	Average slab panel area within the floor, variability of beam sizes, repetition of floor layouts, floor area, beam to floor ratio, intersection of beams, percentage of curved beams; and percentage of nonrectangular slab panels in floors affects the buildability. Which resulting simplicity, uniformity, standardization, and repetition of elements on formwork labour productivity system and this can also be depend upon the material selected	Reusability, standardization and minimize repetition effect Faster and lower cost delivery of the product with the corporation of new technology
Site Conditions	Storage facilities, accessibility of site, underground pipe line and adjacent buildings need to be considered since it highly affect the security and maintenance of the formwork.	Lesser damage at site conditions, save space and time consuming for supporting, handling and maintenance
Crew Factors	Gang size labour percentage is more critical. Since depending on the number of skilled unskilled labourers and their age levels the time required for the construction may differ.	Properly trained labours
Weather Conditions	Temperature of the environment, humidity factor, wind speed and precipitation highly effects since depending on the material, those factors may affect the potential properties of the each formwork type	Material which is highly steady in the change of different weather conditions

Source: Tam (2004); Smith and Hann (1993); Nemati (2007); Jarka (2010); Jarkas (2012); Moselhi and Khan (2010)

2.7. SIGNIFICANCE OF THE ALUMINIUM SYSTEM FORMWORK IN THE SRI LANKAN LOW COST HOUSING PROJECTS COMPARED TO CONVENTIONAL FORMWORK SYSTEM

Wijesekara and Gunathilaka (n.d.), thoroughly mentioned that, in terms of speed, quality and safety of the formwork system used, nearly 40% of the cost of structure, 60 % of time, success of the construction project can be determined. Huanga and Chenb (2004) also highlighted that, modular formwork systems have become the optimum solution to improve the productivity and the cost effectiveness. Further Sattigari*et al.* (2007), also pointed out that amongst various alternatives used at mass housing construction, Aluminium system formwork is in the highest position. Basically, according to Suryakant (n.d.), under the parameters of cost, time quality as well as quantity conventional and the Aluminium formwork system is compared firstly according to the Table 2.

Table 2: Compare and Contrast the Aluminium System Formwork with the Other Conventional Formwork System

Requirement	Conventional (Timber and Plywood)	Aluminium System Formwork
Quality	Normal- Sometimes good quality cannot be achieved when dismantling	Superior- In-situ casting of whole structure using controlled concrete mixers, places and compacted in leak proof moulds using high frequency vibrators
Speed of Construction (Time)	Due to step by step completion of different stages Erection of formwork is done in the site as well as concreting and de-shuttering take a long cycle nearly two weeks and then only plastering and other finishing activities can commence	In a one continuous operation the walls and floors are cast together and enable removal and re-use of forms on daily cycle basis due to special in built accelerated curing overnight
External Finishes	Finishing- Painted with cement based needs every in three years, since plastering needed to be done.	Finishing- No need of frequent repainting. Textured concrete fascia can be provided
Maintenance	The major expenditure is involved due to; plaster of walls / ceiling etc., require repairs and maintenance. Outer and inner walls painting Leakages occurred in plumbing and sanitation installation.	Concrete repairs for plastering and leakage's are not at all required due to the walls and ceiling being smooth and high quality
Requirement of Labour	Extensive labour requirement	Less skill labour requirement, due to standardized and simple installation
Installation Procedure and Reusability	Maximum 5 or 6 times, since the shuttering can get damaged when de-shuttering.	Facilitating less material wastage can be reused over and over within or between projects with more effectiveness and standardized and simple installation procedure
Safety	Need remove props when dismantling slab panels	Not necessary to remove props when dismantling slab panel

Source: Common Formwork System (n.d.); Hanna (1999); Huanga and Chenb (2004); Kumkang Kind Co.Ltd. (2011); Wijesekara and Gunathilaka (n.d.); Rahim and Haron (2013)

Significance of system formwork is identified by Wijesekara and Gunathilaka (n.d.) as very much economical type of formwork used in high-rise buildings and in Sri Lankan context it is feasible to be used in low cost housing projects. Further, Man (n.d.), clearly pointed out that the major highlighted difference in between Steel and Aluminium is, Aluminium is lightweight but the steel panels are heavy weight and when considering the cost, aluminium would be more economical and suitable to support the low cost housing concept, and specifically Aluminium system formwork has its own authority for high-rise and typical apartment, housing construction.

2.8. SIGNIFICANCE OF ALUMINIUM SYSTEM FORMWORK WITH RESPECT TO THE LABOUR PRODUCTIVITY

In obtaining labour productivity in low-cost housing projects, the uniqueness of the Aluminium system formwork is highlighted by Prasanth (n.d.) and has stressed that, urbanization, increasing housing demand cannot be fulfilled using conventional materials since, limited quality, slow process Ultimately Suryakant (n.d.) exaggerated that, Aluminium system formwork is advanced, fast, simple and adoptable for mass housing construction and provides a total quality work with planned complete methodology to enhance the labour productivity. Therefore, it is very much crucial to select the best choice of formwork which is compatible with the building structure with a more collaboration between all the stakeholders. Therefore, AACE International Recommended Practice (2004) suggested, measuring and tracking work hours for a particular working elements and building up norms allows to determine the root cause poor labour productivity. In the meantime, Gatti*et al.* (2013) found that Aluminium system formwork found somewhat unsuccessful in achieving the potential productivity advantage, due to lack planning in high rise construction. Even though, the literature vastly describes the above topic still remains two questions as “what is the actual importance of a norm with respect to the labour productivity analysis?” and “how to build up the labour productivity norms for the Aluminium System Formwork to analyse its productivity?”. The data collection and analysis should be done in order to find the answers to these problems.

3. RESEARCH METHODOLOGY

Tellis (1997) emphasised that, when a holistic and in-depth investigation is in needed, the case study is an ideal research approach under quantitative methodology. Therefore, in order to accomplish the aim of this research as to investigate the realistic measure for the labour productivity for Aluminium System Formwork used in low cost housing projects, sensitive observations of the human behaviour has been used under the case study approach. In case study design two main aspects were considered as identification of unit of analysis and selection of cases. The unit of analysis in this research is the labour productivity norms for the Aluminium system formwork and it was within the boundary of low-cost housing projects in Sri Lanka. Under the selection of cases, only the 4 available low cost housing projects having Aluminium System Formwork in Colombo were selected and the study was limited to the preparation of productivity norms only for the selected structural elements such as slabs, beams and columns, by conducting time studies. There the collected data under the direct observations by observing the time duration for labour work done in a selected area were analysed statistically using the mean value of the numerical figures and eventually detailed cross case analysis is done in establishing the labour productivity norms.

4. ANALYSIS AND RESEARCH FINDINGS

Four low cost housing projects were selected in Colombo using Aluminium system formwork. Out of four, three projects have already finished the structural work and only one project is running at the later part of the structural work. Table 3 indicates the general information about the projects. Therefore due to the time restrictions and resource availability.

Table 3: Summary of the Cases

Description	Case 1	Case 2	Case 3	Case 4
Type	Low cost housing projects / Urban Regeneration Projects in City of Colombo for underserved settlements			
Employer	Government - Urban Development Authority			
Condition	Work is on progress	Nearly Completed	Nearly Completed	Nearly Completed
ICTAD Grading	C1	C1	C1	C1
	For building works			
Duration	24 Months	24 Months	30 Months	24 Months
Contract Price	Rs. 2.18 Billion	Rs. 1.36 Billion	Rs. 2.89 Billion	Rs. 915 Million
Floors	12	12	12	12
Work Status	ASF on progress	Aluminium system formwork have already been used		
Data Collection	Direct observation- Time study	Document review		

4.1. *CONDUCTING DOCUMENT REVIEW AND DIRECT OBSERVATION*

At the time of the data collection, only one case was remaining with the ongoing superstructure to observe the procedure going on with Aluminium System Formwork. Therefore due to the time restrictions and resource availability it was decided to carry out the document review for three cases and direct observation for the remaining case which was the only case available in line with the requirement. There the document review was conducted using the site labour attendance documents and the measurement sheets available at site regarding the Aluminium System Formwork labour work done for a particular month. The observed date were entered to the observation sheet and then finalised in the checklist while keeping time allowances for performance rating and (Performance, Fatigue, Delay) PFD allowance. Thereafter, number of labours (Skilled and unskilled) in each task were multiplied by the total time allowed for the each task. After calculating the related areas to particular item, labour productivity norm was calculated.

4.2. *COMPARISON OF THE FINDINGS IN DOCUMENT REVIEW AND DIRECT OBSERVATIONS*

Under the time restrictions, document review had been done for Cases 2, 3 and 4 where, for Case 1, the time studies have been done. Therefore, arrived labour productivity norms in both methods were compared and a remarkable deviation was highlighted since the results generated through the process of document review were considerably lesser than the labour productivity norms which were achieved through the direct observations. Therefore, the analysis of labour productivity norms in an advanced manner were emphasised as essential in the detailed analysis.

4.3. *DETAILED ANALYSIS OF THE TIME STUDY RESULTS BASED ON THE EFFECT OF LABOUR PRODUCTIVITY FACTOR*

In depth analysis was done for the varying effect labour productivity factor time studies.

Weather Condition

In a fair weather condition, increment in the labour productivity can be observed. Whereas the mix of all weather conditions results vast deviations of labour efficiency. The impact of the weather conditions in transporting, erecting, dismantling, fasting jacks and aligning the elements, implied that heavy rains had not affect the tasks in a considerable manner. Whereas the average labour productivity norm had been increased gradually especially upper floors due to the impact of the wind speed.

Crew Factor

Gang head`s involvement especially for the levelling, alignment and setting out activities and the proper labour mix, geared the labour efficiency in to a higher level. Experience and skills are critically important, for this systematic process and teamwork, cooperativeness is essential to follow the order properly while saving time and enhancing labour efficiency.

Management and Project Factors

Supervision is needed in planning the site schedule and it is highlighted, that the less supervision for the activities is one of the major issues. Apart from that in planning some concurrent activities was impacted such as concreting activities. Further, the delays in proceeding activities such as reinforcement fixing, cleaning concreting and scaffolding work create a large effect.

Site Conditions

In time studies 3 and 4, labours were not used safety belts when transporting the panels due to the improper mechanism in ensuring the safety at site and lack of site supervision and delaying in scaffolding work. Moreover, the labour facilities and site security was in an averaged manner. Consequently, the analysis concluded that not only a single parameter or factor, but also a combine effect of the several parameters in different factors had contributed the considerable deviations in labour productivity norms.

4.4. DETAILED ANALYSIS OF THE TIME STUDY RESULTS IN STRUCTURAL ELEMENT BASIS

The in-depth study was done considering the structural elements such as columns, beams and slabs. Therefore, the results obtained through each time study based on structural elements illustrated in Figure 1.

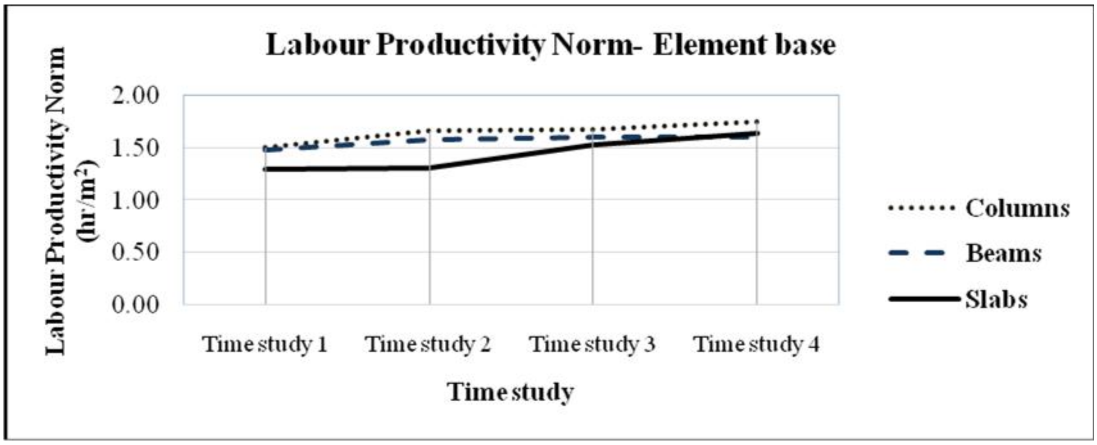


Figure 1: Element Base LPN

According to Figure 1, a slight deviations among columns, beams and slabs was identified and it is clear that some hidden factors creating a deviation for norms arrived in each structural elements. Therefore, following factors identified as critical such as; initial setting out, effect of fixing points, need of supports or props, necessity for alignment, gang head`s involvement in alignment, effect from handling panels, effect of re-fixing, and arrangement of the element and it is notified that, depending on the columns alignment all the other structural elements stand. Therefore it is clear that a considerable effect can be identified through a an element base comparison which provides a strong evidence for the necessity of in depth analysis since some element base factors are unique compared to conventional formwork. Moreover the labour efficiency also based on the labour mix, time spent for each task, the ratio between areas observed for each element. Further, when productive work, non-productive work and supportive work inherited were measured, in each element the productive labour hours had been increased whereas in non-productive and supportive labour hours were divided in nearly same amounts while proving the need of supportive labour hours relating to the main tasks. Therefore, proper balance in the productive and non-productive labour hours critically resulted in labour efficiency. Ultimately, in different conditions the effect of labour productivity factors and differentiating effect of structural element on labour productivity norm had been identified as more critical. Whereas slight deviations need to be considered on the basis of the factors which make unique, the element among other elements and to have a realistic outcome for the labour performance both.

4.5. PREPARATION OF LABOUR PRODUCTIVITY NORMS (LPN)

Based on the analysis in each time study, labour productivity norms had been prepared for four different occasions, to provide a realistic outcome for the labour performance for the Aluminium system formwork.

- ***Step 1 -*** Each element generate the different labour performances even within the situation where the same conditions were applied.
- ***Step 2 -*** Having considering the factors related to the each element labour mix and the ratio between the areas of each elements are considered maintaining the labour mix by 50 % in-between skilled and unskilled within each element create an average labour performance while correlating with the other factors identified in each element.
- ***Step 3 -*** Thereby, having considering the each element and there differencing characteristics, the varying effect of the labour productivity factors need to be considered in different occasions.
- ***Step 4 -*** All these four occasions demonstrated, the changing sequence of the labour productivity factors and its impact to the labour productivity norm shown in Table 4 and it must be notified that this significant change had been clearly identified in each occasion and thereby with a thorough analysis a realistic figures had been obtained.

Table 4: Four Different Occasions Identified

STEP 4	**Occasion 1**			**Occasion 2**			**Occasion 3**			**Occasion 4**		
Characteristic	▪ fair weather condition ▪ good combination ▪ supervision and corporation of the labours ▪ average planning sequence better site supervision ▪ average site conditions prevails such as site safety and security			▪ an average weather condition specially sunny day with cloudy sky, ▪ average combination, ▪ lesser corporation of the labours as a team, average planning sequence ▪ site supervision exist , average site conditions including site safety and security			▪ poor weather conditions (sunny weather to heavy rains as a mix. ▪ average crew factors poor gang head`s involvement. ▪ poor planning sequence ▪ poor site conditions specially the safety factors.			▪ poor weather condition (mix of all the effects) ▪ having lesser experience and lack of team spirit, ▪ poor site management and lack of site safety poor site condition		
Element	**Column**	**Beam**	**Slab**	**Column**	**Beam**	**Slab**	**Column**	**Beam**	**Slab**	**Column**	**Beam**	**Slab**
Avg. LPN (hr/m^2) for occasion	1.42	1.42	1.42	1.53	1.53	1.53	1.60	1.60	1.60	1.67	1.67	1.67
Avg. LPN (hr/m^2) Element	1.50	1.49	1.29	1.66	1.56	1.38	1.67	1.67	1.53	1.74	1.65	1.63
% of Deviation	5%	4%	10%	8%	2%	10%	4%	0%	4%	4%	2%	2%

Table 4 clearly depicts that when the severity of the occasion is high the LPN arrived are high compared to the calm situations like in occasions 1 and 2. For the occasion 1, the average LPN is 1.49, since it inheriting a better advantage where in any kind of a project can adopt with higher level of labour efficiency. Meanwhile the LPN has been changed accordingly with the element indicating 1.50 for the columns and 1.29 for slabs depicting the different productivity levels which can be achieved in each element within the same occasion. Other than that when occasion 2 is considered it too contains the same characteristics but clearly shown the deviations which can be addressed due to the effect of Crew factors. Since the average figure has been taken as 1.53 compared to occasion 1. Occasion 3 has been created addressing the shortcomings of the weather, management factors and accordingly 1.60 average figure can be obtained and as the finally occasion 4 is defined as a situation where lesser amount of labour efficiency leading the worse impact of the labour productivity factors and having a 1.67 average labour productivity. There it had been shown how the element wise figures changed accordingly based on the productivity levels of the element and the finds clearly adopt the percentage deviations between the figures of average labour productivity norm and the labour productivity norms for each element. Thereby the LPN can be taken in to practise where the element wise deviation can be maintained within the given percentage level from the average LPNs in different occasions.

5. CONCLUSIONS

In order to sustenance the concept of the low-cost housing projects, better labour productivity can be thoroughly taken in to consideration. Since the better productivity automatically enhanced the affordability, improve quality and save the time as well. Therefore, an appropriate formwork system was one of the ideal creature in facilitating the concept of low-cost housing and the impact of labour productivity factors such as weather conditions, design, buildability, site, management and project factors and crew factors were need to be considered. Specifically the direct relationship between labour productivity factors and the productivity of the formwork enhance the importance of using formwork as a material to achieve the expectable productivity.

Eventually, Aluminium system formwork is heavily used in Sri Lankan low-cost housing construction projects, due to its systematic and advanced procedure compared to conventional formwork. Further, a positive effect towards labour productivity factors in Aluminium System Formwork and a considerable incensement in labour productivity were highly beneficial in achieving the objectives of parties in the contract. Therefore, Aluminium system formwork had been accepted by the Sri Lankan construction industry as the easiest and most suitable advanced method in obtaining the best of labour productivity thereby, the introduction of a proper labour productivity norm under the elemental basis in a position of addressing the incensement of the labour productivity, facilitating the project planning and management, standardization and efficient evaluation generated a clear picture for the construction practitioners regarding the labour productivity while investigating the in-depth analysis of the characteristics of each element.

When building up labour productivity norms, it indicates the differences in each elements while considering the fluctuating effect of the labour proactivity factors. Further the labour productivity norms for Aluminium system formwork was targeting at the planning stage of the construction activates and also in estimating procedures for all the parties interested. Here, in element wise consideration and critical analysis of the labour productivity factors in different occasions elaborated that varying effect of the LPN in each occasion and each element is mainly due to the factors differentiating each structural element such as initial setting out, effect of fixing points need of supports or props, necessity of alignment, arrangement of the element and etc. Furthermore when building up mores to measure the labour productivity labour mix and the ratio between the areas covered under each element need to the thoroughly considered. Thereafter occasional deviation can be highlighted due to the varying effect of the labour productivity factors, such as weather conditions, crew factors, management and project factors and site conditions due to unforeseeable circumstances since the slight can of those can provide the ultimate outcome totally deviated from each other thereby a realistic measure, can be obtained for the construction labour performance for Aluminium system formwork to facilities the concept of time cost and quality product while embossing the low cost housing concept as another beneficial pathway for its stakeholders, when adopting the advanced nature of the technological outcomes.

6. REFERENCES

AACE International Recommended Practice, 2004, January. *Estimating lost labour productivity in construction claims* (Publication No. 25R-03) [online]. Available from: http://www.aacei.org/non/rps/25r-03.pdf [Accessed 17 April 2014].

AbouRizk, S.M. and Dozzi, S.P., 1993. Productivity in construction. *National Research Council*[online]. Available from: http://www.nrc-cnrc.gc.ca/irc [Accessed 17 April 2014].

Baxi, C.K., 2011. Formwork - a concrete quality tool. In: *36th Conference on our World in Concrete & Structur,* Singapore 14 - 16 August 2011.CI-Premier Pte. Limited,:Ghent University,58-59.

Cheetham, D.W. andLewis, J., 2001. Productivity, buildability and constructability: is work study the missing link?. In: *17th Annual ARCOM Conference*. 5-7 September 2001. Association of Researchers in Construction: University of Salford..

Chia, F. C., Skitmore, M., Runeson, G. and Bridge, A., 2012. An analysis of construction productivity in Malaysia. *Construction Management and Economics,* 30(12), 1055-1069.

CICRA Lanka and ICRA Management Consulting Services Limited, 2011. *Construction 9/1/2011* [online]. Available from: http://www.icralanka.com/Sri%20Lanka%20Construction%20-%20Sept%2015%20final.pdf [Accessed 20 February 2014].

Common formwork Sysytem, n.d. *Common Formwork System* [online]. Available from: http://www6.cityu.edu.hk/construction_archive/major_reference_pdf.aspx?id=124 [Accessed 12 March 2014].

Construction Industry South Australia, 2012. Industry guide for formwork [online]. Available from: http://www.safework.sa.gov.au/contentPages/docs/formwork_guide.pdf [Accessed 23 March 2014].

Doloi, H., 2008. Measuring productivity in the construction industry. *Construction Management and Economics, 26*(8), 841-854.

Durdyev, S. and Machu, J., 2011. On-site labour productivity of New Zealand construction industry: Key constraint. *Australasian Journal of Construction Economics and Building,* 11(3), 18-33.

Elbeltagi, E., Hosny, O. A, Elhakeem, A., Abd-Elrazek, M. E. and Abdullah, A., 2011. Selection of slab formwork system using fuzzy logic. *Construction Management and Economics*, 29, 659-670.

Enshassi, A., Mohamed, S., Mustafa, Z.A. and Mayer, P.E., 2007. Projects in the Gaza strip. *Journal of Civil Engineering and Management,* 8(4), 245-254.

Formwork, n.d. *Guide to concrete construction* 15.1-15.15 [online]. Available from: http://www.ccanz.org.nz/files/documents/20f91a78-0489-40f8-911d-b36c66c9f085/Chapter%2015%20-%20Formwork.pdf [Accessed 19 March 2014].

Gatti, U.C., Migliaccio, G.C., Bogus, S. M. and Schnei, S., 2013. An exploratory study of the relationship between construction workforce physical strain and task level productivity. *Construction Management and Economics*,32(6), 548-564.

Hanna, A.S., 1999. Concrete formwork systems (Report No.2). Madison, Wisconsin: University of Wisconsin-Madison, Civil and environmental engineering series [online]. Available from: http://www.dekker.com [Accessed 02 April 2014].

Huanga, R. and Chenb, J., 2004. Planning gang formwork operations for building construction using simulations. *Automation in Construction,* 13, 765-779.

International Labour Organisation, Advisory Support, Information Services, and Training (ASIST), 1998. *Productivity norms for labour-based construction* (Technical Brief No. 3) [online]. Available from: http://www.ilo.org/public/english/employment/recon/eiip/download/prod_norms.pdf [Accessed 17 March 2014].

Jarkas, A.M., 2010. Buildability factors affecting formwork labour productivity of building floors productivity of building floors. *Can. J. Civ. Eng*., 37, 1383-1394.

Jarkas, A.M., 2012. Factors influencing power-trowelling productivity of concrete surface floors. *Journal of Engineering, Design and Technology,* 10(1), 34-51.

Jayaweera, K.I. P., 1997. *A factor model for macro level productivity in Sri Lanka.* Unpublished Dissertation (Bsc.). University of Moratuwa, Moratuwa, Sri Lanka.

Johnston, D.W., n.d. Design and construction of concrete formwork. *Concrete construction engineering handbook,* 7.41-7.51..

Karim, N.A., Hassan, S., Yunus J., andHashim J., 2012. Factors influence labour productivity and the impacts on construction industry. *Caspian Journal of Applied Sciences Research*, 349-354..

Karunatilake, C.P.A., 2009, July. Trends in labour markets and future challenges. The experience of Sri Lanka. *Centre for banking studies central bank of Sri Lanka Rajagiriya..*

Kazaz, A. andUlubeyli, S., 2007. Drivers of productivity among construction workers: A study in a developing country. *Building and Environment*, 42(5), 2132-2140.

Kumkang Kind Co. Ltd., 2011. Kumkang kind aluminium formwork system [online]. Available from: http://www.gokulconstruction.com/wp-content/uploads/2011/09/Kumkang-Kinds-Aluminium-Formwork.pdf [Accessed 15 March 2014].

Lyngcoln, K.J., 1991. *Plywood in concrete formwork* [online]. Available from: http://www.ewp.asn.au/library/downloads/ewpaa_plywood_in_concrete_formwork.pdf [Accessed 02 March 2014].

Man, R.W.W., n.d. *Application of formwork for high-rise and complex building structures*: [Lecture notes] [online]. City University of Hong Kong, Division of Building Science and Technology, Hong Kong.

Mar, D., 1985. *Operation and industrial management-designing and managing for productivity*. New York, NY: McGraw-Hill book company.

Ministry of Defence and Urban Development - Democratic Socialist Republic of Sri Lanka, 2013 [online]. *Colombo low income housing projects nearing completion*. Available from: http://www.defence.lk/new.asp?fname=Colombo_low_income_housing_projects_nearing_completion_20130828_04 [Accessed 12 April 2014].

Ministry of Federal Affairs, n.d.*Low-cost housing technical manual*[online].Available from: http://cd3wd.com/data/1003_core_vet_vocat_/_co_lowcost_housing_manual_72pps_h4258e_en_125270_.pdf [Accessed 11 April 2014].

Mivan (Alluminium formwork), 2012, February. *Construction updates* [online]. Available from:http://constructionduniya.blogspot.com/2012/02/mivan-aluminium-formwork.html [Accessed 11 April 2014].

Moselhi, O. and Khan, Z., 2010. Analysis of labour productivity of formwork operations in building construction. *Construction Innovation*, 10(3), 286-303.

Nasira, H., Ahmeda, H., Haasa, C. and Goodrum, P.M., 2013. Differences between Canada and the United States [online]. *Construction Management and Economics.* Available from: http://dx.doi.org/10.1080/01446193.2013.848995 [Accessed 11 April 2014].

Nemati, K.M., 2007. *Formwork for concrete*[online]. Washington, USA: University of Washington, Department of Construction Management. Available from: http://courses.washington.edu/cm420/Lesson1.pdf [Accessed 15 April 2014].

Nes, H.V., 2015. *Performance Improvement from Measurement to Action Key Performance Indicators and Key Exception Indicators* [online]. Available from: http://www.consider.biz/wp-content/uploads/2013/09/Performance-Improvement-from-Measurement-to-Action-KPIs-KEIs.pdf [Accessed 15 January 2015].

Olotuah, A.O., 2000. Recourse to earth for low-cost housing in Nigeria. *Building and Environment*, 37(2002), 123- 129.

Prasanth, S., n.d. *Aluminium form work system*[online]. Grand Edifice Developers. Available from: http://files.hostgator.co.in/hostgator181958/file/aluminiumformworksystemintro.pdf [Accessed 08 May 2014].

Rahim, M.S.M. and Haron, N.A., 2013. Construction cost comparison between conventional and formwork system for condominium project [online]. *IJASCSE International Journal of Computer Science & Engineering*, 2(5).

Richard, R., 2014. Looking for an optimal urban residential building system?. *International Journal of Construction Management*, 5(2), 93-103.

Rubaratuka, I.A., 2013. Influence of formwork materials on the surface quality of reinforced concrete structures [online]. *International Journal of Engineering and Applied Sciences*, 4(5), 31-34.

Samaratunga, T., 2012.Appropriate housing solutions for low income groups in Colombo city[online]. *The Sundy Times*. Available from: http://www.sundaytimes.lk/120318/BusinessTimes/bt41.html [Accessed 04 April 2014].

Sattigari, N.R., Mahalingam, A. and Thomas, G., 2007. Automation of scheme preparation and BOQ calculation for L&T-aluform [online]. *24th International Synposium on Automation & Robotics in Construction (ISARC 2007) Construction Automation Group, I.I.T. Madras*, 274-280.

Smith, G.R. and Hanna, A.S., 1993. Factors influencing formwork productivity. *Can. J. Civ. Eng.*, 20, 144-153. doi:10.1139/l93-015

Stiedl, D., 1998. Productivity Norms for labour-based construction [online]. *Institutional labour organisations Zimbabwe: ASIST technical team in Harare.* Available from:http://www.ilo.org/public/english/employment/recon/eiip/download/prod_norms.pdf [Accessed 12 March 2014].

Suryakant, P.D., n.d.Emerging trends in formwork - cost analysis & effectiveness of Mivan formwork over the conventional formwork [online]. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 27-30. Available from:www.iosrjournals.org [Accessed 08 April 2014].

Tam, C.M., 2004. Selection of vertical formwork system by probabilistic neural networks models [online]. *Construction Management and Economics*, 23, 245–254. Available from: http://www.tandfonline.com/doi/abs/10.1080/0144619042000205912 [Accessed 04 April 2014].

Tam, C.M., Tong, T.K.L., Lau, T.C.T. and Chan, K.K., 2005. Selection of vertical formwork system by probabilistic neural networks models. *Construction Management and Economics*, 23(3), 245-254.

Tellis, W., 1997. *Application of a case study methodology. The qualitative report* (Report No. 3) [online]. Available from: http://www.nova.edu/ssss/QR/QR3-3/tellis2.html [Accessed 11 April 2014].

Vliet, M.S.J., 2011. DACE labor productivity norms - The new “gulf coast” ? [online]. In *Proceeding of 2011 AACE International Transactions*. Available from: http://www.costandvalue.org/download/?id=2050 [Accessed 17 April 2014].

Wijesekare, D.M. and Gunathilaka, W.D.A.D., n.d.*Cost Effective and Speedy Construction for High-Rise Buildings Using System Formworks.* Available from: http://www.civil.mrt.ac.lk/conference/ICSBE2012/SBE-12-242.pdf [Accessed 12 April 2014].

Wijesundara, J., n.d.Towards planned urban renewal: comparative approaches in Germany and Sri Lanka [online]. *SLiA Journal, 103*(4), 19-25. Available from: http://dl.nsf.ac.lk/bitstream/1/8537/2/SLA-103(4)-19.pdf [Accessed 08 April 2014].

MINIMISING VARIATIONS IN LUMP SUM CONTRACTS

N.H.A. Sampath, P.A.P.V.D.S. Disaratna and M. Francis*
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Construction industry is large, complex and uncertain in nature. Thus, variations have become an inevitable situation in construction projects irrespective of the type, size and complexity. This research therefore focuses on lump sum projects which account for a significant amount of variations in Sri Lanka. The research aimed at investigating the nature of variations in lump sum projects, significant effects of variations and the means of minimizing variations.

Semi-structured interviews and questionnaire survey were carried out to investigate the research phenomena. The professionals who involved in variation handling of lump sum projects were taken for collecting data. The results through questionnaires were analyzed using RII and interviewee outcome were analyzed using content analysis. It was found that there are a number of factors contributing to variations in lump sum contracts. The variations occur very often during the design stage of projects. The research findings revealed that delay in completion of project, increase in project cost, rework and demolition, quality standards enhancement and delay in payments are the most significant effects of variation. The research emphasized that identification of client's requirements is essential to minimize variations within the project.

The research recommended freezing design, preparation of detailed project brief, conducting comprehensive site investigations, involving owner at planning and design stage and reducing contingency sum could minimize the occurrence of variations. Further, the current study enables the professionals to assess and take proactive measures to mitigate the adverse impacts of variations through the identified controls for variations.

Keywords: *Effects; Lump Sum Contracts; Minimize; Variation.*

1. INTRODUCTION

Construction projects are multidisciplinary in nature (Egan, 1998). Thus, construction projects involve many human and non-human factors, long duration, various uncertainties and complex relationships among the participants (Arain *et al.*, 2004). The construction industry embraces a wide range of loosely integrated organisations that collectively construct, alter, refurbish and repair a wide range of different building and civil engineering structures. The industry has certain unique characteristics, stemming mainly from the physical nature of the construction product and its demand (Balchin and Bull, 2006). Most of the time outcomes of the construction industry are buildings or other related civil engineering structures. To obtain those outcomes it needs a proper management structure defined as a procurement system.

The need to make changes in a construction project is a matter of practical reality and even the well planned projects are experiencing variations in the construction industry (Arian and Pheng, 2007). Variation means any change to the work, which is instructed or approved as a variation (Jaeger *et al.*, 2009). The definition of the term variation indicates the broad scope for the exercise of the architect's influence to vary the works (Ramus *et al.*, 2006). According to Baxendale and Schofield (1986), variations are any revolutionize to the source on which the contract was signed. Even the most considerately planned project may demand changes due to a range of factors (Arain and Pheng, 2007). Then those changes are subjected for the variations in construction projects. A variation is any deviation from an agreed well-defined scope and schedule. Stated differently; this is a change in any modification

* Corresponding Author: E-mail - mathushaf@yahoo.com,

to the contractual guidance provided to the contractor by the owner or owner's representative. This includes changes to plans, specifications or any other contract documents (Arain and Pheng, 2005). Variations are inevitable on major construction projects particularly where the project is complex (Keith, 1995). Building and civil engineering contracts are of such a nature that it is almost impossible, especially where work has to be carried out in the ground, design and construct a project so that the final product is identical in every way to the original design which formed the basis of the contractor's tender (Thomas, 1993).

Variations effect on project in means of changes to cost time and quality of the project. The effect can be tangible and/or intangible. The omission may disrupt the continuity of work type of labour and plant, both of which may become idle due to a disruption of the project programmed or sequence activities (Oxley and Poskitt, 1996). Variation has become so prevalent in construction. Hardly possible to complete a project without changes to the plans or the construction process itself. Variations are common in all types of construction projects. The client releases the design and documentation, the contractor submits the price and undertakes the work. Any change to the documentation may entitle the contractor to request for extra payments through variations (Oladapo, 2007). Furthermore, it is revealed that "In a perfect world, changes will be confined to the planning stages. However, late changes do occur, often during construction, these frequently cause serious disruption to the project". Proper management of variations and case related issues are very significant for all types of construction projects including lump sum projects.

A contract is a written agreement that clearly defines the responsibilities and obligations of each included party, is legally enforceable, and is dated and signed by authorized representatives of each party (Werremeyer, 2006). Construction contracts do not differ fundamentally in nature from other types of contracts (Turner and Turner, 1999). Under the lump sum contract each contractor is required to estimate the quantities and value the works, based on the client's designer's drawings and specifications, using whatever methods considered as suitable. Bill of quantity items, quantities and metaphors are at contractor's risk. On completion of the works, the lump sum contract price would be paid in full to the contractor subject to the approved variations (Turner, 1993). Contractors could then either be required to submit one lump sum for the whole works, or to give a breakdown of the total sum against major activities or sections of the work. Payment is usually on a monthly basis and can be linked to the achievement of progress milestones (Potts and Patchell, 1995). Although there are number of variations and cases related to lump sum contracts, there is no critical solution to minimize those issues and variations. A lump sum contract is one in which a stated sum is totally paid at the completion of whole works. This is operable for both very minor and major works but it is usually necessary to make provision for variations in the work (Jayalath, 2010).

There are number of researches addressed on "variations". However none of them have focused on variations in lump sum contracts. The variations in lump sum contracts could be more critical compared to other types of contracts. Therefore, there is a necessity to fill this potential research gap. The research tends to investigate the ways of minimising variations in lump sum contracts through identifying the prevailing practices related to variations in Sri Lanka. Further the research investigates the effects of variations in a lump sum contract and the ways of minimising the variations.

2. LITERATURE REVIEW

2.1. VARIATIONS IN CONSTRUCTION PROJECTS

Construction projects are complex because they involve many human and non-human factors and variables. They usually have a long duration, various uncertainties and complex relationships among the participants. The need to make changes in a construction project is a matter of practical reality. These changes are identified as the variations. A variation is any deviation from an agreed well-defined scope and schedule. Stated differently; this is a change or any modification to the contractual guidance provided to the contractor by the owner or owner's representative. This includes changes to plans, specifications or any other contract documents (Arain and Pheng, 2007).

Variation, according to Baxendale and Schofield (1986), is any change to the basis on which the contract was signed. The variation clauses will provide power for the employer to call for varied or additional work including additions, omissions, substitutions and alterations, changes in the quality, form, character, kind, position, dimension, level or line. Some of the contracts go even further. In the JCT 1998 contracts provision is made for the addition, alteration or omission of any restriction imposed in the contract such as access to the works, limitation of working space, limitation of working hours and the execution of work in any order. However, what constitutes a variation in a contract is not only found in one clause, but also in a range of clauses such as procedure of claims, time extension and other causes related to project changes. It is hardly possible to complete a project without changes to the plans or the construction process itself. Even if carefully planned, it is likely that there will be changes to the scope of the contract as the work progresses (Singh, 2003). In common, variation is defined as additions, omissions and substitutions to the original work agreed. The nature of variations is usually defined by a variation clause in the contract (O'Brien, 1998). Furthermore, nature of variations had been identified by studying variations in different projects.

2.1.1. VARIATION PROCEDURES

As mentioned in the conditions of contract in Standard Bidding Document, if the Engineer request a proposal, prior to instructing a variation, the contractor shall respond in writing as soon as practicable, either by giving reasons why he cannot comply or by submitting.

a. A description of the proposed work to be performed and a program for its execution.
b. The contractor's proposal for any necessary modifications to the programme according to the time for completion.
c. The contractor's proposal for evaluation of the variation. Otherwise the engineer can issue an instruction without asking for a proposal.

2.1.2. VALUATION OF VARIATIONS

There are several ways of valuing variations (Ramus *et al.*, 2006), they are;

a. By the inclusion in the variation, accounts of a lump sum in accordance with a quotation submitted by the contractor and accepted by the architect.
b. By pricing measured items in the variation accounts
c. By ascertaining the total prime cost of additional work and applying appropriate percentage additions.

The each work item can be measured using existing rates or new rates. If there are similar work items for varied work item, the prevailing rates can be used. Otherwise some adjustment can be done. If the new rates are going to be applied, following three requirements should be fulfilled. If there is a new item, this is not applicable.

- The amount of changes of the quantity > 10% of the Quantity of item in the BOQ
- Amount change due to the variation > 0.01% of the accepted contract amount
- New value of cost per unit quantity x100 > 1%

2.1.3. VARIATIONS IN LUMP SUM CONTRACTS

In lump sum contract the contractor undertakes to carry out a defined amount of work in return for an agreed sum. This can be a fixed amount not subject to recalculation, in which case there would be no opportunity for the employer to make variations (Davis *et al.*, 2008). Contract sum is agreed before the construction starts and risk is very high to the employer. These contracts render maximum price certainty before the start, provided that client's requirements are fully specified (Turner, 1997).

Most of the time any type of contract may contain any type of variations as identified earlier. In this scenario client gives his idea through a checklist. To have a clear idea about the variations it is essential to refer to the variation clauses under the lump sum contracts and general clauses in SBD. For the project success, the project scope must be defined and understood by all parties (Songer and Molenaar, 1996). Ling and Poh (2004) suggested that the experience of the contractor is crucial to lump sum projects.

2.2. POTENTIAL VARIATIONS AND ITS CAUSES

An effective analysis of variations and variation orders requires a comprehensive understanding of the root causes of variations (Hester and Poh, 1991). Arain and Pheng (2007) stated four origin agents of variations as client, consultant, contractor and others. Variations can be categorized as follows.

2.2.1. UNAVOIDABLE VARIATIONS

When there are unexpected events or circumstances, unavoidable variations are occurred and they are necessary in order to minimize adverse effects. They may be required to avoid health, safety or security problems. They do not result in a change to the scope of the work.

Examples of unavoidable variations include;

- A variation to minimize the increase in cost or other adverse impact of a latent condition (for example unanticipated ground conditions, hazardous materials or existing services)
- A variation to overcome a fault (for example an error, ambiguity or inconsistency other than an omission or lack of completeness which may be the responsibility of the Contractor) in the principle design or documentation which, unless it is remedied, could result in health, safety or security problems or prevent work from continuing.

2.2.2. VARIATIONS FOR THE CONVENIENCE OF THE CLIENT

Due to a change in the client’s requirements, some variations are requested by the client. Uyun (2007) remarked that it is sometimes very difficult to determine the exact requirements of the client. If the objectives of the project are inadequately defined, it is common that clients will tend to change their minds along the way. It is possible to complete the Contract without making the changes requested. This type of variations will change the scope of the work and usually increase the cost of the work. Even variations that appear to reduce the scope may increase the cost.

Change of plans or scope by the owner: This is significant cause to generate more and more variations and is usually the result of insufficient planning at the project definition stage. Uyun (2007) remarked that the principal reason for the client to initiate variation is a change in requirements. Furthermore, Arain *et al.,* (2004) stated that there is a lack of involvement of the owner in the design phase. These variations affect the project severely during the later phases.

Change of schedule by the owner: A change of schedule during the project construction phase may result in major resource reallocation, rethinking of the needs or change of the use of the anticipated future utilization of finished works (Fisk, 1997).

Owner’s financial problems: The owner of the facility may run into difficult financial situations that force him to make changes in an attempt to reduce cost. Owner’s financial problems affect project progress and quality (Clough and Sears, 1994). Proper planning and review of project cash flow would be effective in eliminating this problem.

Inadequate project objectives: Inadequate project objectives are important causes of variation in construction projects (Ibbs and Allen, 1995). If there were an inadequacy of project objectives, the designer would not be able to develop a comprehensive design. Therefore, it may be a cause to initiate a number of variations.

Replacement of materials or procedures: Replacement of materials or procedures may cause major variations during the construction phase. Chappell and Willis (1996) concluded that the substitution of procedures includes variations in application methods. Therefore, if there is a change in procedures, an adjustment to the original contract value is required.

Impediment in prompt decision-making process: Prompt decision-making is an important factor for project success (Sanvido *et al.,* 1992). A delay in decision-making may hinder subsequent construction activities that may eventually delay the project progress.

Obstinate nature of the owner: A building project is the result of the combined efforts of the professionals. They have to work at the various interfaces of a project (Wang, 2000). If the owner is obstinate, he may not accommodate other creative and beneficial ideas. Eventually, this may cause major variations in the later stages and affect the project adversely.

Change in specifications by the owner: Changes in specifications are frequent in construction projects with inadequate project objectives (O'Brien, 1998).

2.2.3. VARIATIONS FOR THE CONVENIENCE OF THE CONSULTANT

These types of variations are initiated by the consultant. However, in a design and build projects occurrence of these types of variations are limited since both design and construction is done by a single party. Therefore, only the causes are highlighted without giving explanations. Now most of construction projects are complex, therefore the responsibility on the consultant party is high. In some cases, the consultant directly initiates variations or the variations are required because the consultant fails to fulfill certain requirements for carrying out the project.

For those reasons, Acharya *et al.* (2006) suggested that consultants should aim at getting an understanding of the overall scope and goals of the project, make sure they understand deliverables and offer specific suggestions when it makes sense.

2.2.4. VARIATIONS FOR THE CONVENIENCE OF THE CONTRACTOR

Variations for the convenience of the Contractor are variations that are requested by the Contractor. There is no obligation on the Principal to agree to a variation for the convenience of the Contractor.

To maintain good contractual relationships, when a request is made, it should be considered. Then it may be beneficial to the project. Levy (2002) indicated that general contractors or their subcontractors might discover an obvious discrepancy, omission, error or conflict in the contract document and request that the architect review that problem, discuss the additional costs to correct the situation, agree on a price and authorize the variation order.

Lack of contractor's involvement in design: Involvement of the contractor in the design may assist in developing better designs by accommodating his creative and practical ideas (Arain *et al.,* 2004). Lack of contractor's involvement in design may eventually cause variations. Practical ideas which are not accommodated during the design phase will eventually affect the project adversely.

Differing site conditions: Differing site condition can be an important cause of delays in large building projects (Assaf *et al.,* 1995). The contractor may face different soil conditions than those indicated in the tender documents. Eventually this may affect his cost estimates and schedule adversely.

Unavailability of skills (shortage of skilled work force): Skilled work force is one of the major resources required for complex technological projects (Arain *et al.,* 2004) Shortage of skilled is more likely to occur in complex technological projects. This lack can be a cause for variations that may delay the project completion.

Contractor's financial difficulties: Construction is a labour intensive industry. Whether the contractor has been paid or not, the wages of the worker must still be paid (Thomas and Napolitan, 1995). Contractor's financial difficulties may cause major variations during a project, affecting its quality and progress.

Contractor's desired profitability: Contractor's desired profitability can be a potential cause of variations in construction projects. O'Brien (1998) stated that this is because variations are considered a common source of additional works for the contractor.

The existing literature reveals that defective workmanship, unfamiliarity with local conditions, lack of a specialized construction manager, fast track construction, poor procurement process, lack of communication, contractor's lack of judgment and experience and complex design and technology could also be identified as causes of variations due to contractor.

Thus, the research discussed the aspects in relation to variations in construction projects, variation procedure, evaluation of variations, variations in lump sum contracts, potential variations and their causes. The next section tends to furnish the methodology adapted to this study.

3. METHODOLOGY

The current research adapted a mixed approach which consists of both qualitative and quantitative approaches in different stages. Researchers urge to use both quantitative and qualitative approaches in order to triangulate results which guide to integrate both approaches by the investigator (Yin, 1997). The data collection was done in two different stages. The first stage of the data collection was done using semi structured face to face interviews. The interviews were conducted among the experienced professionals who involved in handling variations in lumps sum contracts. An interview is an in-depth discussion in between two or more people (Saunders and Lewis, 2003). In semi-structured interviews, the researcher could ask questions which even slightly differs from one to another interview without deviating from the objective of the research. Thus, semi-structured interviews have the flexibility to allow the researcher to do such modifications. The semi structured interviews were conducted in order to explore the current practices of variations in lump sum projects in Sri Lanka. The results through interviews were analysed using content analysis. Content analysis facilitates the researcher to extract the important facts from the interview transcripts under different themes.

In the second stage of the data collection evolved questionnaire survey. Questionnaires were issued to experienced professionals who are involving in variations of construction projects particularly lump sum contracts. The questionnaire survey was conducted in order to identify and rank the most common causes of variations in lump sum projects. Further, the survey facilitated the researcher to rank the practice mechanisms used to minimize those variations. Relative importance index (RII) formula was used to rank the causes of variations which have obtained from the literature survey and questionnaire survey. Using RII formula, the researcher could achieve the objectives; rank the effects of variations in lump sum project and the ways of minimising variations.

$$RII = \frac{\sum (Wn)}{NxA} \qquad \text{(Eq:01)}$$

Where, W-Rating of each Factor given by respondent, n-Frequency of Responses, N-Total number of responses, A-Highest Weight. Thus, the research identified the most significant causes of variations in lump sum projects. Hence, the methodology was set in order to achieve the aim and objectives of the study.

4. RESEARCH FINDINGS AND ANALYSIS

4.1. VARIATIONS IN SRI LANKAN CONSTRUCTION INDUSTRY: THE POSITIVE AND NEGATIVE ASPECTS

4.1.1. PROFILE OF THE INTERVIEWEES

The interviews were conducted to collect data from experienced professionals who are currently working in the construction companies in Sri Lanka and involved in lump sum projects. Interviewees were selected deputing both consultants' and contractors' fields including project managers and quantity surveyors as shown in Table 1.

Table 1: Interview Participants' Profile

Project Participants	Experience in Construction Industry (Years)	Number
Consultant	>15	3 (A, B, C)
Contractor	>15	3 (D, E, F)
Total		6

4.1.2. FINDINGS OF INTERVIEWS

According to the responses of the research participants, the existence of both negative and positive impacts of variations in construction projects were clearly identified in both contractor's and consultant's sides. Out of above six, three respondents (Interviewee D, E and F) from contractor's side clearly stated that they prefer variations to occur within projects and it could cause several advantages for the contractors. An interviewee D agreed that "*Generally, most of the contractors look forward for variations within the project in order to earn an extra profit. However, very rarely there can be some fair contractors who try to proceed the project without any deviation to the original scope of works and the schedule."* By this statement, the contractors' adherence with variations was clearly identified. On a different note, an interviewee E stated that "*we have to deal with variations without considering the negative impacts as variations are inevitable to proceed the project and it would be a practical reality in the construction industry. Therefore, it is impossible to get rid of variations.*" This statement proves the vitality of enhancing knowledge in dealing with variations in construction projects to achieve successful projects. Moreover, Interviewee F also mentioned that variations are important to get project done in a desired level. This seems the variations are inevitable in construction projects.

Majority of participants in consultant sector mentioned that the contractors accept variations in order to get higher profits through variations. Interviewee A stated that *"Generally contractors ask additional payments for any work which is not included in the BOQ. However, in such cases most probably that relevant item can be already included in specifications or drawings. The common scenario here is that the contractors tend to miss items and ask for variations fraudulently whenever possible. So we should pay our special attention when dealing with variations and issuing instructions otherwise it will be a double payment to the contractor*". In consultants' point of view, the contractors earn additional profit using variations.

Most of the respondents from contracting sector stressed that the consultants show lack of tendency to accept variation requests from contractors. An interviewee D added that" *The consultants often try to refuse variation requests by including the varied work under BOQ items by giving many reasons. Ultimately the contractor is the person who is going to suffer due to loss of payments"*. In contractor's point of view, one of the most significant positive impacts of the variations is increasing the profit margin of the contractor. An interviewee C stated that "*The variations are beneficial to the contractor since it carries additional payments to him and accordingly the profit margin goes up"*. Moreover, the respondent C expressed that "*The contractor's higher earning of money from the project may reduce the risk involved in the project. So that the contractors tend to go for variations with these dual purposes of earning profits and reducing the risk related to performance of the project."* Thus, the research found that the contractors accept variations in construction projects while considering the benefits: extra income, risk reduction and increase in profit margin.

The consultant representative (B) opined that "*In some instances, the variations assist in mitigation of tendering errors and there fails to find another way to cover up the tendering errors than variations"*. Accordingly, variations give space to recover the mistakes in the tender/contract document and this lead to successful projects.

The chances of arising conflicts and possibility for disputes between parties were identified as significant negative impacts of variations in construction industry. Interviewee C stated that" *Variations may cause large number of disputes between parties to the contract and this would affect the project progress at last.*

Therefore, those disputes need to be managed in a proper way otherwise it will affect to the project as a whole and the contractor's reputation in the industry". On a different note, an interviewee A stated that "the variations could decrease the profit margin when it is not managed properly with increased number of variations. This revealed that allowing high number of variations could not be always beneficial to contractors.

In accordance with the above facts, it can be concluded that there are both positive and negative effects of variations. The same effect can negatively and positively impact on two parties: contractors and consultants. Thus, the research found the positive and negative impacts due to variations in construction projects. The next section explains the analysis of questionnaire survey.

4.2. QUESTIONNAIRE SURVEY ANALYSIS

The questionnaire survey was conducted among the professionals who are currently working in the industry and especially it was based on lump sum projects. The questionnaires were issued to a total of thirty five professionals. Out of thirty five, thirty questionnaires were properly completed and returned. Duly completed questionnaires were from industry professionals and include cost consultants (47%), consultant engineering (13%) and contractors (40%) who deputed the various organisations in construction industry. The research concerns that the questionnaire survey evolves both the contractor and consultant representatives. The questionnaires were issued to the professionals: engineers and quantity surveyors who have experience of more than ten years. This affirms the quality and the reliability of the research.

4.2.1. FREQUENCY OF VARIATIONS IN LUMP SUM PROJECTS

The respondents were asked to indicate their opinion on existence of variations in lump sum projects. The responses of the research participants on closed ended questions were collected basically using the ordinal scale of 1-5. Also, in some instances, respondents were asked to state their own views by means of a percentage value in order to derive a mean-average response. The following Figure 1 shows the frequency of variations in lump sum projects in Sri Lanka.

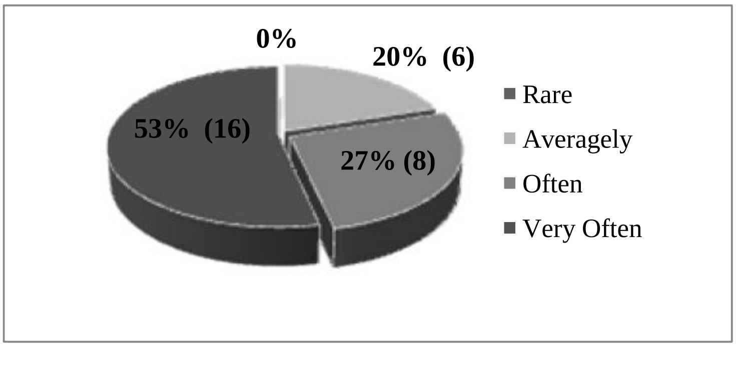


Figure 1: Frequency of Variations

According to Figure 1, most of the participants (53%) indicated that variation occur very often in lump sum projects. It is identified that variations occur often and averagely by 27% and 20% participants respectively. None of the respondent revealed that variation happens rarely. This confirms that variations are reality and inevitable in construction industry. Further this in line with the interview findings.

4.2.2. MAGNITUDE OF VARIATIONS IN DIFFERENT PROJECT PHASES

The magnitude of variation occurrence in different stages of the project would not be the same. Thus, the research participants were asked to indicate the magnitude of variations in different stages of project: design, construction and the end. The research finding was illustrated in Figure 2.

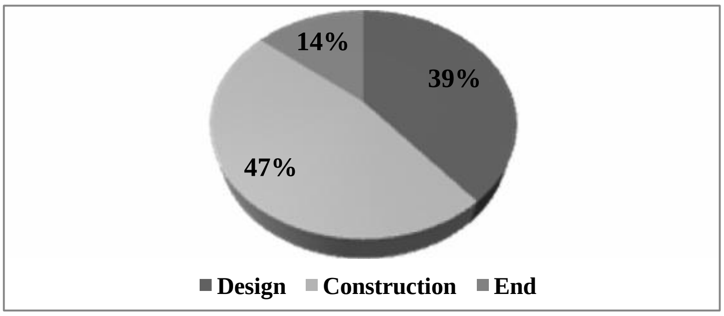


Figure 2: Magnitude of Variation in Different Project Phases

According to Figure 2, 47% of the participants indicated that most of the variations are occurred during the construction process. The client tends to change his requirements time to time during the construction stage then and there when he visits site. Moreover, the new work items occur while construction. Therefore, there is a high tendency for variations. The occurrence of variations during design was accounted by 39% of the research participants. At the end of the project, the chance of occurring variations was indicated as less and 14% of the participants indicated so.

4.2.3. Effects of Variations in Lump Sum Contracts

A variation needs to be carefully assessed in terms of its direct impact on the cost of the project, quality, schedule and the work progress. Even a small scope change can be accountable into a significant amount of increase in cost of project. Thus, the variations should be highlighted in each and every phase of construction due to the significance of the impact of changes and its effect on the success of the project.

The research participants were asked to indicate the effects of variations in lump sum projects using the ordinal scale of 1-5. A total number of 23 effects were included in the questionnaire. The findings through questionnaires were ranked using RII. Table 2 shows the significant effects with the respective RII value.

Table 2: Significant Effects of Variations in Lump Sum Projects

Effects of Variations in Lump Sum Projects	RII	Rank
Delay in project completion	0.800	1
Increase in project cost	0.760	2
Rework and demolition	0.760	2
Quality standards enhanced	0.760	2
Delay in payments	0.733	5
Wastage of resources and non-value adding activities	0.706	6
Increase in overhead expenses	0.693	7
Additional payments for contractor	0.680	8
Logistic delays	0.680	8
Productivity degradation	0.653	10

As illustrated in Figure 2, delay in project completion was identified as the most significant impact of variations in construction projects. Generally it is accepted that the maximum project performance could be achieved if the work progress flows smoothly within the time frame. However, the practical reality is, it is almost difficult to continue the work proceedings exactly within the initially scheduled time frame due to variations which may arise due to unavoidable obstacles and uncertainties. The negative influence of variations on the efficiency of construction activities has to be clearly identified and well managed as much as possible in order to avoid unnecessary delays.

Increase in project cost, Rework and demolition, Enhancement of quality standards were observed as second most significant effect of variations. The effects, increase in project cost and Rework and demolition are inter-related as the rework and demolition evolve additional cost. Each and every additional work involve additional cost simply because it needs extra material, labour force, supervision and some instances specialized knowledge. Rework and demolitions are often occurred when the ongoing process is not according to the requirement at the initial stages. Enhancement of quality standards is identified as a positive impact of variations. The variations take place in order to achieve the final output in a desired level. Thus the quality of project increases.

Delayed payments occurred frequently due to variations which may slow down the project progress and leading with project delays. Eventually payment delays to main contractor may affect the payments to the sub-contractors. Wastage of resources is considered as a significant impact of variations. This causes due to demolitions of the already constructed structures, change of the materials, plant and equipment which were already hired or purchased. According to the results of questionnaire survey, additional payments to the contractor can be a potential positive effect of variations in lump sum contracts. The client, as the person who invests and finances for the project should always bear up the cost involved in variations. Thus, the research ranked the effects variations in lump sum projects. The next section explains the ways of minimizing variations in lump sum projects.

4.2.4. WAYS OF MINIMIZING VARIATIONS IN LUMP SUM PROJECTS

The views of respondents regarding ways of minimizing variations in lump sum projects were collected basically under three major categories: design stage, construction stage and at the end of the project. The research participants were asked to indicate their opinion on the degree of contribution of each and every strategy to minimize variations. Table 3 furnishes the research outcome on the ways of minimizing variations with the respective frequencies.

Table 3: Ways of Minimizing Variations in Lump Sum Projects

Ways of Minimizing Variations in Lump Sum Projects	During Design	During Construction	At the End of the Project	Total
Review of contract documents	62	32	6	100%
Freezing design	75	21	4	100%
Value engineering at conceptual phase	56	40	4	100%
Involvement of professionals at initial stages of project	63	32	5	100%
Owner's involvement at planning and design phases	66	32	2	100%
Thorough detailing of design	57	36	7	100%
Clear and thorough project brief	71	27	2	100%
Reducing contingency sum	65	35	0	100%
Clarity of variation order procedures	5	86	9	100%
Written approvals	19	73	8	100%
Variation order scope	25	72	3	100%
Variation logic and justification	26	69	5	100%
Project manager from an independent firm to manage the project	24	67	9	100%
Restricted pre-qualification system for awarding projects	14	78	8	100%
Owner's involvement during construction phase	5	90	5	100%
Avoid the use of open tendering	10	85	5	100%
Use of project scheduling techniques	25	67	8	100%
Comprehensive documentation of variations	14	77	9	100%
Prompt approval procedures	25	62	13	100%
Valuation of indirect effects	27	65	8	100%
Team effort by owner, consultant and contractor to control variation	32	61	7	100%
Utilize work breakdown structure	16	82	2	100%
Continuous coordination and direct communication	34	55	11	100%
Control the potential for variation orders to arise through contractual clauses	17	80	3	100%
Comprehensive site investigation	70	28	2	100%
Use of collected and organized project data compiled by owner, consultant and contractor	64	32	4	100%

The above Table 3 listed the available strategies and the usage level during the stages: design, construction and end of project. The Table shows that strategies under design stage and construction stage were predominantly promoted to minimize variations respectively with different magnitudes. Review of contract document is identified as 62%, 32%, 6% in the stages design, construction and end of the project respectively. Freezing design to minimize variations in lump sum contract is indicated with a mean percentage contribution of 75%. Variations in design can adversely affect to a project depending on the timing of occurring changes. Therefore, freezing the design would be a highly important controlling method during design stage. Respondents mentioned that after proper completion of the drawings, many clients tend to freeze the design and obstruct the chances of occurring changes to minimize variations.

Clear and thorough project brief, Comprehensive site investigation, Owner's involvement at planning and design stage and Reducing contingency sum were indicated with a mean percentage contribution of 71%, 70%, 66%, and 65% respectively to minimize variations during design stage. According to the respondents' views, Clear and thorough project brief is considered as a significant control for variations in lump sum projects as it helps in clarifying the project objectives to the participants and eventually it may cause for reduction of both design errors and non-compliance with the requirements of the owner. Comprehensive site investigation is needed to build up unambiguous and broad understanding about the actual conditions of the site and practical obstructions before implementing the works in order to minimize variations. Similarly, owner's involvement at planning and design stage is needed in clarifying project objectives and identifying noncompliance and conflicts with their requirement at the initial stage of the project. Therefore, it would assist in eliminating variations during the construction stage where the occurrence of variations can be severe.

The provision of a large contingency sum for the project may heavily affect the participants' work handling approaches because of the designer's lack of tendency to develop a comprehensive design and consequently it may result to carry out rectifications in design as variation orders during the later stages of the project. Therefore, by reducing the contingency sum the professionals would perform and complete their tasks up to their maximum level. In addition, contract documents are the main source of providing information for any project. Therefore, it is advisable to have comprehensive, balanced and well-written variation clauses to eliminate conflicts between parties and minimize variations. As presented in Table 3, the mean percentage contribution for Review of contract documents is 62% in design stage.

Throughout the questionnaire survey, the contribution of controls for variations during construction stage was indicated with relatively higher mean percentage values. Owner's involvement in construction phase was taken place with 90% mean percentage contribution. The owners would assist in identifying noncompliance with requirements and eventually may aware of the current ongoing activities with prompt decision making. Clarity of variation order procedures was indicated with a mean percentage contribution of 86%, as an effective way of minimizing variations in lump sum projects and would help in reducing processing time and mishandling issues of variations in the project. The research identified that the mean contribution value is comparably less during the end of projects as it was found already that fewer variations arise during end of project. Thus, the research revealed the ways of minimizing variations and the respective mean values in the stages of project separately.

5. CONCLUSIONS AND RECOMMENDATIONS

A variation is any deviation from an agreed well-defined scope and schedule. Client is aware about variations to some extent and not always fully. There could be unnecessary costs that accrue due to variation orders. The research found that the variations cause negative and positive impact to the parties to the contract: client, consultant and contractor. The interviewees revealed that the contractor tends to get advantages through variations. The positive impacts to contractors are extra income, risk reduction and increase in profit margin. The research participants further found that the variations give space to correct the mistakes of contract document and lead to fulfill the client's requirements completely. In contrary, the variations could cause disputes within project parties.

The research participants ranked the effects of variations. The most significant effect of variation is identified as delay in completion with RII value of 0.80. Increase in project cost, Rework and demolition and Enhance quality standards are identified as second significant effects with a RII value of 0.76. The research further found that most of the time client's satisfaction becomes much higher with the occurrence of variations since the major role of a variation is to perform the project according to the desired output to be achieved at the end of the project. Disputes between parties also may significantly involve with variations in a project.

According to the research findings, client's requirements need to be clearly identified by the design team prior to the implementation of the project. Hence, the proper relationship and understanding between client and the design team is vital to perform the project without unnecessary deviations. The contract should be awarded to the most suitable and potential contractor selected through the tendering process. This could also minimize unnecessary variations. Moreover, the good communication and cooperation between parties also will be helpful to build up a proper relationship among them and similarly it may reduce the disagreements and conflicts which can be seen as root causes of variations. The research recommended that the construction industry could minimize variations by adopting the strategies during the respective stages of construction projects.

6. REFERENCES

Acharya, N.K., Lee, Y.D. and Im, H.M., 2006. Design errors: Tragic for the clients. *Construction Research*, 7(1), 177-190.

Arain, F.M. and Pheng, L.S., 2005. Modelling for management of variations in building projects. *Engineering, Construction and Architectural Management*, 14(5), 420-433.

Arain, F.M. and Pheng, L.S., 2007. The potencial effects of variation order on institutional building projects. *Facilities*, 22(11), 496-510.

Arain, F.M., Assaf, S.A. and Low, S.P., 2004. Causes of discrepancies between design and construction. *Architectural Science Review*, 47(3), 237-249.

Assaf, S.A., Al-Khalil, M. and Al-Hasmi, M., 1990. Causes of delays in large building construction projects. *Construction Engineering and Management*, 11(2), 45-50.

Balchin, P.N. and Bull, G.H., 2006. *Urban land economics and public policy*. 5th ed. Hound Mills: Macmillan Distribution.

Baxendale, A.T. and Schofield, T.J., 1989. Planning and progressing project variations. London: EandFN SPON.

Chappell, D. and Willis, A., 1996. *The architect in practice.* 8th ed. USA: Blackwell Science Ltd.

Clough, R.H. and Sears, G.A., 1994. *Construction contracting.* 6th ed. New York: John Wiley and Sons.Davis,

Love, P. and Baccarini, D., 2008. *Building Procurement Methods.* Australia: CRC Construction Innovation.

Egan, J., 1998. *Rethinking construction: Report of the constriction task force*. HMSO: London.

Fisk, E.R., 1997. *Construction project administration.* 5th ed. New Jersey: Prentice Hall.

Hester, F.Y. and Poh, B.H., 1991. Problems encountered by owners of design–build projects in Singapore. *Project Management*, 26(2), 164-173.

Jaeger, C.W. and Allen, W.E., 1995. *Quantitative impacts of project change*. 4th ed. USA: University of California at Berkeley.

Jaeger, A. V. and Hök, G., 2009. *Fidic.* 5th ed. Heidelberg: Springer.

Jayalath, C., 2010. *Contractual dimensions in construction*. Bloominton, USA: Universe.

Keith, P., 1995. *Major construction works.* 4th ed. Eastbourne: Longman group.

Levy, S.M., 2002. *Project management in construction.* 4th ed. Columbus: Mcgraw-Hill.

Ling, F.Y. and Poh, B.H., 2008. Problems encountered by owners of design–build projects in Singapore. *Project Management*, 26(2), 164-173.

O'Brien, J.J., 1998. *Construction change orders.* 4th ed. New York: McGraw Hill.

Oladapo, A.A., 2007. A quantitative assessment of the cost and time impact of variation orders on construction projects. *Engineering, Design and Technology, 5*(1), 35-48.

Oxley, R. and Poskitt, J., 1996. *Management techniques applied to the construction industry.* 5th ed. UK: Blackwell Science Ltd.

Potts, K. F. and Patchell, B., 1995. *Major construction works.* 4th ed. Harlow: Longman Scientific and Technical.

Ramus, J., Birchal, S. and Griffiths, P., 2006. *Contract practice for surveyors*. 4th ed. Elsever: Jordan Hill.

Sanvido, V., Parfitt, K., Guvensia, M. and Coyle, M., 1992. Critical success factors for construction projects. *Construction Engineering and Management,* 118(1), 94-111.

Saunders, S. and Lewis, P., 2003. *Research methods for business students*. 4th ed. UK: Prentice Hall.

Singh, H. S., 2003. Valuation of varied work. *Bulletin Ingenieur*, 20(3), 33-42.

Songer, A.D. and Molenaar, A., 1996. Selecting design-build: Public and private sector owner attitudes. *Management in Engineering*, 12(6), 47-53.

Thomas, R.W., 1993. *Construction contract claims.* 2nd ed. Basingstoke: Macmillan.

Thomas, H.R. and Napolitan, C.L., 1995. Quantitative effects of construction changes on labor productivity. *Construction Engineering and Management*, 121(3), 290-296.

Turner, D. F., 1993. *Building contracts*. Harlow: Longman Scientific and Technical.

Turner, D. F., 1997. *Building contracts claims*. Harlow: Longman Scientific and Technical.

Turner, A. and Turner, D.F., 1999. Building contract claims and disputes. Harlow: Longman.

Uyun, N. M., 2007. *Variation control affecting construction works for Lembaga Kemajuan Tanah Persekutuan (Felda)*. Malaysia: University Technologi.

Wang, Y., 2000. Coordination issues in Chinese large building projects. *Management in Engineering*, *16*(6), 54-61.

Werremeyer, K., 2006. *Understanding and negotiating construction contracts*. Kingston, MA: Reed Construction Data.

Yin, R.K., 1994. *Case research design: design and methods*. 3rd ed. London: Sage publications.

MITIGATING CLAIMS THROUGH CONFLICT AVOIDANCE IN CONSTRUCTION INDUSTRY

H.D. Sendanayake*, P.A.P.V.D.S. Disaratna and M. Francis
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Conflict is defined as a serious disagreement or argument about something important between parties. When there are differences, incompatibilities in interests among parties involved, it is obvious a conflict could be exist. Construction industry is a place where the conflicting situations arise very often and it continues to act as a high explosive character. When a conflict is not managed properly it will lead to claims and if these claims are not clearly resolved the claims may turn into disputes.

This study explored how to avoid conflicts in construction projects by addressing their types, causes and effects. Moreover the types and causes of claims were also addressed. The aim of the study was to develop a framework as a strategy that could reduce effectively the occurrences of conflicts to mitigate claims in construction projects in Sri Lanka. As a means to achieve the aim of this research, the study was structured into two main parts; the first part aimed at mapping up the nature of conflicts in construction projects by establishing types of conflicts, critical symptoms of conflicts, factors causing them and the strategies used in avoiding the conflicts. Moreover types of claims and causes of claims were also investigated. This was done through the literature synthesis. Secondly, a collection of data was done through a questionnaire survey and expert interviews.

Through the analysed data the framework for conflict avoidance to mitigate claims has been created for the Sri Lankan context. Notwithstanding, it can be recommended to use for the construction industry as a whole. The study provides field level experiences from which the inexperience construction site professionals could learn the instances of conflicts and claims and not repeat the mistakes in their projects.

Keywords: *Claims; Conflicts; Construction Projects; Sri Lanka.*

1. INTRODUCTION

Conflict is defined as a serious disagreement or argument about something important between people. When there are differences, incompatibilities in interests among parties involved, it is obvious a conflict can be exist (Kumaraswamy, 1997; Fenn *et al.*, 1997; Chou and Yeh, 2007; Lee, 2008). Although the conflict is defined as an incompatibility of goals or values between two or more parties in a relationship, combined with attempts to control each other, conflict is not actually being a bad thing. Conflicts should be there for a certain extent to keep meaningful interactions among people. Existence of conflicts would create new thoughts, innovative ideas, methods, and productive ways of management (Fisher, 2000; Acharya *et al.*, 2006; Ohbuchi and Suzuki, 2003). However, the way or method of the conflict is being handled, is deciding whether the conflict is going to be constructive or destructive. A conflict is not always a negative situation. Rather it can also create a positive impact for the situation as well (DeChurch *et al.*, 2007; Ohbuchi and Suzuki, 2003). Construction industry is a place where the conflicting situations arise very often and it continues to act as a high explosive character (Acharya *et al.*, 2006).

Claim is basically a term for assertion for additional compensation in terms of time and cost in relation to change in the contract or assertion of right to property or money (Kumaraswamy, 1997; Jayalath, 2013). Ren *et al.* (2003) pointed out that inefficiently handled claims may lead to disputes and when these conflicts are not being managed and mishandled, the conflict may grow as a dispute. Accordingly, when a

* Corresponding Author: E-mail - hasarads@gmail.com

conflict is not managed properly it will lead to claims and if these claims are not clearly resolved the claims may lead to be disputes (Acahrya *et al.*, 2006; Kumaraswamy, 1998; Fenn *et al.*, 1997). Therefore, it seems it is better to avoid conflicts in initial stages before they grow. It is a silkier way to face the disagreements in the initial stages rather than they get overgrown and difficult to be resolved.

The aim of the research was to develop a framework for conflict avoidance in order to minimize claims in the construction industry. This paper initially provides a comprehensive literature review in order to identify the prevailing knowledge about the conflicts and claims in the construction industry. Then the findings were further subjected to a discussion. Finally, conclusions are drawn from the findings.

2. DEFINITION OF A CONFLICT

Popovic and Hocenski (2009) and Acharya *et al.* (2006) stated that conflict can be defined as a struggle or contest between people with opposing needs, ideas, values, beliefs or goals. In the same way, Fisher (2000) pointed out that the conflict is an incompatibility of goals or values between two or more parties in a relationship combined with attempts to control each other's feelings. So that, conflict can be identified as, incompatibility of goals or ideas between two or more parties in a simpler meaning. Conflicts can be occurred between all kinds of relationships and social settings. However, according to Acharya *et al.* (2006) if there is a perfect construction world the conflicts may not be existed. But there is no perfect construction world. So it is obvious during the construction process conflicting situations may arise.

Tjosvold (2006) stressed that, conflicts can be either constructive or destructive but definitely need proper management. It is important to consider about destructive conflicts rather than productive conflicts since they disturb the successful completion of the construction project. However, having a conflict among people may lead to meaningful interactions among people and this situation may create success of the project.

2.1. TYPES OF CONFLICTS AND CAUSES OF CONFLICTS

Various researchers have found that there are many types of conflicts and these conflicts are happening due to various reasons. Acharya *et al.* (2006) expressed that there are five main types of conflicts and the reasons / sources of those conflict types. They are;

Owner Evoked Conflicts (OEC) – confusing requirements of owner , excessive change orders, supremacy of owner/consultant, project scope definition not clear, site access delays, lack of space in construction site, financial failure of owner, unbalanced risks, owner furnished material, delay in decision by owner, late handover of construction site, owner-furnished equipment and delay in running bill payment.

Consultant Evoked Conflicts (CEC) – defective design, errors and omissions in design, excessive extra work, differing site conditions, excessive quantity variations and specification related work.

Contractor Evoked Conflicts (COEC) – financial failure of contractor, slow work of contractor, incompetent contractor, major defects in maintenance, local people interruptions/protests, subcontractor inefficiency, non-payment to subcontractors, mentality of contractor and defective construction (quality)

Third Parties Evoked Conflicts (TPEC) – change in government codes, labour disputes/union strikes, adverse weather, market inflation, public disorder and third party delays

Other Project Matter Evoked Conflicts (OPMEC) – conflicts in documents, change order negotiation, issues of security of construction site, lack of communication, accident/safety, labour, equipment, material shortage , interpretation of escalation/de-escalation, necessity of environment improvement, negligence or negative attitudes of project participants and environmental hazards.

Jaffar *et al.* (2011) discovered that there are three main causes of conflicts. They are behavioral problems, contractual problems and technical problems. Behavioural problems include human interaction, personality, cultures and professional background among project team. Other issues in human behaviour such as individual's ambition, frustration, dissatisfaction, desire for growth, communication and level of power, fraud and faith are also causes of conflicts. Absolutely construction is not science, it is an art. So, construction is based on the people and understanding the people may help to successfully face the behavioural problems. Contractual problems include variation, extension of time, payment, quality of technical specifications, availability of information, administration and management, unrealistic client expectation and determination. Actually construction process is going on with various contractual agreements for exchange of services and the money. So that to solve the contractual problems the law can be used. The technical problems include basically the engineering clarifications. To solve such types of problems altering the methods, environment, duration or conditions can be taken place.

2.2. EFFECTS OF CONFLICTS

Tjosvold (2006) argued that conflicts are not always destructive. They can be constructive as well if they are well managed. Tjosvold (2006) further stated that neither conflicts just happen nor escalate by themselves. 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. 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 fertilizes 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.

The ultimate result of unmanaged conflicts will be disputes which require expensive dispute resolution with a lot of wastage of time, money and energy. 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.

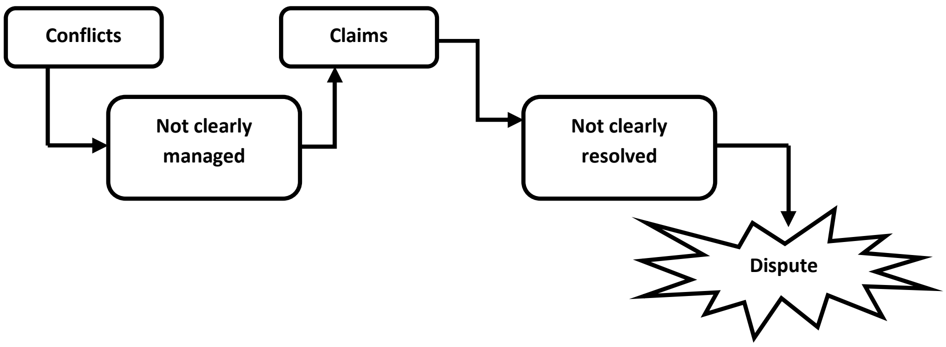


Figure 1: Conflict, Claim and Dispute Continuum Model
Source: Acharya *et al.* (2006, p.545)

According to Adnan *et al.* (2011) conflicts may come up with several serious effects such as delays in development of the project, reduction of requirements due to unavailability of enough time, reduced performance of employees and broken professional relationships.

It can be seen that effects of unmanaged conflicts might cause a devastating damage to the construction project. Therefore, it is very important to provide a good attention to any type of conflict, even if it has the slightest effect on the project, before it destroys the successful completion of the project.

According to Figure 1 it is clear that the unresolved conflicts are causing claims. It is rather important to have a handsome knowledge about claims and their characteristics for the clarification of the relationships between conflicts and claims.

3. WHAT IS A CONSTRUCTION CLAIM?

Chappel *et al.* (2005) stated that a claim can be defined as the assertion of a right, usually by the contractor, to an extension of the contract period and to payment arising under the express or implied terms of construction contract. Similarly, Jayalath (2013) expressed that a claim is basically an assertion for additional compensation in terms of time and/ or cost in relation to a change in the contract or otherwise. Jayalath (2013) further stated that there is no universally adoptable definition for the word claim. There is no stereo-type formula for it, but certain elements must be present. Basis for a good claim provide evidence for how it is being arisen, under what grounds it is claimable, duration of the effects in monetary terms, the quantities and rates applicable.

3.1. TYPES OF CLAIMS

According to Kumaraswamy (1997) there are two main types of claims. The constructions claims may arise as assertion for time or money. Simply claims for extra time and claims for extra money. Chappel *et al.* (2005) explained that there are four main categories of the claims and they are;

- ***Contractual Claims*** - These types of claims are arising out of the express provisions of the particular contract. Most of the standard forms of contracts provide the facility to the contractor's right to seek damages.
- ***Common Law Claims*** - These types of claims are claims for the damages for breach of contract under common law or legally enforceable claims for breach of some other aspects of law.
- ***Quantum Meruit Claims*** **-** These types of claims are providing a remedy where no price has been agreed.
- ***Ex-gratia Claims*** **-** These types of claims are which the employer is under no legal obligation to meet. That means the compensations are paid on ground of hardship or sympathy.

However, there are reasons and causes for the occurrence of claims. It is important identification of the causes of claims as well as identification of the relationships among conflicts and claims.

3.2. CAUSES OF CLAIMS

Kumaraswamy (1997) identified ten major common causes of construction claims. Those are ranked in descending order for overall perceived significance and they are; inaccurate design information, inadequate design information, inadequate site investigations, slow client response (decisions), poor communications, unrealistic time targets, inadequate contract administration, uncontrollable external events, incomplete tender information and unclear risk allocation.

4. CONFLICT AVOIDANCE STRATEGIES

Conflict avoidance is used to avoid conflict before it occurs rather than managing it after it occurs. Hence using the conflict avoidance strategies will be more useful for construction industry. According to Pathmapperuma (2013) there are five major dispute avoidance strategies. In such a way those similar strategies can be used as the conflict avoidance strategies. In case they can be identified as, clarity of scope, early, contractor involvement, equitable sharing of risks, open communication, collaboration, team work and relationship among parties and early notification and resolution of issues.

Therefore not only the understanding of conflict avoidance strategies but also a clear understanding about the occurrence, sequence and types of conflicts is important in conflict avoidance. The importance of preparation of a framework comes to the stage with that need of gaining knowledge about conflicts in construction industry.

5. RESEARCH METHOD

The approach undertaken for this research comprised of a literature review and data collection through questionnaire survey and expert interview. Firstly 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 conflicts and claims in construction industry. The expert interviews were carried out to get the general opinions about literature findings and through the questionnaire survey the ranking of the findings were done.

Under this research two methods were used for analysis in case of combining the collected data under two categories namely significance and occurrence of the factors. So that median of the answers calculated for significance and the RII value of the answers of occurrence has been calculated and a new risk index has been created by using those two.

- Created risk index formula,

  Average significance (Median) x Probability of occurrence (RII) = Risk Index (Eq: 01)

According to the research the average value of the answers of the respondents were needed to calculate the significance (impact) and extreme answers should be disregarded. In that case, the best method to calculate average is the median for the discrete data. Relative Important Index (RII) was used as the analysis technique of quantitative data under the category occurrence. RII value represents the probability of the factor.

6. RESEARCH FINDINGS AND DATA ANALYSIS

Main five types of conflicts established from literature synthesis and interviews were ranked using the questionnaire survey findings. The main categories are owner evoked conflicts, consultant evoked conflicts, contractor evoked conflicts, third party evoked conflicts and other project matter evoked conflicts. Under those main five types the sub related conflict types were categorized. The major owner evoked conflicts were unclear project scope definition, excessive changing orders, delay in decision by owner, financial failures of the owner and delay in running bill payments. Major consultant evoked conflicts were excessive extra work, errors and omissions of the design, defective designs, excessive quantity variations and differing site conditions. Major contractor evoked conflicts were financial failures of contractor, slow work, subcontractor inefficiency, incompetent contractor and non payment to subcontractor. Major third party evoked conflicts were adverse weather conditions, inflation, third party delays, local people interruptions, change in government codes and labour disputes. Major other project matter evoked conflicts were change order negotiations, shortage of resources, lack of communication, environmental hazards and conflicts in documents.

Main three causes of conflicts were established from literature synthesis and they are behavioural problems, contractual problems and technical problems. Under those main three types the sub related causes of conflict are categorized and ranked in the data analysis step. According to the analysis major behavioural causes were communication, faith and fraud, individual ambitions, human interactions and personality. Major contractual problems were extension of time, variation, payments, quality of technical specifications, and availability of information. The major technical problem was engineering clarifications.

The identified claim types from the literature synthesis were divided in to two main categories namely claims for extra time and claims for extra money. Contractual claims, common law claims, *quantum meruit* claims and ex-gratia claims can be categorized under those main two categories, because each and every claim category identified can be divided in to claims for extra money and extra time.

Purpose of adding these causes of claims for the research is to provide a comparison and validation for the findings and prove that the claims in construction industry occur befitting to the conflicts. According to the data analysis change or variation orders, delay caused by contractor, incomplete tender information, inadequate design information and low price of contract due to high competition can be identified as the major causes of claims.

The major effects of conflicts ranked accordance with the data analysis were time overruns, unavailability of time, delay the development of the project, costly dispute resolution methods and break professional relationships.

According to the data analysis the major conflict avoidance strategies were early notification and resolution of issues, clarity of the scope and contract, open communication, collaboration, team work and relationship among parties, early contractor involvement and equitable sharing of risks.

7. DISCUSSION

Both literature review and findings confirm that the identified types and causes of conflicts, types and causes of claims, effects of conflicts and strategies to avoid conflicts compatible with each other. However the ranking of the analyzed data can be used to support the framework prepared to avoid conflicts in order to mitigate claims in Sri Lankan construction industry.

The final outcome, the framework to avoid conflicts in construction projects in Sri Lanka which was developed based on the findings of the research study is illustrated in Figure 2. A five stage process to avoid construction conflicts includes in the framework and those are establish context, identify potential conflicts, analyse potential conflicts, evaluate potential conflicts and treat the causes of conflicts.

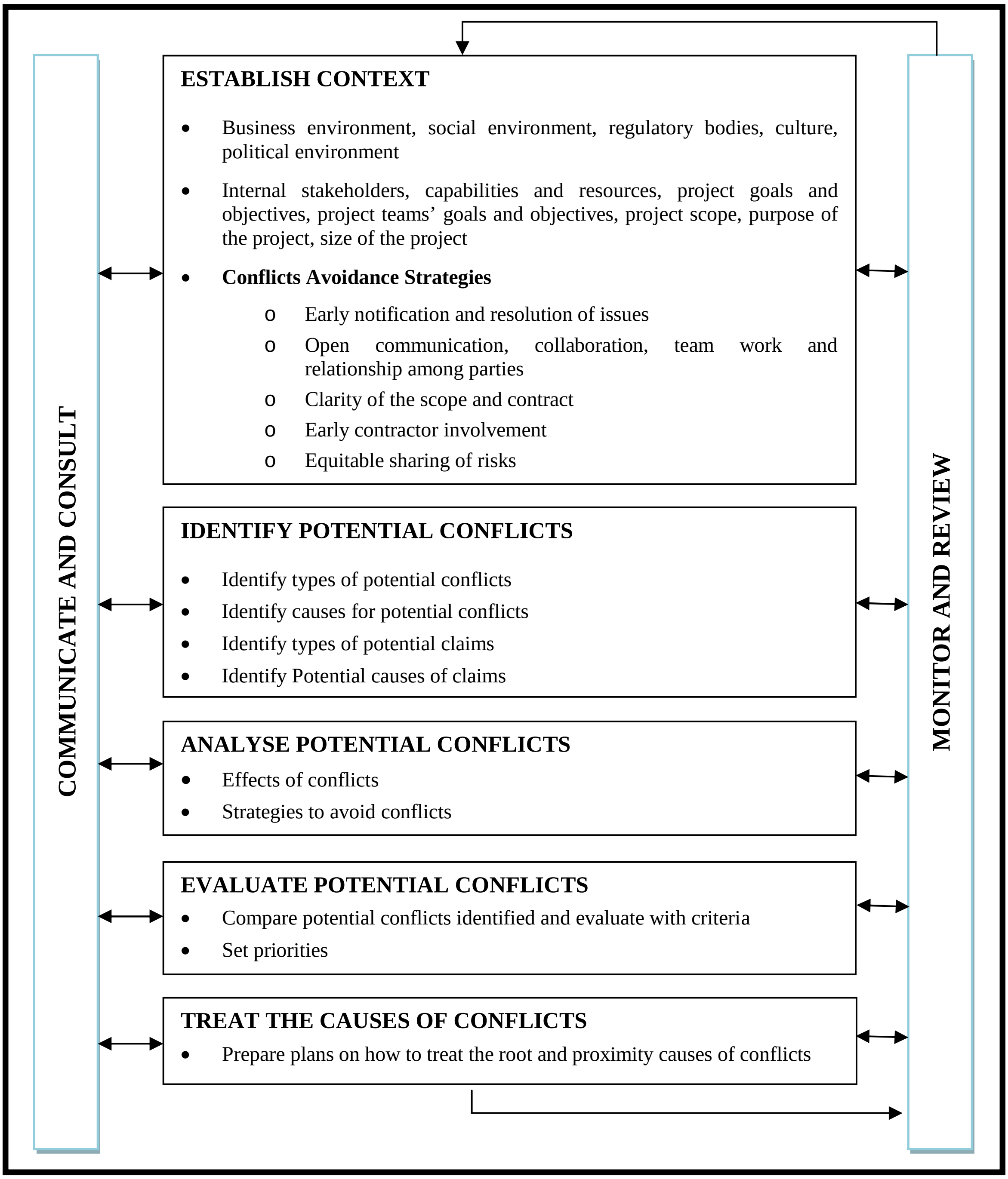


Figure 2: Conflict Avoidance Framework

As the first step establish the context of the project should be done. For that the internal and external details about the specific project should be identified. As the external details business environment, social environment, regulatory bodies, culture and political environment can be identified. On the other hand internal stakeholders, scope, size, goals and objectives of the project and purpose of project should be identified as the internal details. The second step is identifying potential conflicts. In that step types of conflicts, causes of conflicts, types of claims and causes of claims related to the construction project should be identified. Thirdly effects of potential conflicts and conflict avoidance strategies should be identified under analyzing the potential conflicts step. Comparing, evaluating and setting priorities of the identified findings should be done under the fourth step evaluate potential conflicts. Finally, for treating the causes of conflicts in a comprehensive manner, implementing the appropriate conflict avoidance strategies should be done. Throughout above five steps communication and consultation regarding the progress of each step to all relevant project team members should be done while monitoring and reviewing the process.

The framework was created as a generic framework and not specified for a special type of project. So the final framework can be used for the construction industry as a whole. Though the research findings were based on Sri Lankan construction industry rankings of the analysed data only can be used for Sri Lankan construction projects. However the framework can be used as a generic guide for mitigate claims through conflict avoidance in any construction project.

8. CONCLUSIONS

In order to mitigate claims which arise due to conflicts the conflict avoidance framework can be used successfully. The data was collected and analysed by using the literature survey findings. Those analysed and ranked data can be used to support the prepared framework.

However the research was done only to prepare the framework to avoid conflicts in Sri Lankan construction industry. But after the preparation of the framework the researcher identified that the framework can be used not only for Sri Lanka but also for the construction industry as a whole. But the rankings of the factors may be different with the nature and the environment of the country.

9. REFERENCES

Acharya, N.K., Lee, Y.D. and Im, H.M., 2006. Conflicting Factors in Construction Projects: Korean Perspective. *Engineering, Construction and Architectural Management*, 13(6), 543-566.

Adnan, H., Shamsuddin, S.M., Supardi, A. and Ahmad, A., 2012. Conflict Prevention in Partnering Projects. In: *Asia Pacific International Conference on Environment-Behaviour Studies,* 2011. 772- 781.

Chappel, D., Sims, J. and Smith, V.P., 2005. *Building Contract Claims.* 4th ed. UK: Blackwell publishing.

Chou, H.W. and Yeh, Y.J., 2007. Conflict, Conflict Management and Performance in ERP Teams. *Social Behaviour and Personality*, 35(8), 1035-1048.

DeChurch, L.A., Hamilton, K.L. and Haas, C., 2007. Effects of Conflict Management Strategies on Perceptions of Intragroup Conflict. *Group Dynamics: Theory, Research, and Practice*, 11(1), 66-78.

Fenn, P., Lowe, D. and Speck, C., 1997. Conflict and Dispute in Construction. *Construction Management and Economics,* 15, 513-518.

Fisher, R.J., 2000. *Sources of Conflict and Methods of Conflict Resolution* [online]. Available from: http://www.ulstergaa.ie/wp-content/uploads/coaching/team-management-2012/unit-3/sources-of-conflict-and-methods-of-resolution.pdf [Accessed 10 May 2013].

Jaffar, N., Tharim, A.H.A. and Shuib, M.N., 2011. Factors of Conflict in Construction Industry: A Literature Review. In: *2nd International Building Control Conference 2011* [online], 193-202. Available from: http://www.science direct.com [Accessed 10 May 2013].

Jayalath, C., 2013. *Arguing Construction Claims.* Sri Lanka: S. Godage and Brothers (Pvt) Ltd.

Kumaraswamy, M.M., 1997. Conflict, Claim and Dispute in Construction. *Engineering, Construction and Architectural Management*, 4(2), 95-111.

Kumaraswamy, M.M., 1998. Consequences of Construction Conflict: A Hong Kong Perspective. *Journal of Management in Engineering*, May/June, 66-74.

Lee, K.L., 2008. An Examination between the Relationships of Conflict Management Styles and Employees' Satisfaction. *International Journal of Business and Management*, 3(9), 11-25.

Ohbuchi, K. and Suzuki, M., 2003. Three Dimensions of Conflict Issues and their Effects on Resolution Strategies in Organisational Settings. *The International Journal of Conflict Management,* 14(1), 61-73.

Pathmaperuma, P.K., 2013. *Framework to Avoid Disputes in Public Sector Construction Projects in Sri Lanka: The Client's Perspective.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Moratuwa.

Popovic, K. and Hocenski, Z., 2009. *Conflict Management* [online]. Available from: http://www.slideshare.net/KresimirPopovic/conflict-management-11488705 [Accessed 10 May 2013].

Ren, Z., Anumba, C.J. and Ugwu, O.O., 2003. The development of a Multi-Agent System for Construction Claims Negotiation [online]. *Advances in Engineering Software*, 34, 683-696. Available from: http://www.sciencedirect.com [Accessed 10 May 2013].

Tjosvold, D., 2006. Defining Conflict and Making Choices about its Management - Lighting the Dark Side of Organisational Life. *International Journal of Conflict Management*, 17(2), 87-95.

Yiu, K.T.W. and Cheung, S.O., 2005. A Catastrophe Model of Construction Conflict Behaviour. *Building and Environment,* 41, 438–447.

PARTNERING TO BRIDGE THE GAP BETWEEN CONVENTIONAL AND BIM BASED PROJECT PROCUREMENT

K.A.R.V.D. Kahandawa*
VFORM Consultants (Pvt) Ltd, Nawala, Sri Lanka.

Himal Suranga Jayasena
Department of Building Economics, University of Moratuwa, Sri Lanka.

ABSTRACT

Building Information Modelling (BIM), has not yet been used in the Sri Lankan context. It has not yet become a clearly identified and proven standard method in building procurement. As a procurement method, Integrated Project Delivery (IPD) is key contender in BIM implementation process worldwide. But due to the lack of integrated projects in Sri Lanka and the reluctance of professional, changing their methods for the sake of BIM would be impractical. Therefore it is vital to identify the minimum requirement needed, to implement BIM. Partnering is a concept that is also alien to the Sri Lankan context; but is more of the intangible procurement method laid on top of the existing procurement system. This method creates the environment that dissolves the contractual boundaries, enabling working together to achieve mutual as well as individual goals. Therefore it could be used to create the collaborative environment needed for BIM, rather than changing the whole system. Through an extensive literature survey, the characteristics of partnering, including its benefits, barriers were identified. Thereafter the applicability of BIM to the current context was recognized. Then it was discovered of CIC BIM protocol to bridge the contractual gap, that would give out the smallest change required for BIM. Thereafter, the applicability of the BIM protocol and barriers that prevents BIM from implementation in the Sri Lankan context was analysed based on interview responses of the professionals. It was also identified that CIC BIM protocol is not covering all the barriers in concern. With the addition of partnering to the equation it was identified that partnering together with the BIM protocol creates the most suitable environment for BIM implementation in the Sri Lankan context.

Keywords: *Barriers; Building Information Modelling (BIM); BIM Protocol; CIC; Construction; Partnering; Sri Lanka.*

1. INTRODUCTION

Building Information Modelling (BIM) and partnering are two new concepts that are yet to enter to the realm of construction. United States Army Corps of Engineers (USACE) (2010) declares, partnering is there to inspire parties to alter from their traditional confrontational interactions to a more supportive, team-based attitude, and to avoid problems from progressing into disputes. While Kassem *et al.* (2013) explains that Building Information Modelling (BIM) is a developing scientific and procedural change within the Architecture, Engineering, and Construction and Operations (AECO) industry. But the Sri Lankan industry is yet reaping its benefit due to the fact that it had not yet been implemented it. There are number contracts that are used internationally to implement BIM. However the usual resistance to change in Construction Industry, challenges the adoption of these contracts in Sri Lanka. This research was aimed to identify how to bridge the gap between conventional and BIM based project procurement with a minimum change to existing contractual arrangements, so that the resistance to change would become minimum.

* Corresponding Author: E-mail – kad2ravindu@gamil.com

2. BACKGROUND

BIM is one of the methods that can be used for integration of information. Jin and Levitt (1996, cited Coates *et al.*, 2010) said that BIM signify the new basis that is being adopted to make possible Information and Communication Technology (ICT) in the business of architecture design, which is an aggregation of many information interactions between parties.

Jayasena and Weddikkara (2012) added that BIM technology is not yet in Sri Lankan construction industry and since the country has relatively high IT literacy which was also within Architecture, Engineering and Construction (AEC) professionals, it would not be a dare to adopt BIM technologies. However, they alarmed that there would be resistance to change due to overlapping professional boundaries perceived.

Associated General Contractors of America (2005), in 2005 declared that at the time “there was no clear accord, as how to implement or use BIM. Unlike many other construction practices, there was no single document or treatise on BIM that instructs on its application or usage”. Six years later, Singh *et al.* (2011) held that, “In the current practice, a customized project instruction document is generally developed to serve as a guide for the project operation.” More recently Porwal and Hewage (2013) wrote that “no such methodology, framework, or analysis in public procurement with BIM is available in the published literature”. However, the rapid developments occurred in the field has developed several solutions, and the time is needed to validate their suitability and to find challenges within them.

Consideration should be given to the resistance, due to perceived overlapping boundaries of professionals in Sri Lanka by providing a pragmatic solution and also to the need for effective collaboration among parties. No standard form of contract currently being used in Sri Lanka is focused on collaborative approach; and neither the project participants will readily embrace such new contract. A partnering charter would enable them to use the existing contract as a standard, while creating the collaborative environment. Hence, it is timely to find the possibility and methods to bridge the gap between conventional and BIM based project procurement with the help of partnering.

2.1. PARTNERING

USACE in 1991, which, was later updated and reintroduced by Edelman *et al.* (2010) in November 1, 2006, states: “Partnering is a voluntary organized process by which multiple stakeholders having shared interests perform as a team to achieve mutually beneficial goals. It is based on establishing these goals early in the project lifecycle, building trusting relationships, and engaging in collaborative problem solving” . Table 1 depicts those characteristics expressed by Ng *et al.* (2002), Li, Cheng and Love (2000) Edelman *et al.* (2010) and Meng *et al.* (2011).

Table 1: Characteristics of Partnering

Characteristics	Justification
Mutual Goals	The parties to the partnering set goals that both parties agree on.
Shared Interests	The partners agree to mutual targets of the project and shared principles of the partnering relationship.
Commitment	Though the contract is not legally binding, the stake holder must be working together, willingly and making a realistic effort to make the charter become reality
Teamwork	The partnering effort is not a singular participation. It is working together to achieve the mutual goals set forth. Hence the pre-set organisation boundaries are dissolved
Problem Solving	It uses the bottom up method to resolve problems to prevent development of the conflict
Trust	The stakeholder do not hide any details from one another where, the communication between them is open and honest
Synergistic Relationship	Without working as separated entities, the stakeholders pool together their resources in a joint effort. This is very strong, due to the fact that, it can minimize resource wastage,

Characteristics	Justification
	use expertise knowledge.
Continuous Evaluation	The method needs to be continuously evaluated. Thus, adaptation of the method for any dynamic situation is possible
Shared Risk	Partners share the risk of the goals achievement and create collaborative atmosphere to face risk, yet, the responsibilities a kept within the said party.
Equity	The parities of the arrangement are considered equal and their goals, considerations and requirements are mutually addressed
Win/win Approach	It is considered that none of the parties partnering arrangement wins, if, a one party fails to reach their objectives
Freedom and Openness	All the member of each organisation are encouraged to create an open relationship with other organisations. They are to predict, identify problems and resolve them if possible
Innovation	The exchange of new and cooperate ideas to resolve daily problems

2.2. *PROBLEMS IN PARTNERING*

Problems in Partnering as identified by Ng *et al.* (2002), Bresnen and Marshall (2000), Imrie and Morris (1992), Eisenstat and Spector (1990, cited Bresnen and Marshall, 2000) presented in Table 2 below.

Table 2: Problems in Partnering

Problems
▪ Problem in open and honest communication
▪ Stakeholders development of a win loose approach
▪ Reduced intimacy between partners
▪ Issue not addressed at the beginning
▪ Partners not willing to comprimize their goals and attitudes
▪ Less empowerment of the representatives
▪ Large and traditionally bureaucratic organisation
▪ Lack of technical knowhow of the Employer or controlling party
▪ Financial pressures
▪ Lack of training and guidance in the project partnering arrangement
▪ Use of a competitive tendering arrangement inhibits flexibility
▪ Not involving all the vital stake holders
▪ Partnering is not suitable for a particular project
▪ Reducing the broader view
▪ Different commitment in the organisation

2.3. *RESOLVING THE PROBLEMS IN PARTNERING*

Ng *et al.* (2002) identified methods to resolve problems in partnering as:

1. Total commitment to partnering arrangement by building required attitudes because it is the main requirement of the arrangement
2. Provide knowledge so that the parties must have total understanding of the partnering arrangement and ensure that other needed qualities achieved through the process of training. The partnering training must mainly target inexperienced parties.
3. Develop non-contractual personnel relationship with the main parties so that it would ensure that all the stakeholder realize the importance of them self and their need in the project.

4. Commitment is key in partnering therefore, encourage every stakeholder to accept the implementation of agreement
5. Encouragement and utilization of flexibility for the stakeholders' organisations and its regulations to benefit the partnering
6. Selection of contractor not only forcing on price but mainly on past performance. Therefore the mutual understanding of the organisations are already in place facilitate better results.
7. Encouragement and empower the representatives of the parties to identify potential problems make decisions at lowest level.
8. Establish independent initiator to the entire project to compensate for lack of experiences of the parties and representatives.
9. Create and establish joint problem solving method to which all the parties agree.

2.4. BIM PROTOCOLS

Many institutes are in production of protocol to incorporate BIM for the existing procurement systems. Construction industrial council have produced a protocol on 2013 February. Which incorporates all the legal boundaries needed for BIM implementation. Construction Industrial Council (CIC) have produced this document to be incorporated into the contracts, between all parties including sub-contractor document. The protocol overlays on existing contracts: both main contract and sub-contracts.

2.5. PARTNERING AS A STRATEGY FOR BIM IMPLEMENTATION

Since partnering is tool that creates a collaborative relationship, it could be the answer to the key BIM challenge that exists. Effectiveness of partnering could be theoretically emphasized using the considering following areas.

Partnering is a collaborative approach that has no legal emphasis; thus, it would not be used as another contract. Therefore, the parties would not reject such an approach. Moreover, partnering sets mutual goals that every party would benefit. Hence, commitment of the parties would be more. On the other hand, setting up of strict rules and conditions to parties who had not used advance a digital setup like BIM would find it hard to swallow. This could lead to rejection of BIM.

Partnering also helps the parties to collaborate resources in creating the singular Federate Model and other Models. This could be extremely helpful for small sub-contractors, suppliers as well as contractor and consultants who are not aware of BIM and could pool resources like experts, software, knowledge and hardware. Partnering draw backs discussed earlier, could be minimized by careful implementation and its success depends on practice than more than the theory.

There should still be certain legal provisions needed for BIM, especially those associated with data sharing and data specifications in the needed phases as stated earlier. Such provisions are not met in common contracts used in Sri Lanka such as, ICTAD Standard bidding document (SBD) and FIDIC Standard biding documents. According to Richard and Jason (2010, cited Porwal and Hewage, 2013), BIM introduces new risks which must be distributed among parties. These include assumption of contribution from a party is accurate, software malfunction and data corruption. Additionally, they describe that intellectual right are there to parties that have produced the documents and transfer of sub licenses to other parties. Finally, Legal provisions should be changed to remove the Information Manager role and divided the responsibility to other parties. Thus, change the BIM protocols' legal provisions could be used suit the partnering approach.

3. RESEARCH METHODOLOGY

The qualitative method was used in this research due to its nature. This involved a desk study of the current document involved in the construction to establish the conceptual premise. The ideology was that, those documents produced by panels of experts, represented the opinion of industry experts. The main review was conducted on the CIC BIM protocol. Since the areas of the research, BIM and partnering, were not present in the current context, only a few number of local professional were knowing about such systems and only a handful had encountered the capabilities of the systems. Using the desk study findings, a questionnaire was developed to interview the professionals on practical application of BIM and BIM protocol followed by the applicability of partnering in local industry. Transcribed interviews were analysed using content analysis method with the aid of computer software (Nvivo).

4. FINDINGS OF THE RESEARCH

Findings of the research can be presented under four key areas viz. problems in BIM contracts, barriers for BIM implementation, applicability of Partnering, and Partnering and BIM Protocol.

4.1. PROBLEMS IN THE BIM CONTRACT

This BIM contract was produced before the professional and the interview guide had been prepared to address the effects of its salient clauses on the current practice. The problematic areas identified are divided into following sections (shown in Table 3).

Table 3: Problems in BIM Contracts

Section		Explanation
Contractual changes	-	Problems raised due to the new contractual changes
Drawing goals	-	Setting exact drawing goals, with specific details
Information manager	-	New role, duties responsibilities not defined and specified according to project
Subcontractors using BIM	-	Ability of the sub-contractor in Sri Lanka to handle
Sub licences	-	Giving sub licences to others to use drawing models
Transferring problems	-	Problems due to the transfer of the data from one platform to another

4.2. BARRIERS FOR BIM IMPLEMENTATION

In connection with BIM, the respondents were questioned in relation to other factors that would affect the implementation in Sri Lanka. The main factors discussed, and responses are given in Table 4.

Table 4: Barriers for Implementation

Factor		Explanation
Cost	-	The unknown whole life cycle cost has not yet been calculated. Thus it remains a problem
Change for the professionals	-	The professional are not willing to change and the barrier preventing them from change
Age gap and the use copy type	-	The different age group are comfortable with different type of format like hard copies, 2D format 3D format like wise
Incompatibility with the current system	-	There are IT systems that are used construction like BMS systems that would need to change to coordinate integrate with BIM
Uncertainty of the IT system	-	People are have no confidence on the IT system relating to construction
Unavailability of perfect example	-	There is no perfect examples that has implemented BIM
Transparency of the system	-	The increased transparency would create problems
Working in a collective model	-	The collective model would create problems because the need go beyond the strict boundaries

4.3. APPLICABILITY OF PARTNERING

Contracts do not solve all the problems, according as these barriers identified by the professionals. It's therefore referred to partnering to see what are barriers or problems that can mitigated or removed by it. Hence each barrier is discussed separately as follows.

4.3.1. COST

Partnering does not create direct cost reduction to the implementation such as equipment, or transition or maintenance. But since the contracts are dissolved a bit, the total of these cost could be indirectly reduced. For example if the contractor, sub-contractors or consultants are needed to be trained for BIM, there are practical things to learn, which could be learned only by experience. Partnering could be used to reduce cost spent for third party expertise.

Furthermore, they could share resources, same as drawings and information as per BIM, thus change from per entity BIM unit at site to one per site. Therefore we could pool resources to reduce cost per project.

4.3.2. CHANGE FOR THE PROFESSIONALS

Since every professional is somewhat reluctant to change to BIM, it is main barrier holding back BIM in Sri Lankan. When it comes partnering, it is all about working together, to achieve individual as well as project goals, with transparency. This is the platform that is created by BIM, but with less transparency and individual goals achieved.

As forwarded by the professionals, some are running chaotic system to achieve construction goals. Thus applying strict set of rule would not be method to achieve time, cost, quality targets, which are the main reasons for construction, whether it's chaotic or not. Thus partnering in its ambiguous nature could be gel to which the BIM could be stuck. It could be used to ensure trust in the professional, to go ahead with BIM. The consultants and contractors could be flexible towards each other in achieving targets. Furthermore they could help each other in BIM related matters like knowledge, problems, built families. Since they are helping, with the knowledge of the client disclosure is there. Furthermore, it is for the betterment of the project as well as increase in individual entity efficiency and effectiveness.

But this is would only work to the extent partnering is allowed into the system. This could not change the consultants or contractors that are unwilling to change since it is not enforced on each other. It will work as much as they are willing.

4.3.3. AGE GAP AND THE USED COPY TYPE

The age gap would be very much useful if partnering is in play. For example if the professional is young, he would have more IT based knowledge and would probably good in the modelling side. On the other hand more mature professional would have much more experience and better practical error detection that could not be detected by BIM. Thus, they could help each other by pooling this knowledge, experience and skill, whether it's in the same entity of cross entities.

Furthermore, when referring to the above advantages, it could be said that BIM supports, both hard copies and soft 2D and 3D with section from any place. Thus the younger could go ahead with model and do the work, detect problems. The matured could use the hard copies to detect practical problems, not detected by BIM, as well use it for his work. Thus, the mature professional could use the young professionals to insert it to the model, thus mixing the young with matured, like grandparents and grandchildren together.

4.3.4. INCOMPATIBILITY WITH THE CURRENT SYSTEM

Partnering will not solve this problem as it cannot directly change the current practices that local government uses or the current systems like BMS. But, it could easy ease the clash with such professionals, due to partnering. They could come to comprise with other systems or help them to change to BIM. But, the system has to be change to be compatible with public systems when connecting with them.

4.3.5. UNCERTAINTY OF THE IT SYSTEM

Since the IT systems reliability, is not related to construction sector professionals, this could be ensured by a system or the producer and its operators. But for the safety of the project, the professional could keep server copies individual, at interim levels, with each other's agreement. Thus if a system fails, you can go ahead.

4.3.6. UNAVAILABILITY OF PERFECT EXAMPLE

This problem would when it comes to partnering in the construction practice in Sri Lanka as of now. Therefore this could be issue, but there is some kind of practice in Sri Lanka due to the chaotic nature of the system. Thus, this could, theoretically be said it can be done, but practical example creation is a priority.

4.3.7. TRANSPARENCY OF THE SYSTEM

Partnering truly works, if they system is transparent and open. Thus if the parties are not comfortable in transparency then partnering could be problematic to extent. However if the partnering is established, parties are confident and trust the other parties. If partnering is established transparency would not be a problem.

4.3.8. WORKING IN A COLLECTIVE MODEL

As explained in literature and analysed as per the interviews above, BIM a cross cultural collaboration in information storage and working platform. But partnering is more extensive cross collaboration of professional targeted on project goals as well as individuals. Thus if partnering is implemented BIM collaborative model would be supported throughout the project. This would enable client, consultant and contractor excel in BIM, as all want to make it work.

4.4. PARTNERING AND BIM PROTOCOL

As identified before sector, CIC BIM protocol has some issues that are not agreeable to the current construction sector practice in Sri Lanka. Hence forth, impact of partnering should be discussed

Contractual changes would create problematic situation. This is due to the fact it is not used by professional elsewhere and all the problems are detected. But it is imperative that we have contractual changes in practice, because partnering would not create any definite obligations thus, if it fails there must be a backup. Thus the contract must be there.

When discussing about the drawing goals, it is explained that work would be done on time if partnering is there. It is said also work would be effective and efficient as per the literature. Thus it is could be analytically said that practical drawing goals could be achieved if partnering is set, furthermore the buffer needed as per the culture of Sri Lanka could be through partnering.

Information manager would mostly benefit from the partnering agreement as collaboration would at its peak as per BIM. Therefore information manager role would be easier to manage the information as well as the system.

Sub-contractors using the system would get more help from the other professional and would need less costs to bear on BIM as well as would create a sound footing in BIM due to chare of knowledge, experience and skill with the consultants and main contractors.

Sub licensing should be there as is create the footing for contractual authorization to use other model and would most certainly, necessary. This would not come in to contact with partnering.

In the case of transferring of the data, and the issues it create would be mitigated, as per theory of partnering, because without blaming someone or wiping their hands from the problem, the professional would pool resources to find compatibility or transfer data loss. There if an error occur they would mitigate it, at that stage, thus reduces the problems from data transfer error.

5. CONCLUSIONS

According to the findings of the study BIM cannot be implemented with only partnering or a protocol like CIC BIM protocol. It can be concluded that CIC BIM protocol will give out the contractual needs for BIM and partnering will create the collaborative environment needed for BIM. Thus, the gap between traditional contract and BIM based project procurement would be bridged with the help of partnering and CIC BIM protocol.

6. RECOMMENDATIONS

In relation to the finding realised and concluded, following recommendations could be given in order to bridge the gap between traditional contracts and BIM contracts with help of partnering.

6.1. STANDARDS TO LOCAL PRACTICE

In Sri Lanka, the construction industry adopts Standard Bidding Documents published by ICTAD. These documents are based on international standards like JCT and FIDIC. However, there is no standard document yet for BIM, partnering or sub-contracting. The need that local standard document to enable effective BIM implementation could be fulfilled by utilize CIC BIM protocol to develop standards to the local practise. Furthermore, it is recommended that partnering also is introduced to the local scenario, with a standard partnering charter.

6.2. APPLICATION TO THE CURRENT PRACTICE

Since there is no project using BIM in Sri Lankan, it is recommended to implement one project with proper planning and BIM protocol, if possible, to create a practical situation. It is also suggested by the professional to use it for a project, but with proper methods. If not, it could back fire creating fear for BIM.

6.3. INCREASE SKILL, KNOWLEDGE IN THE BIM RELATED ENVIRONMENT

Use of software like Revit or Bentley is not fully understood by the professionals. It is imperative that professionals possess such skill in order to grasp BIM. Therefore it is advised that workshops and training programmes to be conducted by professional bodies to create awareness and the need of BIM to Sri Lanka environment.

7. LIMITATIONS

New concepts are always bound to change with time and expertise in order to refine them. In the process of such development, early identification of limitations becomes a cornerstone. Due to the fact that BIM is a newly developing field in Sri Lankan context the research process encountered the following limitations. Addressing these limitations can help in building a better platform for implementing BIM and partnering in the future.

7.1. NO PRACTICAL EXAMPLES

Setting up an example is always difficult and for that to be a perfect example even more so. The construction industry participants in Sri Lankan are not that much aware of BIM, therefore the responses from professional seems to be more hypothetical. Examples relating to our context are still at their infant age. Furthermore there is no project using partnering in Sri Lanka to identify the practical extent that partnering could achieve in terms of our context.

7.2. UNAWARENESS OF BIM

It was also seen that the professionals were not much aware of BIM. Therefore it could be seen that some professional were reluctant to express their true views due to less knowledge and uncertainty of the situation. Therefore they were introduced as 3D modelling and then explained on the collaborative nature of BIM. Thus the response would depend on the understanding ability of the professionals and their pre-existing knowledge of the issues raised in interviewing.

7.3. UNAVAILABILITY OF COST ANALYSIS FOR BIM

Since the initial cost of BIM is higher, it was key limitation to the research on whether BIM is cost effective. This was needed to create the mind-set need to implement BIM. The cost analysis should be done as Whole Life Cycle Cost with relation to the Sri Lankan context.

8. REFERENCES

Associated General Contractors of America, 2005. *The Contractor's Guide to BIM*. Las Vegas: AGC Research Foundation.

Bresnen, M. and Marshall, N., 2000. Partnering in construction: a critical review of issues, problems and dilemmas. *Construction Management and Economics*, 18(2), 229--237.

Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C. and O'reilly, K., 2010. *The key performance indicators of the bim implementation process* [online]. Nottingham University Press. Available from: http://usir.salford.ac.uk/9551/5/ID_15_camera_ready.pdf. [Accessed 14 August 2014]

Edelman, L., Carr, F.and Lancaster, C., 2010. *Partnering: A Tool for USACE*, Engineering [Online]. Alternative dispute resolution series pamphlet #4. Houston, United States of America. Available from: http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/91-ADR-P-4.pdf. [Accessed 14 August 2014]

Imrie, R. and Morris, J., 1992. A review of recent changes in buyer-supplier relations. *Omega*, 20(5), 641-652.

Jayasena, H.S. and Weddikkara, C., 2012. Building information modelling for Sri Lankan construction industry [online]. In: *World Construction Symposium 2012: Global Challenges in Construction Industry*. 196–201. Available from: https://worldconstructionsymposium.com/downloads/Proceedings.pdf. [Accessed 14 August 2014]

Kassem, M., Iqbal, N and Dawood, N., 2013. A Practice oriented BIM framework and workflows, *Computing in Civil Engineering* (2013), 524-532.

Li, H., Cheng, E. and Love, P., 2000. Partnering research in construction. *Engineering, Construction and Architectural Management*, 7(1), 76-92.

Meng, X., Sun, M. and Jones, M., 2011. Maturity model for supply chain relationships in construction. *Journal of Management in Engineering*, 27(2), 97-105.

Ng, S., Rose, T., Mak, M. and Chen, S., 2002. Problematic issues associated with project partnering—the contractor perspective. *International Journal of Project Management*, 20(6), 437-449.

Porwal, A. and Hewage, K., 2013. Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction*, 31, 204-214.

Singh, V., Gu, N. and Wang, X., 2011. A theoretical framework of a bim-based multi-disciplinary collaboration platform. *Automation in Construction*, 20(2), 134-144.

PAYMENT EVALUATION METHOD FOR CONTROLLING ENVIRONMENTAL DEFILEMENT IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA

W.M.P.C. Walimuni*, Lalith de Silva and Aparna Samaraweera
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Various attempts have been taken in order to achieve the objective of environmental soundness in road construction activities. Effectiveness of allocating the funds and the due payment for the contractor can create a great influence in achieving such an objective. Thus, this study aims to identify what is the optimum payment evaluation method of contractor's due payment for controlling environmental defilement in road construction projects. The aforesaid research problem was approached through a multiple case study including three road construction projects in Sri Lanka. Different environmental hazards occurred due to different road construction activities, related hazard mitigation methods, fund allocation for environmental hazard controlling and the associated existing payment methods for contractors could be identified through the data collected by means of semi-structured interviews conducted with the professionals who are involved in the projects having knowledge on both environmental and monetary aspects. Further, direct observations and documentary survey strengthened these findings. Quantitative data was collected from each case through a questionnaire survey and prioritized the payment method under each specific hazard controlling method using Relative Importance Index in terms of effectiveness to identify the optimum payment method to the contractor for controlling environmental hazard. Findings revealed that there are four types of such payment methods available including; payments by unit rate, payments where a provisional sum established in the contract; payments where fixed amounts are assigned in the contract and payments made along with some main work item in the contract which were identified being the optimum method under different hazard controlling methods. These findings would be useful for bidders and estimators at the pre-construction stages to develop more effective modes of payment evaluation and to improve effectiveness in estimation.

Keywords: *Due Payment; Environmental Hazards; Fund Allocation; Hazard Mitigation; Payment Evolution Methods.*

1. INTRODUCTION

The construction industry bears a substantial responsibility among the various causes of impacts on environment (Ashworth, 1996). According to Chaudhary (2011), when the road development is compared with other development projects, it involves in wide range of environmental impacts. As stated by Ashworth (1996), there is a growing trend of concern in society about the effects on the environment by the human activities. There by, environment related statutes, regulations, codes and general policies have lot of interferences for the construction industry (Ofori, 1992). According to one of the researches by Da Silva and Amaral (2009), there are costs to be identified in a process of controlling environmental hazards. ICF International, Venner Consulting, CH2M Hill and the University of Florida (2008) have described the environmental cost in road construction projects as the cost where the cost of labor, environmental staff members' or consultant's costs of travel, equipment or material usage, the cost incurs in producing of an environmental document, and the cost of constructing or performing an environmental mitigation feature during construction are directly involved. The builder is the one to incur the production cost in construction industry (Ferry, 1964). This replicates that the payment for the aforementioned

* Corresponding Author: E-mail- pcwalimuni@gmail.com

builder or the contractor has an affiliation with the environmental protection because the contractor has the obligation on executing the construction works. In addition, Darrington (2010) has mentioned that a contractor can be encouraged in proper execution of work for some extent by the payment. Thus, selecting the most suitable method of fund allocation is an essential aspect which requires a thorough consideration. However, the 'Standard Specifications for Construction and Maintenance of Roads and Bridges' published in 1989 by the Road Development Authority of the Ministry of Highways in Sri Lanka, which plays a huge role regarding road construction, does not contain any direct fund allocation for controlling environmental hazards. As specified by Central Provincial Road Development Authority - Sri Lanka (2012), the cost of the services under environmental protection has to be covered under the rates of relevant work items. As stated in the Particular Specifications in bidding document of Miscellaneous Foreign Aided projects by Road Development Authority in Sri Lanka (2011), the payment for hazard controlling has been given as a 'Provisional Sum'. All these ensure that there are different ways of allocating a provision to cover the cost of environmental protection in a road construction project. Each of these different methods of payment may contain its own advantages and disadvantages. However, those have become mere modes of payment without a proper attention to it as a way of encouraging the contractor for proper protection of the environment as Darrington (2010) depicted. In fact, it is worth studying the connection between the payment for the contractor and the minimization of the environmental hazards as it is not yet been theoretically confirmed. Hence, this research intends to fill that research gap by studying the possibility and optimum ways of allocating the funds for controlling environment hazards and the most effective way of payment to the contractor under each environmental hazard in order to take the maximum control of it. However, this research is limited to studying the environmental hazard controlling only during construction phases of the road construction projects in Sri Lankan road network.

This paper is structured in five sections. Following the introduction, second section discusses the environmental hazards; the related controlling methods in road construction; fund allocation and payment for the prevention of environmental impacts. Third section elaborates the research methodology adopted, while fourth section depicts the research findings in detail. Finally, the conclusions drawn from the study is discussed in the fifth section.

2. ENVIRONMENT AND ROAD DEVELOPMENT

It is becoming increasingly difficult to ignore the fact that the attention to the development cannot be drawn without governing the environment. Even though it directs our attention to the importance of maintaining a proper balance between environment and developments, generally environment confronts with negative impacts. This is substantiated by Chen *et al.*(2000) through depicting that China is confronting a serious problem because of pollution and hazards due to urban civil construction projects. As explained by Chaudhary (2011), although road and highways development can be recognized as beneficial in terms of economic and social aspects, it can have substantial negative impacts on communities and natural environment. If this concept is abridged, the roadway construction is an unavoidable requirement of a country to be contented, but as a consequence, it leads to the destruction of natural environment. This replicates the importance of attention associated with the environmental protection.

2.1. ENVIRONMENTAL HAZARDS AND CONTROLLING METHODS RELATED TO ROAD CONSTRUCTION

When evaluating the impacts on environment by road development, the main attention is drawn to the activities appertain to the road construction. Chaudhary (2011) and Local Government of UK (2013), have described that construction include the activities such as: site clearance; construction camp establishments; mobilization of heavy plant; construction of earthworks; construction of structures and basic course/surfacing; excavation and compaction; operation of heavy machinery and equipment; erection of structures; metal joining and finishing; mechanical activities; transport of materials and supplies; generation of solid wastes and debris. As recognized by Chen *et al.* (2000), dusts; harmful gases; noises; solid and liquid wastes and ground movements can be identified as sources of pollution and/or hazards from road construction activities. The control of all human activities which have either considerable or minor harmful impact on the environment during the construction process can be identified as the pollution control in construction projects (Griffith *et al.*, 2000). According to the findings of Chen *et al.* (2000) and Deng *et al.* (2013), the actions related to mitigation of environmental hazards due to construction activities can be implemented in many different ways in terms of laws, Acts, regulations and specific environmental management strategies under different road construction projects. Table 1 elaborates actions taken to minimize the environmental issues in road construction works. Orr (2014) and Carter (2010) have come up with the opinion that all these environmental hazard controlling methods involves a price. Macek (2006) has identified that environmental hazard controlling cost can be given as a percentage of the total cost of a project and it generally varies from less than 1% to 25%. Therefore, it is obvious that the methods identified above may also include a monetary value, hence, fund allocation becomes essential for executing the environmental hazard elimination.

Table 1: Actions Taken to Minimize the Environmental Issues in Road Construction Activities

Environmental Issue	Generated Source / Activity	Action taken to Minimize the Issue
Generation of dust	Road way excavation ABC laying Material transportation Excavations Clearing and grubbing	Frequent water spreading Covering of materials while transporting Locating stockpiles and dumping yard away from sensitive receptors Speed limitations Cleared areas rehabilitated progressively Washing the wheels of carriage prior to entering into residential area
Vibration	Rock blasting Rolling to compact materials	Managing vibration with the use of sand bags in rock blasting Reducing the level of vibration roller and increasing passes Undertaking a condition survey
Dumping of debris	All construction works By third parties	Removing all debris after finishing of each work. Make aware the surrounding communities. Proper disposal practices
Soil erosion	Clearing and grubbing Roadway excavation Removal of vegetation Embankment constructions	Providing turfing at necessary locations Planting fast growing plants (e.g. Mana) Creating earthen bunds when necessary, with the advice of consultant.
Noise pollution	Rock blasting By machineries and vehicles	Controlling the noise generated by rock blasting Proper maintenances of all vehicles and machineries
Contamination of soil and water	Soil erosion due to constructions Leaking of fuel, oil etc.	Taking actions to prevent soil erosion Disposing derbies in a proper manner Programming of construction activates closer to the water stream in dry season
Disruption to road users	All construction works	Implementation of a good traffic management system Dispose all derbies in proper manner
Blockage of drains	All construction works	Clearing of blocked drainage paths periodically
Impact on flora and fauna	Clearing and grubbing Road widening, excavation Embankment constructions Removal of trees	Proper identification and management after commencing the project Obtaining approval for removal of trees from consultant

Source: Adapted from Lakmal (2013)

2.2. *FUND ALLOCATION AND PAYMENT FOR THE PREVENTION OF ENVIRONMENTAL IMPACTS*

As the contractor is the executor of the work, costs of environmental hazard controlling may have a direct influence on the contractor. According to Bass and Avolio (1993), everyone has a price required for the motivation of work. As explained by Darrington (2010), economic human motives play a key role in job performance. It reflects that the motivation of contractor through due payment is a considerable factor when it comes to the environmental hazard controlling. Further, it could be argued that the contractor can be motivated for proper execution of environmental protection through the due payment.

United States Department of Agriculture (2011), Florida Department of Transportation (2013) and Iowa Department of Transportation(2005) have identified the main types of available payment methods for environmental hazard controlling as 'lump sum payment in equal basis', 'lump sum payment depending on the completion of a work item', 'using a unit price' and 'including in the contract price'. Several examples for deferent payment methods proposed by the existing literature can be elaborated as follows.

As declared by the United States Department of Agriculture (2011), pollution controlling of road construction project is considered as a pay item in the contract. According to their specifications, there are 3 main methods of payment. As the first method, payment for each item is made at the contract unit price of that item where unit prices are assigned. In the second method, payment is made as the work proceeds considering the expenses, where a lump sum price is established in the contract. Third method is used for some items of work where lump sum prices are assigned in the contract. Here, the payment is provided in equal amounts on pro-rata basis in each month. Further, Iowa Department of Transportation (2005) suggests payment for most of the water pollution control items to be paid depending on a unit price rate.

However, a properly defined way of measuring and paying method for environmental hazard controlling items does not exist in extent literature. Further, no literature popular for identifying ways and means for proper control of environmental hazards through allocation of funds and due payment for the contractor in road construction projects. Thus, Figure 1 depicts the framework developed by reviewing the extent literature for studying the same.

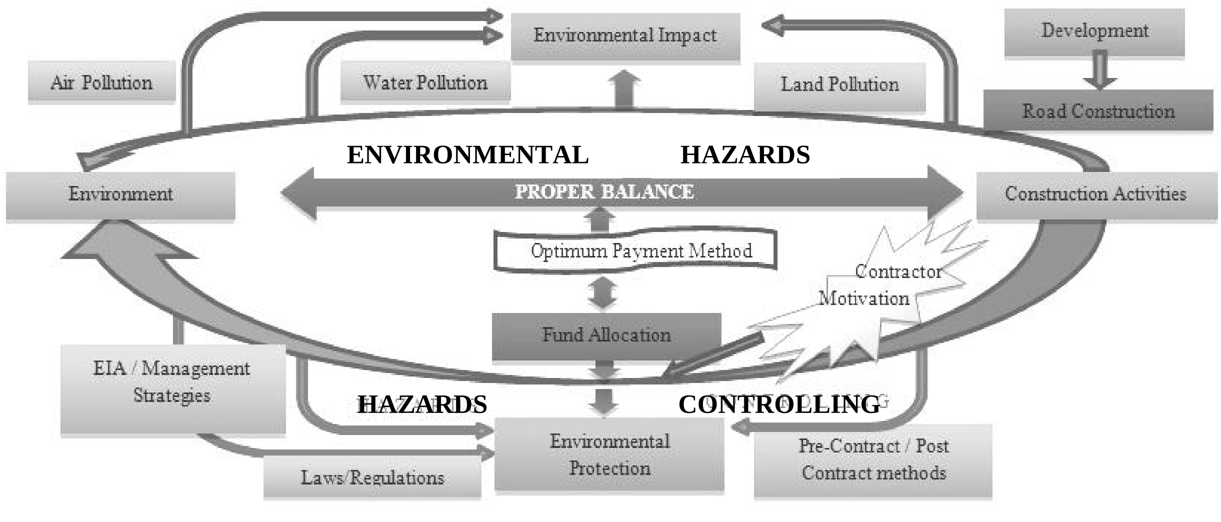


Figure 1: Conceptual Framework for Establishing Correlation between Environmental Hazard Controlling and Monetary Aspects

According to the conceptual framework in Figure 1, construction activities are the interconnecting aspects of environment and the development which is depicted through the curved arrow. The upper arrow replicates the path where the environment is harmed with the construction activities whilst the lower arrow imitates the path where the proper balance is achieved. Activities executed in road construction projects, directly involve in generating environmental hazards. These hazards lead to impacts on the environment mainly in terms of land, water and air pollutions. Conversely, on the other path, environmental hazard controlling methods are followed. For proper execution of work, a fund allocation is done. As this may lead to motivation of the contractor, effective environmental protection can be expected. However, literature review has consistently shown that many methods of payment for contractor exist in construction industry. Therefore, in order to achieve the proper balance between the environment and development, the optimum method of payment to the contractor should be identified. The next section elaborates the research methodology adopted to study the optimum payment evaluation method of contractor's due payment for controlling environmental defilement in road construction projects in Sri Lanka.

3. RESEARCH METHODOLOGY

As the literature revealed, the impacts and extent of hazard mitigating methods vary according to the characteristics of the project. Thus, case study was selected as the research strategy for this study due to the required in-depth investigation into the project specific construction activities and environmental hazards to identify the optimum payment method for contractor's due payment. According to Yin (2003), when the boundaries between a phenomenon and the context are not clear, a case study offers an in-depth investigation into a contemporary phenomenon in its real-life setting. Therefore, a qualitative approach has been embraced for in depth investigation of the selected projects. Further, as the ultimate expectation of the study was to identify the optimum payment method for the contractor under each environmental hazard controlling method, a quantitative approach had been adopted to provide a measurable image.

Therefore, embedded multiple case study design under mixed research method had been selected as the research design. While designing the case study, 'the road construction project' was selected as the unit of analysis and three cases were selected. The three projects (projects A, B and C) were selected including projects A and C adopting traditional procurement method and project B adopting design and build procurement method. Details of the selected cases are provided in Table 1. Data collection was done in two stages. At the initial stage, interviews, direct observations and documentation were used as data collection techniques and at the second stage, a questionnaire survey was used for the data collection. Interviews were conducted with five professionals from each project, who are aware of both environmental and monitory aspects of the project to identify possible environmental hazards, hazard controlling methods and payment methods for the contractor. These interviewees were professionals such as Environmental officers, Quantity Surveyors and Project Managers. The quantitative data has been collected through questionnaire survey with the same sample within each case separately to recognize the optimum payment method for the contractor which provides maximum controlling of environmental hazards on each identified hazard controlling method. Case study data has been analyzed with content analysis and cognitive maps while questionnaire findings were analyzed through RII (Relative Important Index) method.

Table 2: Details of the Cases

Case	Case A	Case B	Case C
Type	Road improvement	Road improvement	New construction
Project Cost (Rs.)	1.2 billion	1.8 billion	45 billion
Project Duration	20 months	18 months	36 months
Stage Completion % up to month of August 2014	82% completed	28% completed	68% completed
Procurement method	Traditional Method	Design and build	Traditional Method
Payment Method	Measure and pay	Lump sum	Measure and pay
Scope	Total length of the road is 31km and carriageway width is 6.2 m for each side 31km long road	A linking road which makes a short cut and its length is about 16.7km	2km embankments, 2km cut sections and 4.9km viaducts construction
Location	Mannar; lagoon area	Eheliyagoda	Colombo District
Physical condition	Dry, hot and windy Very less population	Rainy and wet climate. Less populated	There are many soft grounds
Particulars of projects	Located near preservation.	Area is supplied with water by a community water supply system	Site requires lots of soft ground treatments

4. CROSS CASE ANALYSIS AND FINDINGS

Cross case analysis was carried out on the main areas indicated in the developed frame work which include: road construction activities; environmental hazards; hazard mitigation and fund allocation for environmental hazard controlling and payment to the contractor. These are discussed in detail in the following sections.

4.1. ROAD CONSTRUCTION ACTIVITIES IN THE SELECTED CASES

As revealed by the empirical study, most of the construction activities identified found to be common to the selected three cases. Those main activities include: site survey and investigation; site clearance; establishing construction camps; demolition of structures; excavation, rock blasting and disposal; sub base construction; base course construction; laying of wearing course; material transportation; construction of structures; mobilization of heavy plants to the site could be identified. These main road construction activities were very much similar to the construction activities elaborated by Chaudhary (2011) and Local Government of UK (2013) discussed in literature review.

4.2. ENVIRONMENTAL HAZARDS OCCURRED UNDER EACH CONSTRUCTION ACTIVITY

Although the construction activities are common to each selected case, when it comes to the involvement in occurrence of environmental hazards, several similarities as well as differences could be notified. Main environmental hazards highlighted through the cross case analysis include: loss of trees; interference with services; dust nuisance; noise; vibration; water pollution from sanitary and other wastes; reduction in land quality on abandonment; erosion/sediment deposition; interference with natural drainage patterns; reduction in water quality; oil spillage; reduction of rare/endangered species by trapping and temperature differences. The cognitive map which elaborates the relationships of road construction activities and environmental hazards are presented in Figure 2. According to the Figure 2, it is obvious that some construction activities individually contribute to several environmental hazards. Additionally, it could be verified that same environmental hazard can be arisen under several construction activities. Therefore, it becomes apparent that environmental hazards and construction activities are interrelated in a manner where disparity is difficult.

Other than the empirical findings through interviews, observations had revealed several environmental issues in the cases. In ***case A,*** where the road is spread out through a forest area, there is a tendency of disturbance to the natural lives of the animals. As it could be observed in ***case B***, the construction work includes using materials such as asphalt and chemicals used for rock blasting which had been identified as a cause of harmful gases which is an environmental hazard in literature review. Further, inconveniences for the public due to muddy surrounding which is a result of improper handling of disposal material like soil is another environmental hazard not highlighted through the interviews. In ***case C*** the site is located near the river. In order to make the construction work easier, the contractor has acquire a part of the river with the use of a coffer dam. That space is being used as a working space which assists the bridge construction. It is obvious that it becomes harmful for the bio-diversity as it interferes with aquifers. Further, as it could be revealed, there is evidence of the area near the river being under a danger of getting flooded due to the reduction of the capacity in river by embankments getting narrowed by the temporary construction works. In summary, the main hazards that could be identified within the selected cases include harm to bio-diversity; solid and liquid wastes; oil spillage; destruction to utility services, drainage facilities and structures; vibration; noise; dust, air pollution; temperature differences; reduction in water quality; erosion; interference with natural drainage patterns. Most of these hazards can be identified commonly within the three cases.

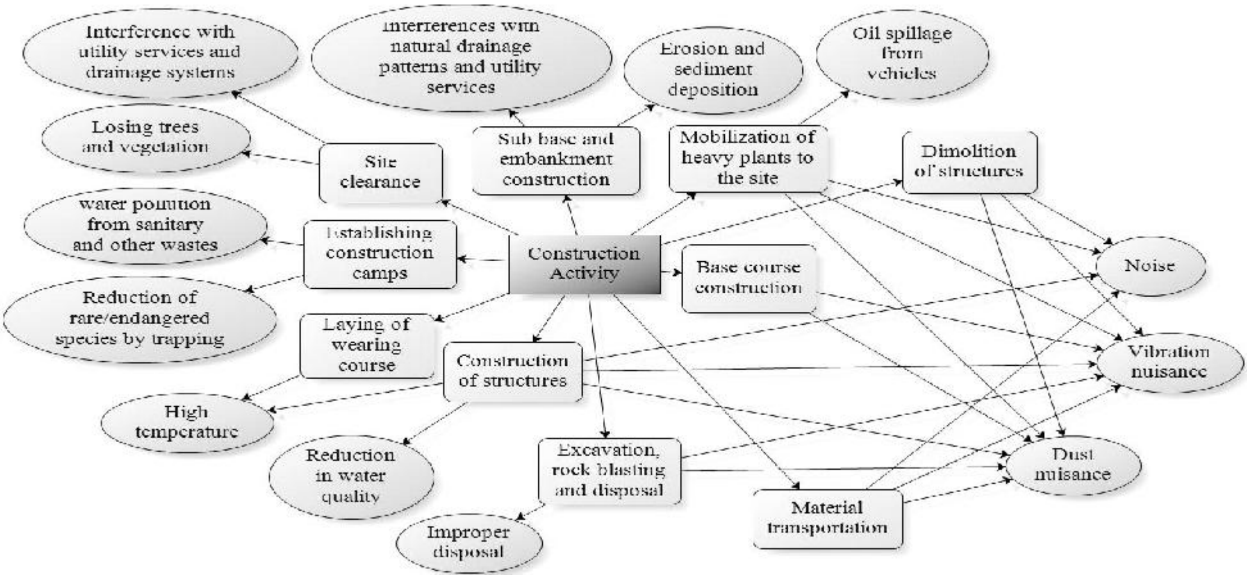


Figure 2: Cognitive Map which Elaborates the Relationships of Road Construction Activities and Environmental Hazards

4.3. ENVIRONMENTAL HAZARD MITIGATION METHODS FOLLOWED IN THE SELECTED CASES

There were several similarities as well as differences in the ways of addressing environmental hazards within each case. Each elimination method followed in the selected cases under identified environmental hazards had been recognized (see Table 2) through interviews as well as documentary survey. According to the empirical data, it was revealed that the magnitudes and effects of environmental hazards differ according to the case characteristics which has affected on environmental hazard controlling being highlighted within the case. However, most of the activities addressed within the cases were found to be common. It is obvious that some of the hazard mitigation methods are to be followed in all the selected cases due to the similarities in construction process.

4.4. FUND ALLOCATION FOR ENVIRONMENTAL HAZARD CONTROLLING AND PAYMENT TO THE CONTRACTOR

As illustrated in Figure 2, there is an obvious relationship among the construction activities and environmental hazards. According to the empirical data, it could be identified that different ways of fund allocating have been followed within the selected cases for addressing these environmental hazards. The empirical data revealed that the cases have been funded for controlling environmental hazards mainly under O/H (overhead), P (profit), provisional sums (PS), as work items and under a main work item. Therefore, it becomes obvious that the environmental hazard controlling costs for the contractor are covered through the contract sum of the project.

Furthermore, the fund allocation within the cases can be categorized under **direct funds** where the payments are done as PS, lump-sum or under unit rates. The direct funding in the selected cases can be highlighted through the mitigation methods adopted within the project such as; ‘top soiling’ used in case A, ‘constructing retaining walls’’ in case B and ‘chemical blasting’ in case C where the payments are done under the work item. Further, **indirect funds** can be identified as O/H, P and covered under a main work item. ‘Using secondary containers to store oil’ in case A, ‘using sand sacks to cover blasting areas’ in case B and ‘moistening transported material such as ABC’ in case C can be identified as some of the examples from the selected cases for indirect funding. Additionally, hazard controlling methods where **no fund** is allocated within the project could also be identified in case A where they had initiated environmental friendly activities going in line with ISO (International Standardization Organisation) 14000 standards. According to the case studies, it was revealed that some unexpected hazard controlling methods had been funded under **variations or project contingencies** such as constructing of bypass roads to avoid unexpected water level increments in case A.

Four types of payment methods cold be derived from the empirical findings named as; Payment methods A, B, C and D which are indicated as existing payment method in Table 2 and further described next. According to the empirical findings, **payment method A** describes the work items where the payment is done according to **a unit rate**. It becomes obvious that according to the sorted out list of hazard controlling methods which are paid under payment method A, mainly each work has significance in providing a basis to be measured. Therefore, it can be identified that where a measurement is directly visible, this payment method has been adopted. For an example, the controlling methods such as using hammers and excavators as alternatives to vibrator machines; backfilling pits after tree removal; top soiling and turfing can be paid considering the area of the work. Further, the methods such as planting shrubs; embankment shrubs; planting interchange palm trees; foliage plants and planting informal hedge trees can be measure either by numbers or linear meter. Additionally, according to contractor Quantity Surveyor (QS) of case A, if the hazard can be identified, justified and quantified, in the initial stage, it can be included under a unit rate. However, System Management Engineer of case A stated that; *"other methods are much effective than including as rate. Most of the hazards are unforeseeable. If the contractor is well experienced, it can be effective for him. If the contractor couldn't cover the cost within the budget, he may not try to control the environmental hazards".*

According to the **payment method B**, a specified item is covered under a **PS** which is paid to the contractor considering the actual costs. The research findings revealed that the work items such as maintaining standards and conditions of waste disposal; constructing temporary structures; rehabilitating utility services; repositioning utility services; design changes on utility services locations and identifying the species that can be affected by construction activities and planning to mitigate the damage are paid under this payment method. Normally, conflicts can occur if a payment is not allocated for environmental issues which are foreseeable but the occurrence is unpredictable. The empirical findings reveal that in order to avoid such circumstances, payment methods like PS can be followed. Further, as revealed by Contractor QS of case B, provisional sum is better as it deals with the actual cost during the execution of the works. Moreover, Consultant QS case B stated that; *"if the cost of a controlling method is included in the rate, the contractor can implement it or neglect it as no one notices. But if it is given as a provisional sum, then it can be forced to be done. And also it is paid if only required. If it is given as a lump sum, then even if the work is so small, the full payment has to be done".*

For some items of work where fixed amounts are assigned in the contract, payment is provided in **equal amounts on pro-rata basis** in each month as identified in **payment method C**. According to the empirical findings, mainly the controlling methods such as conducting base line survey within the project in order to monitor the work generating waste; establishing fuel stations; using an environmental emergency preparedness plans which describe how to mitigate the impact on environment are paid under this payment method. However, the controlling methods are identified as paid under this method as well as under the payment method of D. As revealed by Residential Engineer of case C; *"monthly payment under a rate is more effective as it can be used to influence the contractor by monitoring him against it. If there is something like a check list, then the contractor is forced to do the work. If the payment is reduced, then he knows what he missed to conduct. The specification should include a breakdown with percentage indicating the items to cover by the payment".* Therefore, it can be argued that the payment method C becomes more suitable when there are work items to be paid a certain amount periodically during project duration. However, it was revealed that the limitation that can be found in lump sum payment is estimating the amount. Only a well experienced person can predict a sufficient amount at the beginning of the project.

As revealed by empirical findings, the **payment method D** is used where the cost of the item is included under a certain main item in the contract. The payment for the main work item can either be given as a PS or a unit rate. Work items such as; establishing separate disposal yards; using water bowser to spray water; using the minimum area to excavate pits when removing trees; cutting trees piece by piece can be categorized under this payment method. It was evident that the items where a direct expense cannot be determined without the assistance of main items are categorized under this payment method. However, Contractor Project Manager (PM) of case A revealed that; *"if the mitigation cost is included in the BOQ* *rate, it might be difficult as the expected impacts vary with the perspectives of a person. It cannot be properly measured. If the hazard controlling is included under a rate and if the contractor failed to implement it, an amount can be deducted from the payment. That will be disadvantageous for the contractor. Therefore, it is better if there is a separate item. Then there is no risk of losing the payment for the completed work".* Next, the optimum payment method for environmental hazard controlling process is discussed.

4.5 OPTIMUM PAYMENT METHOD FOR ENVIRONMENTAL HAZARD CONTROLLING PROCESSES

In order to find the most effective payment method, a questionnaire survey was conducted usng the same participants of the interviews and analysed the survey data seperately for each case. The main intention of conducting the survey was to summarize the environmental hazards of each project found through the inteviews, observations and documentary survey and select the most effective payment evaluation method applicable if a proper control of environmental hazards to be obtained. The questionnaire was distributed in order to prioritize the payment method for hazard controlling considering the effectiveness. As the characteristics as well as environmental hazards of the cases were found to be different to each other, 3 different questionnaires had to be developed. Relative Important Index method was used to rank the payment methods under each environmental hazard elimination method. Analysis of the quanititative data was done for each case seperately without aggregating the data. The summarized optimum payment methods under each environmental hazard controlling method of the three cases are tabulated in Table 3.

The payment methods highlighted in bold letters owns the highest RII value when several methods available. Table 3 disclosed that according to the analysis, the optimum payment methods of the contractor for controlling environmental hazard in the selected cases can vary from the existing method. Moreover, it could be identified that certain controlling methods do not contain any optimum payment methods while the second best option of certain payment methods does not reach the expected effectiveness level of the next best payment method.

Table 2: Optimum Payment Method(s) for Hazard Controlling Process

Hazard controlling method		**Payment method**			
		Optimum method(s)	**Next best method(s)**	**Moderately effective method(s)**	**Existing payment method(s)**
CASE A	Using the minimum area to excavate pits when removing trees	D			D
	Cutting trees piece by piece	D			D
	Backfilling pits after tree removal	A	D		A
	Top soiling	A/D			A
	Identifying the species that can be affected by construction activities and planning to mitigate the damage	B/C			B or C
	Providing sanitary facilities	C			D
	Maintain standards and conditions of waste disposal	C	B		B
	Conducting base line survey within the project in order to monitor the work.		B/C		C
	Advising labourers on disposing litter like polythene in a proper manner.			D	D
	Following criteria to properly dispose the waste.			D	D
	Establishing fuel stations	C			C
	Using secondary containers to store oil.			D	D
	The labours are instructed to use a tray to avoid spillage				D
	Using environmental emergency preparedness plans		C		C
	Rehabilitate utility services	B		C	B
	Cleaning the drainage paths and channels	A		B	A
	Design changes on utility services locations	B		C	B
	Covering generator and crusher plant with rubble mountings	D		C	D

	Hazard controlling method	Payment method			
		Optimum method(s)	Next best method(s)	Moderately effective method(s)	Existing payment method(s)
	Following standards when using vehicles	D			D
	Proper monitoring when demolishing structures	D	A		A
	Using hammers and excavators as alternatives to vibrator machines	A	D		A
	Chemical blasting	A	D	C	A
	Measuring and monitoring noise levels			C	A
	Establish separate disposal yards		C/D		C
	Proper disposal of excess asphalt	D			D
	Using shoring	A	D	B/C	A
	Using bitumen bowser as an alternative for manual bitumen spraying	D		B/C	D
	Using water bowser to spray water	C	B/D		C
	Spraying water when demolishing structures	D		C	D
	Constructing asphalt plant to emit the air into a covered water bay		D	B	D
	Turfing	A			A
	Rip rap protection for embankment slopes	A			A
	Constructing lead away structures	A	B		A
	Construction of concrete structures	A			A
	Constructing temporary structures	B	D	C	B
CASE B	Changing the design by shifting the centre line		A/B	D	A
	Providing sanitary facilities	B	A/C	D	D
	Establish separate disposal yards	B	A/C/D		D
	Rehabilitate utility services	B		C/D	B
	Repositioning utility services	B			B
	Chemical blasting	A		B/C/D	A
	Using sand sacks to cover blasting areas		C/D	A/B	D
	Using steel safety nets around blasting areas		B/A/D	C	D
	Proper maintenance of vehicles	B	A/C	D	A
	Maintaining noise level less than 20,000Hz.			C/B/D	D
	Using polythene layer to cover the surface of transported material like ABC	C	B	D	D
	Using tar polythene layer when demolishing structures			B/C/D	D
	Spraying water when demolishing structures	C		B/D	D
	Treating water used for concreting before releasing to the environment	C	B	D	D
	Constructing retaining walls and protection walls	A	B	C/D	A
	Turfing	A		B/C/D	A
	Constructing lead away structures	A	B	C/D	A
	Using polythene layer to cover up erodible areas	C		B/D	D
	Constructing earth drains	A	B	C	A
	Constructing concrete U drains	A	B	C	A
	Top soiling	A		B/C/D	A
	Rehabilitate the old culvers	C	B	A	D
CASE C	Planting shrubs, embankment shrubs, turfing and the like	A/B	C		A
	Planting interchange palm trees	A/B	C	D	A
	Planting interchange foliage plants	A/B	C	D	A
	Planting informal hedge trees	A/B	C	D	A
	Planting informal hedge shrubs	A/B	C	D	A
	Providing sanitary facilities	D		B/C	D
	Rehabilitate utility services	B	D	C	B
	Covering generator with cement blocks	B	A/C	D	A
	Change the machinery when not suitable to work			B/D	D
	Chemical blasting	A	D	B/C	A

Hazard controlling method	Payment method			
	Optimum method(s)	**Next best method(s)**	**Moderately effective method(s)**	**Existing payment method(s)**
Checking and monitoring the status of vehicles	B/C	D		A
Conducting a crack survey	B/C			D
Using ITI technique to monitor vibration	C	B		A
Establish separate disposal yards	C/D	B		A
Using dust barriers	D	A/B	C	D
Using water bowser to spray water	B/D		A/C	D
Moistening transported material like ABC	D	B		D
Following safety regulations		B/C/D	A	A
Covering asphalt while transporting	D		B/C	D
Using a cooling system when placing concrete	D		B/C	D
Stone masonry slope protection	A	B	C	A
Cut slope ground cover	A	B	C	A
Diverting the drain systems	B	C		D
Reconstructing drain systems	B/C			D

5. CONCLUSIONS

For this study, only the activities where the direct involvement of the contractor was visible were taken in to consideration and the environmental hazards within the selected cases had been identified. The identification mainly included with the activities such as site clearance; establishing construction camps; demolition of structures; excavation, rock blasting and disposal; sub-base and embankment construction; base course construction; laying of wearing course; material transportation; construction of structures and mobilization of plants to the site and machinery usage. However, the selected cases revealed that the activities such as borrow pit establishment which had been identified by Chaudhary (2011) as construction activities in road projects are not directly conducted by the contractor due to the involvement of the subcontractors. Therefore, taking such activity in to consideration for the study had to be evaded. The empirical data revealed common as well as project specific environmental hazards in road construction projects under the execution of the selected construction activities. Environmental hazards such as loss of trees; interference with services; dust nuisance; noise; vibration; water pollution from wastes; interference with natural drainage paths; reduction in water quality; oil spillage; reduction of rare species by trapping and temperature differences were identified within the selected cases. Further, the hazards such as gas emission through asphalt which had been addressed as an environmental hazard by Chen *et al*. (2000) have not been recognized within the case studies.

Subsequently the hazard controlling methods followed in the construction industry for achieving proper control of environmental hazards in road construction were discovered. However, the hazard mitigation methods identified by Chaudhary (2011), such as ‘supervising archaeologists for excavation to avoid any damage to the relics and objects’ had not been addressed within the selected cases. The case study findings were then used to identify the methods of fund allocation in road construction projects for environmental hazard controlling in Sri Lankan context. Accordingly, four main fund allocation methods for environmental hazard controlling in road construction projects could be revealed as direct fund allocation, indirect fund allocation, non-fund allocation and variations or contingencies. Even though U.S. Department of Transportation-Federal Highway Administration (1997) has identified that the fund allocation for environmental hazard controlling can be given as a percentage of the total contract sum, the case study revealed it becomes impracticable to do the allocation accurately due to the difficulty in identifying the costs independently.

The main methods of payment for the contractor for environmental hazard controlling include; (A)-payments where a unit price is assigned; (B)-payments where a provisional sum is established in the contract; (C)-payments where fixed amounts are assigned in the contract and (D)-payments made along with some main work item in the contract.

Further, with regard to the outcome of the study recommendations could be provided for selecting the optimum payment method considering the features of the hazard mitigation method used. Thus, the payment method A becomes more suitable for the mitigation methods where a visible measurement is involved. When the cost of a mitigation method is not acutely predictable but can be roughly estimated, method B becomes most suitable. If the mitigation method occurs repetitively and periodically under a certain cost, method C can be recommended. The method D becomes more effective where the cost of the mitigation method is not directly visible. Table 2 summarizes the aforementioned four payment methods selected as the optimum payment method against each environmental hazard controlling mechanism.

Hence, it could be suggested that these findings could be important for bidders/estimators mainly in the pre-contract stage where an effective control of environmental hazards is expected through the due payment for the contractor in a road construction project.

6. REFERENCES

Ashworth, A., 1996. *Pre-Contract Studies: Development Economics, Tendering and Estimating*. England: Addision Wesley Longman Limited.

Bass, B. and Avolio, B., 1993. Transformational Leadership and Organisational Culture. *Public Administrative Quarterly*, 7(1), 112-121.

Carter, H., 2010. *There is a Cost for Everything* [online]. Available from: http://www.firehouse.com/blog/10459706/there-is-a-cost-for-everything [Accessed 4 February 2014].

Central Provincial Road Development Authority Sri Lanka, 2012. *JICA Funded provincial Road Development Project in Central and Sabaragamuwa Provinces: Special Specifications.* Sri Lanka.

CH2M Hill, ICF International, University of Florida and Venner Consulting, 2008. *Guide to Estimating Environmental Costs* [online]. Available from: http://environment.transportation.org/pdf/proj_delivery_stream/nchrp2525task%2039guidance.pdf [Accessed 4 February 2014].

Chaudhary, R., 2011. Environmental Protection Measures in Planning Construction Operation and Maintenance of National Highways in India [online]. *International Journal of Advances in Engineering Research*, 2(3). Available from: http://ijaer.com/ webmaster/upload/Sep_2011_Rakesh%20Chaudhary%201.pdf [Accessed 19 January 2014].

Chen, Z., Li, H. and Wong, C., 2000. Environmental Management of Urban Construction Projects in China. *Journal of Construction Engineering and Management* [online], 126(4), 320–324. Available from: http://www.conradtcwong.com/ environmental_management.pdf [Accessed 18 January 2014].

Da Silva, P.R.S. and Amaral, F.G., 2009. An Integrated Methodology for Environmental Impacts and Costs Evaluation in Industrial Processes [online]. *Journal of Cleaner Production*, 17(15), 1339–1350. Available from: http://www.sciencedirect.com/science/journal/aip/09596526 [Accessed 2 February 2014].

Darrington, J. W., 2010. Addressing Human Motivation [online]. *The Voice of the Construction Industry*, 40(2), 18-19. Available from:

http://www.hansonbridgett.com/~/media/Files/Publications/Addressing%20Human%20Motivation%20in%20construction%20contracts.pdf [Accessed 4 February 2014].

Deng, X., Hu, Y., Deng, Y. and Mahadevan, S., 2013. Environmental Impact Assessment Based on D Numbers [online]. *Expert Systems with Applications*, 41, 635–643. Available from: http://www.sciencedirect.com/science/article/pii/ S0957417413005897 [Accessed 3 January 2014].

Ferry, D. J., 1964. *Cost Planning of Buildings.* 4th ed. Frogmore, St.Albans: Granada Publishing Limited.

Florida Department of Transportation, 2013. *Standard Specifications for Road and Bridge Construction* [online]. Available from: http://www.dot.state.fl.us/specificationsoffice/Implemented/SpecBooks/2013/Files/2013eBook.pdf [Accessed 18 March 2014].

Griffith, A., Stephenson, P. and Watson, P., 2000. *Management System for Construction*. New York: Pearson Education Inc.

Iowa Department of Transportation, 2005. *Section 2602: Water Pollution Control (Soil Erosion)* [online]. Available from: http://www.iowadot.gov/erl/archives/apr_2005 /GS/content /2602.html [Accessed 18 January 2014].

Lakmal, D.M.K., 2013. *Environmental Issues and Their Influence on the Contractors' Performance in Sri Lankan Road Construction Projects*. University of Moratuwa, Sri Lanka.

Local Government of UK, 2013. *Local Government Air Quality Toolkit: Air Quality Guidance Note: Construction Sites* [online]. Available from: http://www.environment.nsw.gov.au/resources/air/mod3p3construc07268.pdf [Accessed 3 January 2014].

Macek, N.M., 2006. *Right of Way and Environmental Mitigation Costs Investment Needs Assessment* [online]. Available from: http://onlinepubs.trb.org/onlinepubs/archive /NotesDocs/20-24(54)_B_%20FR.pdf [Accessed 3 January 2014].

Ofori, G., 1992. The Environment: The Fourth Construction Project Objective? [online]. *Construction Management and Economics*, 10(5), 369-395. Available from: http://www.tandfonline.com/doi/abs/10.1080/0144619 9200000037#.UwhMfTs_uaI [Accessed 4February 2014].

Orr, J., 2014. *Everything Has a Cost* [online]. Available from: http://leadchangegroup.com/everything-has-a-cost/ [Accessed 18 March 2014].

Road Development Authority of the Ministry of Highways, Sri Lanka, 1989. *Standard Specifications for Construction and Maintenance of Roads and Bridge*. Sri Lanka.

Road Development Authority Sri Lanka, 2011. *Miscellaneous Foreign Aided Projects – B093: Bidding Document.* Sri Lanka: Author.

United States Department of Agriculture, 2011. *Construction Specification 405: Pollution Control* [online]. Available from: http://www.nrcs.usda.gov/Internet/FSE_ DOCUMENTS/nrcs141p2_001985.pdf [Accessed 4 February 2014].

U.S. Department of Transportation-Federal Highway Administration, 1997. *Federal Highway Cost Allocation Study Final Report* [online]. Available from: http://www. fhwa.dot.gov/policy/hcas/final/three.htm [Accessed 18 March 2014].

Yin, R.K., 2003. *Case study research: design and method.* 3rd ed. California: Sage publications Inc.

PROJECT COMMUNICATION WITHIN SMALL AND MEDIUM-SIZED CONSTRUCTION FIRMS

B.M. Aidoo*, C.O. Aigbavboa and W.D. Thwala
Department of Construction Management and Quantity Surveying, Faculty of Engineering and Built Environment, University of Johannesburg, Johannesburg, South Africa

ABSTRACT

Communication is considered as a tool in the heart of management in enhancing project targets and Milestones not only in the construction sector but other sectors as well. The construction industry has however been characterized with its massive investment and associated risks. As a result, when main and sub-activities and tasks to be executed on project sites are not properly communicated among project teams and stakeholders, it will vehemently incur additional cost on the project, cause injury from accidents and may delay the entire project completion schedule amongst others. This exploratory study seek to establish the project communication structure used by construction SME's and also to develop a pattern within the communication structure of SME's that will avert uncertainties in a form of barriers to their communication. In order to accomplish the exploratory study, semi-structure interview sessions were conducted among construction professionals and clients via purposive sampling. The targeted population for the study was adequately prepared as a result of the prior notification for the interviews. Findings from the study revealed that most of the construction SME's do not have established communication structure in their operations. Further, the SME's only realized the need for a communication pattern when they encounter complex issues such as dispute on a claim with clients and stakeholders. The study recommends that prior to the execution of projects by SME's, the communication lines must be clearly defined as well as the reporting a system with an in-depth briefing for all team members and stakeholders to be privy.

***Keywords**: Communication; Construction; Project; Small and Medium-Sized Firms.*

1. INTRODUCTION

Communication is an important theme in the construction industry, as has been captured in the literature. As a result, communication is considered as a tool in the heart of management in enhancing project targets and milestones not only in the construction industry but other industries are well. Jeyachandran (2012) asserts that the efficiency and effectiveness of the construction process more importantly depend on the quality of communication (verbal and non-verbal) among the project teams and stakeholders. The need to communicate effectively is the heart of any business such as construction, automobile, pharmaceutical amongst others. No matter the individual's knowledge and skills, if it is not effectively communicated, the ideas will be unable to succeed in their endeavours (Emmitt and Gorse, 2003). Often problems in construction are referred to as communication problems. Latham (1994) and DETR (1998) have established that frequent construction problems that emanate are as a result of communication problems. Communication is as vital to both large and small and medium-size firms. Axley (1994) affirmed that communication is view as a metaphorical pipeline along which information is transferred from one person to another. Further, Awati (2010) affirmed that communication is also the lifeblood of any system of human interaction as, without it, no meaningful or coherent activity can take place (Thomas, 1988). Due to the unique characteristics of the construction industry been labour intensive and the large number of varying ethnic backgrounds of labour recruited for project forms a complex communication environment. Similarly, Construction is a fragmented and dynamic sector with a project based nature, and this makes many stakeholders operate infrequently changing sets of relationships that are contractually driven. The culture shows a reality of conflicts and lack of mutual respect and trust

* Corresponding Author: E-mail – bemardmartins@hotmail.com

(Dainty *et al.*, 2006). As a result, the role of communication in construction projects cannot be over emphasized as various professionals and stakeholders in the construction industry must communicate effectively on any given project for a successful delivery. Communication among small and medium-sized construction firms that lacks managerial skills is a complex activity and, therefore, difficult to be achieved. Communication problems are always associated with these features such as reported late, not having the information, difficulty in accessing information furnished by other stakeholders and also establishing of multiple of communication channel which are not clear to the project teams resulting in further communication problems. These communication problems among SME's are usually characterized with numerous issues during construction project such as hazards, accident, delay of schedule tasks, understanding, waste, delays on the entire project duration and increased in the cost of the project. As the a result, this study seeks to explore the existing communication patterns used by small and medium-sized construction firms on projects and also to determine prudent channels of communication among these firms to facilitate successful implementation of their projects

2. LITERATURE REVIEW

Communication has been defined in the literature in various viewpoints. Perumal and Bakar (2011) established that communication is the process in which information is encoded and imported by a sender to be received via a channel or medium. Fielding (2005) defines communication as a transaction that is People working together to create meaning by exchanging symbols. People have to ensure they share the same meaning when they use words. Similarly, communication is defined as the process require to ensure timely and appropriate generation, collection dissemination, storage, an ultimate implementation of project information (PMI, 2008). According to Barrett (2006) communication is defined as the transmission of meaning from one person to another or many people, whether verbally or non-verbally. The communication process reviews the process of information flow from the sender to the receiver, including how barriers may prevent effective communication. It is important to plan communication because barriers and noise that may influence the effectiveness of the communication (PMI, 2008). Planning communication should include knowing the project structure, what communication plan entails the flow of communication in different directions, and internal and external project communication.

2.1. MANAGEMENT OF PROJECT-BASED COMMUNICATION

Project-based communication management consists of the processes required to ensure timely and suitable generation, collection, distribution, storage, retrieval and ultimate disposal of project information. PMI (2008) asserts that managers of projects spend lots of their time in communicating with team members and other stakeholders, either internally within or externally to the organisation. PMI (2008) further established the following process for efficient management of communication for a project:

- Identify stakeholders
- Plan communications
- Distribute information
- Manage stakeholder expectations
- Report performance

Kerzner (2009) argued that effective communication ensures that project members deliver the right information to the right persons at the right time and in a cost-effective manner. Steyn (2008 cited Zulch 2012) supported that effective communication is the key to ensuring coordination and integration of execution of projects. Communication is essential for all business activities. It makes organising possible, and organising is part of the communication process. Effective communication in and between organisations supplies a positive contribution to construction projects that increase production and improve motivation of team members (Emmitt and Gorse, 2003).

2.2. Types of Communication

In order to facilitate the understanding of communication within SME's firms, the highlights study on the types of communication within the organisation as affirmed by Emmitt and Gorse (2003).

2.2.1. Intra-Personal Communication

The internal communication process cognition includes the manifestation of information in the brain. Intra- personal communication is characterized by only one person such some researchers do not consider it as a communication.

2.2.2. Inter-Personal Communication

This is a conversation that ensues between two or more people to enable individuals to establish and maintain the relationship. This involves the transfer of signals and messages.

2.2.3. Mass Communication

This type of communication uses channels such as media, radio, television, and newspapers, large audience, individuals and groups perceive meanings to the message they receive via this medium depending on their culture and norms.

2.2.4. Group Communication

This communication ensues when messages are conveyed to a group. This is presented in a way that disseminates the message to the entire group or individual**.**

2.3. Communication Flow Processes

The process of communication includes acquiring all relevant information, interpreting this information and effectively disseminating the information to the rightful persons. Communication is of vital importance to everyone involved in and influenced by projects (Emmitt, 2010). Project team members need to collaborate, share, collate and integrate information and knowledge to realise project objectives. Therefore, it is prudent to understand the process of communication (Hoezen *et al.*, 2003). At its most basic level, communication consists of three components: a transmitter/sender, a transmission channel/medium and a receiver. A fourth element, the medium of communication is the code in which a message is transmitted (Steyn, 2008). The message flows from the source or the sender, encodes (package) the message through the transmission channel/medium by a verbal or non-verbal method, to the receiver that decodes the message Zulch (2012). In order to ascertain effective communication, all components must function to prevent unclear communication during the process (Liu 2009). Uncertain barriers and noise may set in during the process of communication if measures are not established to control it. Flowchart of communication process among small and medium-size firms is shown in Figure 1.

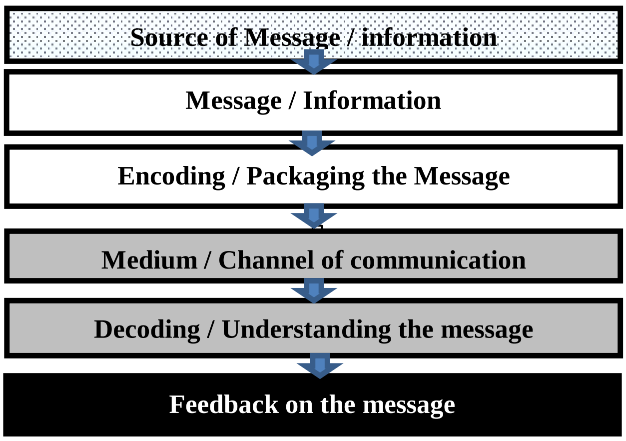


Figure 1: Flowchart of Communication Process (Adapted from Zulch, 2012)

2.4. *BARRIERS TO PROJECT COMMUNICATION*

Communication barriers are the obstacles that prevent the flow of message to be delivered for a successful implementation of an action. No matter how efficient a communication structure of a firm maybe there are possible of barriers occurring. Guffey (2010) established the following as communication barriers as depicted in Table 1 below.

Table 1: Barriers to Project Communication

Item	Type of Barrier	Impact of Communication Barrier
1	Lack of Communication Skills	When the conveyor of the message does not communicate clearly interns of use of grammatical words, it would mean to the recipients.
2	Overloaded message	When received messages are over loaded it turns out to be difficult to comprehend.
3	Inadequate knowledge of the subject	If the conveyor of the message lacks information, then the receiver will likely receive an unclear message.
4	Extended communication chain	The more extended the communication chain, the greater the chance for error.
5	Inadequate feedback	Inadequate feedback can interfere with good communication.
6	Lack of interest	When the receiver gets the message that he or she is not interested, he or she may hurriedly read or ignore it leading to miscommunication.
7	Communicating complex message	Communicating a complex message without the technical skills or grade will make the message unclear to your receivers.

Source: Adapted from Guffey (2010)

3. RESEARCH METHODOLOGY

A number of studies on communication on firm whether large, small and medium size has focused on sole barriers to effective communication and how to control these barriers. However, very little have been done on the existing project communication pattern of small and medium-size firms for a successful project delivery. In view of that exploratory research, technique was adapted to determine existing communication patterns used by small and medium-sized construction firms on projects to determine prudent channels of communication among these firms to facilitate successful implementation of their projects. To accomplish the goal of the study, semi-structured interview session was conducted among construction professionals and clients via purposive sampling. A targeted population size of eighteen was adequately prepared as a result of the prior notification of the semi-structure interviews. However, in all only twelve interview sessions were conducted with the aid of scheduled guide and recorders and were subsequently transcribed. Each Interviewee had a total of eight minutes duration to answer all the scheduled questions.

4. FINDINGS AND DISCUSSIONS

Three of the construction professionals working with the sampled small and medium-sized construction firms remarked that for communication to thoroughly efficient, it is always prudent that strategic issues would generally be communicated at senior management level rather than to the workforce, in general, this affirms Emmitt (2010) which argued that Communication is of vital importance to everyone involved in projects. Further, two of the interviewees stressed that their firms do not have structured standardized communication format. As a result they adopt, and communicable pattern that is available to the firm during the execution of projects and this sometimes make communication vague and unclear as supported by Zulch (2012). Similarly, another interviewees affirmed that because most of the projects engaged in by these construction SME’s are not significant in nature, their management finds it reluctant to formalize the communication within the firm this usually distort communicated messages. The entire professionals interviewed indicated that their firms' draw-up communication lines only when they tender for public contracts, otherwise their firms do not have any identifiable communication pattern. It was clear from the interviews that though owners of these SME's have managers in charge of the routine operations with an agreed way of communication of their owners, this communication lines are always distorted by the owners when it concern finance matters such as reinvesting into another sector. Some of the interviewees were of the view that they operate in a competitive environment and as such their communication structures make their firm unique opens linkages to win contracts. Further, the interviewees stressed that their structured routes in communication includes the regular issue of company magazines, discussion workshops for all employees and consultation committees.

5. CONCLUSIONS

Communication, as captured in this study, is a prerequisite of a successful project delivery. The study concludes that for a project-based communication to be successful, the following consideration must ensue:

- All the project stakeholders must be engaged in communication meeting
- Establishment of unique communication structure (Communication lines must be drawn).
- Detail explanation of agreed communication structure (Free from complex language)
- Availability of accepted communication medium
- Frequent evaluation of approved communication structure (To eliminate any envisage barrier that will encourage any due delay).

Owners of small and medium-sized firms, as established from the findings, do sometimes distort the agreed communication pattern between them and their stewards. Further, the study revealed that because the small and medium-size firms do embark on small projects and as such managers through the influence of the owners do not value the relevance of establishing a communication structure for such small projects they execute.

6. RECOMMENDATIONS

To achieve effective project-based communication among small and medium-sized construction firms, it is significant to manage successfully team communication. A range of factors impact project team communication effectiveness such as the kinds media communication tools use to aid the communication process, large volume of information to manage and to disseminate, the medium in terms of the language to disseminate the message to make it clear and the routine at which communication is done. Further, to accomplish an effective project communication consideration must also be made prior to the execution of projects by SME's, so that communication lines are being clearly defined as well as the reporting system with an in-depth briefing for all team members and stakeholders to be privy this will avert and misunderstanding occurring. There must be collaborations between owners and managers of these SME's so that those owners will have limitation in order not break up any agreed communication structure.

7. REFERENCES

Awati, K., 2010. *Obstacles to Project Communication* [online]. Available from: http://www.projectsmart.co.uk/obstacles-to-project-communication.html [Accessed 20 March 2015].

Axley, S., 2000. Communication Change: Questions to Consider. *Industrial Management*, 42(4), 18- 22.

Barrett, D.J., 2006. *Leadership Communication*. Boston: McGraw-Hill Education.

Burke, R., 2010. *Fundamentals of Project Management: Tools and Techniques*. Ringwood: Burke Publishers.

Dainty, A., Moore, D. and Murray, M., 2006, *Communication in Construction Theory and Practice*. London: Taylor and Francis.

DETR, 1998. *The Report of the Construction Industry Task Force: Rethinking Construction (The Egan Report)*. HMSO.

Emmitt, S. and Gorse, C., 2003. *Construction Communication*. Blackwell Publishing Ltd.

Emmitt, S., 2010. *Managing Interdisciplinary Projects: A Primer for Architecture, Engineering and Construction*. London: Spon Press.

Foley, J. and Macmillan, S., 2005. Patterns of Interaction in Construction Team Meeting Co-Design. *Taylor and Francis Online,* 1(1), 19-37.

Fielding, M., 2005. *Effective Communication in Organisations*. Lansdowne: Juta.

Guffey, M. E., 2010. *Essentials of Business Communication*. 8th ed. South-Western/Cengage: Los Angeles.

Jeyachandran, S., 2012. Communication is the Key to Effective Construction Management in Small and Medium Enterprises. *Strength for Today and Bright Hope for Tomorrow*, 12(2).

Hoezen, M.E.L., Reymen, I.M.M.J. and Dewulf, G.P.M.R., 2003. *The Problem of Communication in Construction*, Netherlands, University of Twente, Enschede

Latham, M., 1994, *Constructing the Team*. HMSO.

Liu, Y., 2009. *Critical Factors for Managing Project Communication among Participants at the Construction Stage*. Thesis (PhD). Hong Kong Polytechnic University.

Kerzner, H., 2009. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*. 10th ed. Hoboken, NJ: Wiley.

Perumal, V.R. and Bakar, A.H.A., 2011. The Need for Standardization of Documentation towards an Efficient Communication in Construction Industry. *World Applied Science Journal*, 13(9), 1988-1995.

Project Management Institute (PMI), 2008. *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*. 4th ed. Newtown Square, Pa: Project Management Institute.

Steyn, H., 2008. *Project Management: A Multi-Disciplinary Approach*. 2nd ed. Pretoria: FPM Publishers South Africa.

Thomas, S.R., Trucker R. L. and Kelly, W.R., 1998. Critical Communication Variables in Journal of Construction. *Engineering and Management*, 24(1).

Zulch, G.B., 2012. *The Construction Project Manager as Communicator in the Property Development and Construction Industries.* Thesis (PhD). University of the Free State Bloemfontein, South Africa.

RE-EXAMINING CONTRACTOR'S BIM STRATEGIES: A CASE STUDY

Hongdi WANG, Leo Ke CHEN* and Weisheng LU
Department of Real Estate and Construction, The University of Hong Kong, Hong Kong

ABSTRACT

In the construction industry, building information modelling (BIM) is a promising technology to maintain a contractor's business competitive advantages. Although some BIM guides for contractors have been released by a set of countries or institutes, the BIM strategies as a part of contractors' business developmental strategies are rarely discussed. This paper aims to empirically investigate the BIM strategies for contractors from the institutional perspective. A case study of a German contractor is conducted. Data collected through interviews, site visit, and survey/questionnaire are analysed to identify the best practices in a leading contractor company in BIM lifecycle implementation. Suggestions are provided to better implement BIM in contractors' long-run business developmental strategies.

Keywords: *Building Information Modelling (BIM); BIM Strategies, Contractor.*

1. INTRODUCTION

Building Information Modelling (BIM) is gaining significant momentum in the development of construction project delivery methods for the past decade (Davies and Harty, 2011; Eastman *et al.*, 2011; Chen *et al.*, 2015). The adoption of BIM possesses enormous potential benefits and meanwhile brings challenges to various professionals in the construction industry. As both the information communication technology and process, BIM shall be appropriately implemented in the company business development strategies. Only by doing this, the potential benefits of BIM implementation could be fully achieved (NBIMS, 2007, 2012; Davies and Harty, 2011). Even though BIM guides or standards have been issued in many countries or regions (Zeiss, 2013; HKIBIM, 2009), and the contractor is increasingly aware of the importance of adopting BIM strategies to sharp their competitiveness in the global and domestic markets, the empirical evidence and best practices on the firm perspective are still scarce. Therefore, related studies would be valuable for the contractors to embrace the new trend of project delivery methods with the implementation of BIM.

This paper starts with the review of BIM concept and the development of BIM in the construction industry. It focuses on the critical factors for a contractor to successfully implement BIM. Particularly, the attention is drawn to regarding BIM implementation as a part of business development strategies for contractors. A case study of a Germany contractor is conducted to investigate the experience and lessons. From the case study, best practices are identified and suggestions on BIM strategies for contractors are made.

2. BIM AND ITS DEVELOPMENT

2.1. CONCEPT

The rise of BIM in the construction industry has been witnessed with an increasing popularity among vast groups of project managers, building professionals, IT vendors, government officers, and the like (RICS, 2013). According to Eastman *et al.* (2011), BIM was "a modelling technology and associated set of processes to produce, communicate and analyse building models". In the National BIM Standard, BIM was defined as "a digital representation of physical and functional characteristics of a facility" which

* Corresponding Author: E-mail - leochen@connecthku.hk

serves as "a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle" (NBIMS, 2007a, 2012b). Davies and Harty (2011) referred BIM to a family of technologies and related practices used to manage the information for the purpose of delivering construction projects.

From the above three elaborations of the BIM concept, two important perspectives are highlighted. One is to regard BIM as information communication technologies (ICT), which enables the storage of building information, such as geometry, spatial relationships, quantities and properties of building components. The other one is to regard BIM as the technology-based processes, which include the 3D design presentation, integrated design and construction, centralized information management, and computer-aided subcontracting management. The basic idea is originated and developed from manufacturing industry. However, it is probably the unique features of the construction project and the traditional managerial processes that hinder the promotion of BIM in the construction industry.

2.2. *ROADMAP*

BIM has gained increasing popularity in the global construction markets. AIA (2006) reported about 60% of large size architecture firms use BIM in the USA. In Finnish, that figure is about 93% according to the Finnish ICT Barometer (2007). A Smart Market Report published by McGraw Hill Construction (2012) found out that 75% of the architecture, engineering, and construction (AEC) professionals in North America used BIM in their projects, and 62% of the surveyed BIM users used BIM on more than 30% of their projects. Furthermore, the promising future of BIM has been notified by many public building owners. Some of them (e.g. UK, USA, Denmark, Finland, Hong Kong, and Singapore) have already issued BIM guides or standards and started to demand the implementation of BIM in their projects. In addition, there has been an international census about the future of BIM in the construction industry. As shown in Table 1, many countries all over the world are building up their BIM roadmaps to utilize the potential benefits of BIM in their infrastructure and building projects.

Table 1: A Summary of BIM Roadmaps in Various Countries

China	12th 5-year plan (2011-2015)
UK	Compulsory after 2016
USA	Compulsory for Government funded Project after 2017
Singapore	Compulsory after 2015
HK	The Hong Kong Housing Authority requires BIM for all its new projects after 2014.
Norway	Encouraging instead of enforcing.
Denmark	Danish state clients such as the Palaces & Properties Agency, the Danish University Property Agency and the Defence Construction Service require BIM to be used for their projects.
Finland	The state property services agency, Senate Properties, require the use of BIM for its projects by 2007.
Germany	National BIM guide has been completed in 2014.
Netherlands	Since 2012 the Dutch Ministry of the Interior (RGD) requires BIM for large building maintenance projects.
South Korea	Compulsory for all large size projects and for all public sector projects by 2016.

Source: Adapted from Zeiss (2013) and HKIBIM (2009)

2.3. *POTENTIALS AND CHALLENGES*

Numerous studies have been conducted to disseminate the potentials of BIM technologies and related practices. The main potential benefits of BIM were summarized by NBIMS (2012) as follows: (1) Reduced cycle time (e.g. better communication, better management of delivery time); (2) Reduced lifecycle cost (e.g. less waste, less re-work, and significantly reduced number of change orders); (3) Improved and sustainable product quality (e.g. off-site prefabrication with higher quality control, less possibility of accident occurrence, and more energy efficient); (4) 3D visualization and planning (e.g. allowing for analysis and simulation, vivid visualization for the client to detail the specifications); (5) Centralized information model (e.g. once established, BIM could be used for various stakeholders throughout the lifecycle); and (6) Fostering collaborative working relationships (e.g. improved communication and collaboration among project participants; higher Quality Project Execution and Decision-Making). Lu *et al.* (2013) summarized that the benefits of BIM implementation in the project delivery have been extensively discussed, such as improvements in engineering and design quality (Patrick and Raja, 2007), better time management (Azhar *et al.*, 2008; Patrick and Raja, 2007), increased labour productivity (Kaner *et al.*, 2008; Patrick and Raja, 2007; Sacks and Barak, 2008), and project cost saving (Sacks *et al.*, 2005). Additionally, these benefits had a number of empirical evidences. For example, CIFE (2007) reported 40% elimination of unbudgeted design changes, enhanced cost estimation accuracy within 3%, 80% reduction in time for cost estimation, and 7% project time saving. Lu *et al.* (2014) and Lu *et al.* (2015) stated that the implementation of BIM contributed about 6.92% cost saving. BIM is even said to be a significant development that it will bring a paradigm shift to the AEC industry.

The challenges of realizing the potential benefits of BIM implementation shall never be overlooked. Azhar (2011) summarized that the major risks of implementing BIM were technical risks (e.g. inter-operability among various information systems, and computability of digital data serving for the professional purposes), management issues (e.g. re-distribution of responsibilities and empowerment, collaborative culture and the operation capabilities of the project participants), legal contracting issues (e.g. ownership and patent rights), and economic issues (e.g. sharing of gains and pains, and payment methods), CIC (2013) pointed out the critical requirements for BIM implementation from the aspect of planning, adoption, technology, and performance, through examining the best practices in some leading countries. Smith (2014) reviewed the development of BIM practices in 10 countries, and identified the challenges of achieving BIM benefits should be handled in aspects of governmental and industrial driving power, national and global technical standard, legal contracts and procurement systems, BIM education and training, and business shift of construction companies. It should be pointed out that some of the challenges could not be dealt by one specific construction company, such as legal issues and the technical bottleneck, whilst some challenges can be overcome within the capacities of a company.

2.4. CONTRACTOR'S BIM STRATEGIES

The contractor is one of the key stakeholders in the delivery processes of the construction projects. Either attitudes of contractors towards BIM or the adopted BIM strategies could have great impacts on the project performance. There are already some reports or standards released especially for the contractors to implement BIM strategies in some countries and regions, like the USA (Ernstrom, 2006) and Singapore (BCA, 2013).More commonly, suggestions for contractors are included in the overall BIM guide or standards, which are made under some conditions and lacking of specificity. One of the assumptions in most of the BIM guides or standards is that every project party in a project open to BIM and dedicated to it. However, the maturity of BIM implementation in the different countries or regions is varying. Only a few countries have achieved relatively high level (see Table 1 as a reference). For most cases with the low level of BIM maturity, a contractor is expected to be more encouraged to take the proactive initiatives to master the BIM as technology and managerial processes.

According to Ernstrom (2006), Eastman *et al.*(2011), and BCA (2013), BIM practices of a contractor can be divided based on the three stages, namely, the tender stage, the pre-construction stage, and the construction stage. For each stage, the processes relating to the BIM implementation are identified: establishing BIM models and cost estimation at the tender stage; reviewing and developing models and model-based project planning/scheduling at the pre-construction stage; construction coordination, setting out and verification on site, prefabrication, and comparison between as-planned and as-built at the construction stage. For every identified process, specific BIM strategies could be employed to enhance the contractor's construction productivity.

However, the project-oriented BIM guides are not enough for a contractor to make significant business shift. As a company, a contractor needs to invest in new technologies, to re-organize its business structure, resources, and working processes, and to lead and train its employees to accept and master new technologies and working processes. To the best knowledge of the authors, the research on the BIM strategies for a contractor, from the perspective of business developmental strategies, is scarce.

3. METHODOLOGY

In this study, institutional analysis of both formal and informal institutions was applied to re-examine the contractors' BIM implementation as a part of their business developmental strategies. Institutional analysis in organisational studies focuses on characterizing the humanly devised rules in a company where humans interact according to certain "rules of the game" (North, 1990). Formal institutions are steady rules, which define the "normative system designed by management" or the "blueprint for behaviour". Whilst informal institutions define the actual behaviour of players (Scott, 1981). North (1990) and Jepperson (1991) argued that formal rules contain political rules, economic rules, and contractual arrangements, and informal rules include taboos, customs, routines, and traditions. Both formal and informal institutions help to give pattern to human behaviour by enabling and constraining their activities.

A case study was carried out in one of the top 10 contractors in Germany (the case company will be referred as the contractor from here on). The construction industry of German has been aware of the potential of BIM, and the contractor has initialled its business shift to BIM early in 2009. Till now, the contractor has harvested the benefits of BIM implementation at the tendering and bidding stage with significant time and cost saving and increased contract winning rate. Three pilot projects are being conducted to strengthen its business competitiveness by implementing BIM throughout the project lifecycle.

The qualitative and quantitative data were collected by mixed research methods, including interviews, field visit, archival records, and survey/questionnaire. Field visit and archival records were used to develop a brief understanding of the management system and strategies of the contractor company. A series of interviews were conducted to deepen the understanding, particularly in the BIM strategies. A survey was then conducted, and questionnaires were sent to the team members of an ongoing project through the company's online survey system. Based on the results of cast study, a framework model of BIM strategies for a contractor is established, and suggestions are made to embed BIM implementation as a part of the contractors' business development strategies.

4. BIM STRATEGIES FOR CONTRACTORS

The institutional settings, including both formal and informal institutions, are important for contractors to achieve BIM strategies in order to realize their business competitiveness. In the case study, some initiatives on formal institutions are identified, i.e. forming a business partnership, adoption of information and communications technology (ICT), setup of organisational structure, procurement arrangement and outsourcing management. Also, some initiatives on informal institutions are identified, which mainly refer to top-to-bottom leadership and encouragement towards new technologies and working processes, BIM education and training, and guidance for gradual BIM based working processes.

4.1. BIM DEVELOPMENT PARTNERSHIP (F1) AND ADOPTION OF ICT (F2)

The strategic shift towards BIM could never be separated from the investment in enterprise information systems and information communication technologies. The contractor is partnering with an IT company R, whose headquarters is located in Germany and business range covers most large-size international construction markets, such as the USA, European region, South Asia, and China. R is providing BIM-based IT solutions and follow-up services for the contractor. In return, the contractor shares building experiences and practical demands with R. A series of software to facilitate the implementation of BIM technologies and processes for owners, designers, and contractors in the construction industry have been introduced to the contractor. In particular, R is providing their software programs, and offering related professional services. As reflected by the project managers and departmental heads of the contractor in the interviews, their partnership has technically helped the contractor in their business strategic shift.

The contractor is delivering dozens of projects in many regions of Germany. A BIM database is created in the headquarters of the contractor, which stores all the building models and related electrical documentary records. Authorization is straight and clearly identified so that the information maintenance and management can be secured.

4.2. ORGANISATIONAL STRUCTURE (F3)

Adjusting the organisational structure is one of the BIM strategies for the contractor. A BIM centre is separated from the former IT department. The centre is in charge of maintaining and managing the BIM database and providing BIM-related solutions or services for on-site project teams. For each project, at least one member of the centre will join the project team in order to bridge the on-site construction work with the virtual BIM and other enterprise information systems.

For the on-site project team of a specific construction project, a business manager and a project manager are in charge of the top commercial and managerial control. Under the project manager, there are usually deputy project manager, construction manager and a secretary assisting the management of on-site construction work, and the BIM coordinator(s) designated by the BIM centre. The responses from the interviews and survey show that both the construction management board and BIM coordinator(s) are important, and extensive interactions between the two groups are reported.

4.3. PROCUREMENT ARRANGEMENT (F4)

Procurement systems shall be prudentially chosen in order to fulfil the benefits of BIM. Procurement systems could be differing to varying extent in terms of financing approaches, distribution of responsibility of design and construction management, payment methods, and outsourcing arrangements (Hughes *et al.,* 2006). In the case study, the contractor is open to innovative procurement systems, especially to those with more flexibility in 3D modelling and integrating design and construction.

At the tender stage of one of the pilot projects, the client briefs the project concept and hires an architect to develop preliminary 2D drawings, and then invites contractors to bid for the building project. The contractor (for the case study) established a 3D model based on the 2D drawings and imported the 3D model into the professional software to make estimation of quantity take-off (QTO). Through the demonstration on strong advantages, such as 3D design accurate and quick QTO calculation, and efficient supply chain management, the contractor successfully persuades the client to employ BIM to accelerate the project delivery and achieve high building quality. Thus, the offer is awarded to the contractor, with a special agreement to implement BIM in the project delivery process. Due to the strict time limitation and new technologies of implementing BIM, a flexible and innovative turnkey contract is signed, and the contractor is responsible for development of the design and the construction of the physical building.

4.4. OUTSOURCING MANAGEMENT (F5)

The contractor has a good management of subcontractors and suppliers in a computer-aided approach. When the 3D model is ready, the contractor divides the work on the computer and sends Request for Quotation (RFQ) forms in the digital format to subcontractors and suppliers. Then, subcontractors and suppliers will firstly read the forms through the specific software, and input price information before sending back the appropriate RFQ forms to the contractor. Based on the assessment and summary of all RFQ data from subcontractors and suppliers, the contractor gives its biding offer to the client. After the contract was awarded, the contractor signed contracts with those whose RFQ information has been included in the final bidding offer.

4.5. TOP-TO-BOTTOM LEADERSHIP AND ENCOURAGEMENT (I1)

The BIM concept was introduced to the top management board of the contractor about 10 years ago. The R&D department of the contractor has conducted extensive research works before making the final decision on adopting BIM strategies to enhance their business competitiveness in the long run. What is worthy to be mentioned is that the IT department forms a special task group, which becomes the BIM centre, to follow up technical issues in BIM implementation, and evaluate the cons and pros from the technical perspective. With the promotion and support from the top management board, the BIM education and training has been provided to all employees in the company.

4.6. BIM EDUCATION AND TRAINING (I2)

BIM education and training amongst the employees are essentially important. In order to well stem the high productivity of BIM implementation, the employees must have the necessary knowledge and capabilities in BIM. The effective education and training should cover two aspects. The first aspect is to gain technical capability that the employees have to understand and operate the BIM-related equipment and software programs. The second aspect to be adapted with the BIM-related processes. The contractor is periodically holding training seminars and experience sharing events to update the knowledge, and to foster the collaborative working habits among the employees. Based on gains and lessons learnt from the pilot projects, the contractor is able to re-evaluate and improve their processes. An internal management manual is created to provide guidance on standardized working processes with the involvement of BIM. The management manual introduces the details of how one specific BIM software program shall be appropriately used in the real practices. A service group at the headquarters of the contractor is responsible for refining the management manual and answering any enquiries about the BIM software programs. In extreme cases, they will contact the IT vendors to seek for solutions.

4.7. GRADUAL SCHEME FOR BIM BASED WORKING PROCESSES (I3)

Changes on the working processes are not easy to be quickly realized. The contractor has paid close attentions to the employees' attitudes towards BIM, and initialled a gradual scheme to make the process changes acceptable and inspiring. It starts with the 3D design and QTO calculation, and then spread to the planning and simulation. During the period of this case study, the process changes have happened at the construction stage, which refers to bridging BIM and actual buildings bi-directionally. The next step is to make the process changes happen at the operation and maintenance stage. The contractor uses internal online survey system to collect the employees' reflection and suggestions. According to some project managers and department heads of the contractor, it takes time to make all employees to be adapted to the changes, iterative interactions among different departments and different managerial levels are often needed.

What is more, the contractor is continuously providing some internship for university students. Those who have knowledge in BIM and can operate BIM software programs are in favour. After training, the selected students will be involved in ongoing construction projects as BIM coordinators. On one hand, the on-site workers will be more productive with the assistance of these BIM coordinators. On the other hand, those students can enhance their capabilities of BIM and get used to the new project delivery processes with BIM implementation.

5. DISCUSSIONS AND CONCLUSIONS

From the perspective of institutional analysis, some BIM strategies for a contractor company are identified. Those for formal institutions consist of:(F1) form partnership with IT vendor company to fulfil their own advantages; (F2) utilize the ICT technologies and refine the working processes; (F3) make change of organisational structure to match with the BIM related processes; (F4) adopt appropriate procurement systems in order to have flexible leadership in BIM implementation; and (F5) use the BIM functions to leverage the tendering and manage outsourcing relationships. Those for informal institutions include: (I1) top-to-bottom leadership and encouragement towards new technologies and working processes; (I2) BIM education and training to help employees gain necessary BIM knowledge and operation capabilities; and (I3) guidance for gradual scheme of BIM-based working processes.

As Zenger *et al.* (2002) argued that the two aspects of institutional settings must be carefully designed and their interplay can have significant impacts on the organisational performance. In the case study, the five formal institutional initiatives are closely related to the three informal institutional initiatives. The investment on the BIM software programs and working processes (i.e. F1 and F2) will never be paid back without the employees' acceptance, understanding, and mastery, which is supported by top management board (i.e. I1), realized by education and training (i.e. I2). The gradual scheme of realizing the BIM-related changes (i.e. I3) is specially designed according to the developmental routine of BIM in the global construction industries and the current situation in the contractor as well. A contractor is suggested to work closely with IT companies (F1) since they have more experience in handling and developing the software. A BIM centre can be established to better support the implementation of BIM throughout the projects lifecycle. Education and training also play an important role because it is one of the methods to understand all efforts the contractor has made to drive the applications of its BIM strategies. All of the formal institutional initiatives are explicated and reviewed on the series of education and training courses. The R&D department of the contractor periodically evaluates the effectiveness of the BIM strategies, particularly referring to those institutional initiatives, through interviews and online surveys. The extent of the fitness between formal and informal institutions can be examined by tracking and checking whether the actual working processes are carried out as designed. When certain conflict is repeatedly reflected by employee(s), the R&D department will follow up the issue with corresponding employee(s) or department(s), and make individual or organisational adjustments when necessary.

This paper reviews the BIM definitions, basic concepts, the development of BIM in the construction industry, and emphasizes the BIM strategies for a contractor in achieving the potential benefits of BIM and enhancing the business competitiveness against its competitors. A case study of a Germany contractor is conducted. Five formal institutional initiatives and three informal institutional initiatives are identified. The findings could serve as a reference for contractors when they are trying to embrace BIM into their business development strategic plans. BIM strategies by pioneering contractor companies should be able to provide considerable guidance and encouragement for other contractors to learn from. For contractors who want to implement BIM in their business, the interplay of formal and informal institutions should be paid close attention in order to achieve the BIM strategies and enhance the business competitiveness in the fiercely competing construction markets.

6. REFERENCES

AIA, 2006. *The Business of Architecture* [online]. Available from: http://www.aia.org/aiaucmp/groups/ek_public/documents/pdf/aiab083575.pdf [Accessed 2 April 2015].

Azhar, S., Hein, M. and Sketo, B., 2008. *Building Information Modelling (BIM): Benefits, Risks and Challenges* [online]. Available from: http://ascpro.ascweb.org/chair/paper/CPGT182002008.pdf [Accessed 2 April 2015]

Azhar, S., 2011. Building Information Modelling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership Manage,* 11(3), 241–252.

BCA, 2013. *BIM Essential Guide for Contractors* [online]. Available from: http://www.corenet.gov.sg/integrated_submission/bim/BIM/Essential_Guide_Contractor_revised_7_Aug.pf [Accessed 6 April 2015].

Chen, K., Lu, W. S.**,** Peng, Y., Rowlinson, S. and Huang, G.Q., 2015. Bridging BIM and Building: From a Literature Review to an Integrated Conceptual Framework. *International Journal of Project Management*. Forthcoming.

CIC, 2013. *Final Draft Report of the Roadmap for BIM Strategic Implementation in Hong Kong's Construction Industry* [online]. Available from:

http://www.hkcic.org/WorkArea/DownloadAsset.aspx?id=11234&langType=1033 [Accessed 2 April 2015].

CIFE, 2007. *CIFE Technical Reports* [online]. Available from: http://cife.stanford.edu/Publications/index.html.[Accessed 2 April 2015].

Davies, R. and Harty, C., 2011. Building Information Modelling as Innovation Journey: BIM Experiences on a Major UK Healthcare Infrastructure Project. In: *6th Nordic Conference on Construction Economics and Organisation–Shaping the Construction/Society Nexus*.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K., 2011. *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors.* John Wiley and Sons.

Ernstrom, J. W., 2006. *The Contractors' Guide to BIM*. Associated General Contractors of America.

Finnish ICT Barometer, 2007. *BIM - Experience in Finland: Virtual Design and Construction in Buildings and Infra Structure*.

Kaner, I., Sacks, R., Kassian, W. and Quitt, T., 2008. Case Studies of BIM Adoption for Precast Concrete Design by Mid-sized Structural Engineering Firms. *Journal of Information Technology in Construction*, 13, 303-323.

HKIBIM, 2009. *BIM* [online]. Available from: http://www.hkibim.org/?page_id=28 [Accessed 20 February 2015].

Hughes, W., Hillebrandt, P. M., Greenwood, D. and Kwawu, W., 2006. *Procurement in the Construction Industry: The Impact and Cost of Alternative Market and Supply Processes*. Routledge.

Jepperson, R. L., 1991. Institutions, Institutional Effects, and Institutionalism. *The New Institutionalism in Organisational Analysis*, 6, 143-163.

Lu, W. S., Fung, A., Peng, Y., Liang, C. and Rowlinson, S., 2015. Demystifying Construction Project Time-effort Distribution Curves: A BIM and Non-BIM comparison. *ASCE Journal of Management in Engineering*. Forthcoming.

Lu, W. S., Fung, A., Peng, Y., Liang, C. and Rowlinson, S., 2014. Cost-benefit Analysis of Building Information Modelling (BIM) Implementation in Construction Projects by Demystifying the Time-effort Distribution Curves. *Building and Environment*, 82, 317-327.

Lu, W. S., Söderlund, J., Fung, A. and Wang, H., 2013. Understanding the Effects of Building Information Modelling on Project-based Organisations Using a Novel Social Network Approach. In: *Innovative Approaches in Project Management Research*, Oslo, Norway.

McGraw-Hill Construction, 2012. *Smart Market Report: The Business Value of BIM in North America* [online]. Available from: http://www.bimformasonry.org/pdf/the-business-value-of-bim-in-north-america.pdf [Accessed 2 April 2015]

NBIMS, 2007. *National Building Information Modelling Standard*.

NBIMS, 2012. *National Building Information Modelling Standard version 2*.

North, D. C., 1990. *Institutions, Institutional Change and Economic Performance*. Cambridge University Press.

Patrick, C. S. and Raja, R. A., 2007. Evaluating the Impact of Building Information Modelling (BIM) on Construction. In: *7th International Conference on Construction Application of Virtual Reality*. 206-215.

RICS, 2013. *What is BIM?* [online]. Available from: http://www.rics.org/hk/tag/bim/ [Accessed 20 February 2015]

Sacks, R., Eastman, C. M., Lee, G. and Orndorff, D., 2005. A Target Benchmark of the Impact of Three-dimensional Parametric Modeling in Precast Construction. *PCI Journal*, 50(4), 126–139.

Scott, W. R., 1981. *Organisations: Rational, Natural, and Open Systems*. Englewood Cliffs: Prentice Hall.

Smith, P., 2014. BIM Implementation – Global Strategies. *Procedia Engineering*, 85, 482 – 492.

Zeiss, G., 2013. *Widespread Adoption of BIM by National Governments* [online]. Available from: http://geospatial.blogs.com/geospatial/2013/07/widespread-adoption-of-bim-by-national-governments.html [Accessed 20 February 2015].

Zenger, T. R., Lazzarini, S. G. and Poppo, L., 2002. Informal and Formal Organisation in New Institutional Economics. *Advances in Strategic Management*, 19, 277-305.

ROLE OF TECHNOLOGY IN PROVIDING BETTER BASIC FACILITIES FOR CONDOMINIUM PROPERTIES

M.D.O.M. Jayarathne and H. Chandanie*
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sri Lanka, as a third world country, rapid urbanization has increased ranks of urban poor, creating demand for housing and urban services which has remained unsatisfied due to lack of resources and urban lands at reasonable prices. Hence, condominium construction has become popular in the present as a solution to provide accommodations for the increasing population. However, providing required facilities to its occupants is a major problem for the condominium management. According to the literature survey, two of condominium facilities, safety and security and ventilation have been identified as basic facilities which are having severe urge to be improved. Therefore the aim of the study was to explore how to improve the basic facilities in condominiums through the concepts of technology.

A comprehensive literature survey was carried out by referring books, journal articles, and relevant other publications leading to a case based field survey, where interviews and observations were used as the data collection techniques. Content analysis was used to analyse the qualitative data. Research has concluded that technology transfer will improve security and safety systems where the techniques identified being Condominium Elevator Safety, Finger Print Readers, Motion Sensors and Access Control. Further ventilation conditions were suggested to be improved through the Balance/Stack Ventilation, Solar Wall/Roof, Heat/ Energy Recovery Ventilators and Wind Catchers. However there are barriers in implementing new technologies which are identified as Lack of cost allocation, Poor mechanism of technology sourcing, transfer and management and Inadequate government or responsible parties' support and involvement.

Keywords: *BIM Strategies; Building Information Modelling (BIM); Contractor.*

1. INTRODUCTION

Condominium construction has become popular in the present as a solution to provide accommodation for the increasing population. Condominium is a system which provides separate ownership of individual units in a multi-story building (Kowshala, 2002). This system was introduced to Sri Lanka when the apartment ownership Act No. 11 of 1973 came to effect (Kajaran, 2006). According to Kirthi (2008, p.5) "condominiums are not everyone's 'cup of tea,' but this is the best alternative home ownership style in urban areas. It will give an instant community feeling, and also provides more security and hassle free living, with all the benefits and facilities available". However, Building Technologies Energy and Environmental Solutions (2005) have identified several challenges and limitations which are affected to condominium properties and management while providing those facilities and requirements.

In overcoming the limitations and challenges in condominium development, the concepts of technology management, technology transfer and technology innovation can be utilised. Therefore this research examines how to use technology to facilitate the essential requirements of safety and security and ventilation in condominium properties in better ways.

*Corresponding Author: E-mail - chandanieqs@yahoo.com,

2. LITERATURE REVIEW

2.1. ROLE OF TECHNOLOGY IN UPHOLDING CONDOMINIUM SAFETY & SECURITY AND VENTILATION

Senarathne *et al*. (2006) have mentioned 24 hours home securities as a main requirement of the condominium properties. Moreover, heating and ventilation is one of major requirement in high rise buildings (Cook, 2009). Many areas in condominiums or apartments complexes call for special caution and awareness on these facilities differently from single family dwellings.

Moreover, with the development of new technologies, there are several types of safety and security systems and ventilation systems are available in the residential units in the moment. Those systems are outlined above Table 1.

Table 1: Safety & Security Technologies and Ventilation Technologies

Safety & Security Technologies	Ventilation Technologies
Close Control Television (CCTV): Bullet/ Dome/Covert/Desktop/Board/Outdoor/Day/Night/ Varifocal/Network/IP/ Wireless / High-Definition Discreet Cameras; Infrared/Night Vision	**Classical envelope infiltration method:** Exhaust/ Compartmentalization/ Multi point exhaust system/ Intermittent exhaust system/ Exhaust with make-up air inlets
Fingerprint Reader	**In-suite ventilation**
Access control	**Central (Roof-mounted)**
Condominium Elevator Safety	**Pressurized corridors**
Motion Sensors: Electronic/Mechanical; Natural organisms (motion perception); Infrared (Passive and active sensors); Optics (Video and camera systems)/Radio Frequency Energy (radar, microwave and tomography motion detection)/ Sound (Microphones and acoustic sensors)/Vibration (Turboelectric, seismic, and inertia-switch sensors)/Magnetism (Magnetic sensors and magnetometers)	**Stack ventilation**: One or more stacks or towers in to the building structure to extract stale air while fresh air enters through provided openings such as trickle vents or louvers
Fire safety: Fire detectors; Fire extinguishers; Sprinkler system; Wet riser system and Hose reel system	**Mixed mode or hybrid ventilation**: Wind/Mechanical ventilation(Fan/Heat exchanger/ CO2 sensors)
Physical security: Security guards; Barriers	**Single-sided ventilation**: Openings/ Windows
	Cross-ventilation; Two or more fixed openings on opposite walls
	Natural ventilation system: Wind and Temperature difference
	Solar Chimney: Stack system fitted with a solar collection panel
	Continuously pressurized corridor ventilation system: Large mechanical unit on the roof with damper controls and a centralized shaft
	Direct supply approach: Pressurized air is supplied directly to each suite/Exhaust
	In-suite ventilation: Automatically controlled/ HVAC
	Ventilator types: Sensible/Latent; heat/ Energyrecovery(HVR)/(ERVs)

Source: Adapted from Condobusiness (2009); Resource Smart Business (2010) and Awbi (2010)

There are three main terms related to technology as technology management, technology transfer and technology innovation. According to the National Research Council (1987), "Technology Management" is engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization. "Technology transfer" is a purposive, conscious effort to move technical devices such as materials, methods, and information from the point of discovery or development to new users (Strawn, 1982) whereas "Innovation" is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change (Slaughter, 1998 cited Blayse *et al*., 2004).

Condominiums are governed by community members, and condominium owners need to follow by-laws that are set up for the entire condominium community. Condominiums owners are responsible for installing burglar alarms, smoke detectors and security systems within their own units if desired. In addition, condominium owners need to buy their own condominium insurance policies, and to regularly update them if required (Dickstein Associates Agency LLC, 2013). A ventilation system is a process which circulates fresh air throughout a confined space or spaces, while removing contaminated or stale air (Wisegeek, 2013). The goal is to optimize building energy costs and improve occupant satisfaction with respect to noise and odour transmission between suites and between common hallways and suites (Cook, 2009).

2.2. Challenges for Different Technological Terms in Condominium Construction

There are some issues in technology and technology management in residential construction. Development and process technology issues are multi-dimensional and the root causes are complex as presented in Table 2.

Table 2: Technology Development Issues and Barriers

Issues	**Barriers**
Out-dated technology	Lack of willing to transfer in to new methods
Lack of innovation/new design development	Lack of foreign investments related to technology
Poor mechanism of technology sourcing, transfer and management	Technology developers/owners not necessarily good commercializes/marketers
Inadequate government or responsible parties' support and ignorance about the consequences of the effects	Bodies needing technology may not have the capacity to search and negotiate or even absorb/adapt the technology
Lack of eco-friendly waste management and drainage system	Low public awareness/public pressure (condominium occupants or government)
	Government barriers (regulations) to technology transfer (import & export)
	No or lack of incentives to the condominium management and to the condominium contractors

Source: Adapted from Dassanayaka and Sardana (2009) and Eskom (2013)

3. Research Method

This research's basic beliefs fall into the paradigm of interpretivism with a qualitative approach. Case studies were used as the method which is an empirical inquiry that investigates a contemporary phenomenon (Yin, 1994). Out of the various research techniques, interviews, observations and discussions were used for data collection which was led by a background study and a literature review. Three cases were considered within this study. Interviews were conducted to gather information from individuals through one-on-one sessions face to face with professional building services engineers or maintenance engineers, condominium consultants and contractors, condominium management and its occupants. Observations were made to identify the available techniques used in the condominiums and the visual inefficiencies. In order to move from raw data to a meaningful understanding, content analysis was used to analyse data which were collected from the case studies.

4. FINDINGS AND DISCUSSION

Three cases were studied to collect data with the developed interview guideline which is consisting with ten questions aiming one of occupants and an individual of the management party of the each case where **Case A** : a Luxury Condominium, **Case B**: Middle income Condominium and **Case C** being a Low income Condominium. Most of the residents of luxury condominiums are highly educated and with good attitudes which is different from the case B and C. Therefore the management of Middle and low income condominiums has to face several difficulties in providing better basic facilities.

4.1. CONTENT ANALYSIS FOR RESPONSES OF THE OCCUPANTS AND MANAGEMENT FOR SAFETY AND SECURITY SYSTEM

According to the view of point of all the interviewees' safety and security is one of critical facility of condominium properties. According to the case A respondent, the safety and security level of the apartment units are up to a satisfactory level. But according to the respondents from cases - B and C, the situation is different. The below discussions were based on the answers received upon the question raised through the interview.

1. Residents: Are you satisfied with the safety & security approaches in your building?

Respondent from the case A are highly satisfied with the present situation. It was declared, every safety and security approach which has been implemented by the management party for safety and security of this building has not become any threat for privacy. Respondent from the case B stated, "*The safety and security approaches of the building are in very low level. There is a huge threat of our apartment units to get robbed when we are not there. As well as there are some people inside the apartment who are with very bad attitudes, therefore they are a huge threat to our children's protection too. So many times we have complained to the police and the management parties of the building, but there is no any favorable response from them. Now it is felt that we are neglected by the relevant parties*". It was further stated that in the case of fire there are no any fire extinguishers. Further, most of fire extinguishers are robbed. Respondent from the case C is also with the same idea and pointed out that, "*there were several robberies in last few months in some apartment units*".

2. Residents: Do you have any idea for further improvements in your safety & security services in your building?

Case A respondent declared that existing safety systems available in here are enough to serve the purpose. Case B respondent stated, "*Yes, already we here suggested some safety and security systems to the responsible parties. Our main suggestion was to fix security cameras*". Furthermore he declared to have at least, necessary accessories and equipment of fire protection. Respondent from the case C is also with the same idea and thoroughly stated, "*There should be a tough physical security in the entrance*". According to the views of all respondents in each case it is clear that safety and security level of the luxury condominiums are up to the satisfactory level of its residents. But the situation is different in middle income and low income condominiums. Further, management category interviewees confirmed the views of residents and stated that safety and security is one of most important facility in condominium properties. Interviewees clarified the importance of different technological terms and how to apply those technological terms for further improvements of the facility, safety and security in condominium context.

3. Management: Are you satisfied with the safety and security approaches which have been taken to protect your occupants and your building?

Respondent from case A declared, "*In the initial stage there was a security burglary alarm system. Then there were CCTV, intercom and video com systems. But burglary alarm system and video com system were failed. Intercom and video com systems are working as one system while recording voice and capturing videos. But video side was failed. Therefore CCTV and Intercom systems are working in the present*". Furthermore it was found that there is a fire electronic system which indicates all the massages and signals regarding any fire prone incidents in the whole area. Maintenance department can easily identify the location or the relevant zone and the fire item through this system. As well as the fire fighting system is consisting with wet riser system hose reel system and sprinkler system (basement, ground floor and 1st floor). Further the fire fighting system comprises with fire hydrant system which fire men can reach to inlet in front of the main entrance. As well as heat detectors, manual call points and fire sounders are located in necessary places to indicate the fire incidents to whole the residents. Further it was observed that they have proper maintenance schedules and procedures for their elevator system as safety precautions. Differently, Case B respondent stated, "*residents are not allowed to do any alterations and residents are advised to do nothing as increasing the weight of the apartment units like floor tiling and air conditioning* " as the safety precautions of the building structure. Further he stated, police and security guards have been directed to provide physical security for the residents. In addition it was observed that some fire safety precautions like fire extinguishers have been provided to the safety and security of the residents and building. Respondent from case C is also with the same idea.

Further, technological terms used to maintain and continuous running for those system were also elaborated through the interviews under the Question 04.

4. Management: Are you familiar with the new local or foreign technologies which are used as safety & security approaches in condominium properties?

Respondent from case A declared, "*of course, there are so many safety and security systems which are not applied in our building like finger print reader, motion sensors, access control system and etc. Actually it should be mentioned that we have an idea to fix some motion sensors as another safety and security approach for our building. Therefore it can be used as energy saving approach*". Further access control was suggested as a better safety and security approach, but it is suggested to be more suitable for commercial buildings. Respondent from cases B and C are familiar with same technologies, CCTV system, and finger print reader and motion sensors as new technologies. It was observed that their major aim to control bad behaviours and robberies in the condominiums by fixing the camera system.

4.2 CONTENT ANALYSIS FOR RESPONSES OF THE OCCUPANTS FOR VENTILATION SYSTEM

According to the view of point of all the interviewees' ventilation is one of critical facility of condominium properties. According to the case A respondent, the ventilation level of their apartment units are up to a satisfactory level. But according to the respondents from cases - B and C, the situation is somewhat negative. Especially, it was mentioned as it is better to have solar walls and solar roof for these middle income and low income condominiums. Because of not having air conditioning, these techniques will control and reduce the heat inside the apartment units. Awbi, (2010) has introduced these two systems as better ventilation systems which are very energy efficient in the literature.

1. Are you satisfied with the ventilation approaches and indoor air quality in your building?

Respondent from case A expressed, "*yeah, actually we are satisfied. Air conditioning and ventilation level is in satisfactory level. Actually indoor air quality is good for both children and elders*". The community has good impression upon the management parties. But the responses of the Respondent from cases B and C were having different viewpoints. Case B respondent stated that there are no enough exhaust fans in the apartment units and in wash rooms. Therefore cooking smell of the neighbour apartment unit comes to the next door. It is one of the huge troubles and sometimes these bad smells make some breathing difficulties for children and old people. Especially, respondent B and C thoroughly stated, "*our apartment units are like hot plates in the night. Therefore we cannot have comfortable sleep in the night*". Further respondent C expressed that waste management system is not active and especially if it is a rainy day, bad smell spreads in the whole area. According to the respondent B and C, it was observed that there is no standard ventilation system or indoor are quality in the middle income and low income condominiums.

2. Resident: Do you have any idea for further improvements in your ventilation approaches and indoor air quality in your building?

According to the respondent A there is already a satisfactory ventilation systems and indoor air quality provided in the luxury condominiums. Therefore there were no new thoughts for further improvement of the ventilation systems. According to the case B and case C interviewees, several ideas were recognized as required further improvements for ventilation systems. Respondent from case B and C thoroughly stated, "*There should be exhaust fans for every apartment unit. As well as at least here should be fans to reduce the heat and to have better air circulation inside the apartment unit*".

The view point of the management was quite parallel to the residents yet there were better options and suggestions with the professional background.

5. **Management: Are you satisfied with the ventilation approaches which have been taken to provide better indoor air quality to your occupants?**

According to the respondent from case A there is a proper hybrid ventilation system which is a better combination of natural and mechanical ventilation approaches. Respondent A stated, "*single-sided ventilation system is one of most energy efficient system in our building. Common areas and entrance lobby are ventilated through this system*". Further she stated, that a continuously pressurized corridor ventilation for the corridors, lobby areas and car park area. According to the respondent from case B and C and according to the observations there are several types of ventilation systems used to ventilate the middle income and low income condominiums. Further single-sided ventilation, cross ventilation, stack ventilation and balance ventilation system are available in these condominiums.

Further it has been inquired from on possible developments as below described.

6. **Management: Are you familiar with the new local or foreign technologies which are used as ventilation approaches in condominium properties?**

Respondent from case A stated, "*yeah, there are several technologies as ventilation approaches in condominiums especially solar wall system and solar roof system are very popular in the present in high rise buildings like condominiums, hotels and commercial buildings. But these two are bit expensive technologies in the industry*". It was further explained that there is a new energy efficient system called wind catchers by fixing these accessories in the roof top, natural ventilation can be exhausted to inside the building. Furthermore it was observed that two types of ventilators called heat recovery ventilation and energy recovery ventilators are used in as new ventilation approaches in the industry. According to the respondents from case B and C there are other technologies like continuously pressurized corridor ventilation, solar wall and solar roof which are not applied in those condominiums are used in other building as ventilation systems. In addition to case B respondent stated, "*there is a new economic advantage system called wind catchers. It exhausts natural wind to inside the building*". According to respondent from case B it is very popular system in the present.

The contractor is delivering dozens of projects in many regions of Germany. A BIM database is created in the headquarters of the contractor, which stores all the building models and related electrical documentary records. Authorization is straight and clearly identified so that the information maintenance and management can be secured.

4.3 BARRIERS FOR NEW TECHNIQUES APPLICATIONS AND BENEFITS OF NEW TECHNIQUES

All the respondents stated that lack of economical allocation for adopting new technologies is the major barrier in the industry. As an example why respondents from case B and C still did not move for CCTV system is lack of initial cost. Further respondents from case B and C stated, "*because of unawareness, sometimes residents may not get enthusiastic for system like finger print reader*". Furthermore it was observed from the respondent from case B and C, now even though it is a necessity to move for fire fighting system like wet riser and hose reel, it will not be successful at this stage, therefore these systems should have been implemented from the planning and designing stage of the construction. As well as respondent from case B toughly stated, "*There are some resistances to prevent the moving for some systems from some responsible parties like government officers*". Especially at the end, all respondents declared that there is no proper mechanism for technology sourcing and transfer in the country; therefore it is a huge loss not only for the condominium industry but also for several fields in the country.

5. CONCLUSIONS AND RECOMMENDATIONS

With increasing urban population condominium construction bas become popular at the present. Therefore providing and improving facilities has become a huge necessity of the era.

There are several techniques available in the condominium industry for providing above mentioned couple of facilities to its residents. Further, there are new techniques which are being introduced to the industry with the development of the technology. Therefore the aim of the study is to explore how to improve the basic facilities in condominium properties through the concepts of technology management, technology transfer and technology innovation.

Safety and security systems and the ventilation systems have been identified as two of most important facilities according to the literature. Table 03 presents currently available safety and security technologies and recommended technologies categorised under technology management, technology transfer and technology innovation concluded through the data analysis which are recommended for different types of condominiums.

Further, interviewees clarified the importance of different technological terms and how to apply those technological terms for further improvements of the ventilation facility in condominium context. The Table 4 presents the current practices and suggested systems for better ventilation in condominiums.

Table 3: Current Practices and Suggestion for Safety and Security System Improvements

Technology Management	**Safety & Security System**						
	CCTV System	Fire Safety System	Physical Security System	Condominium Elevator Safety	Finger Print Reader	Motion Sensors	Access Control
Luxury Condominium							
Current Practice							
Usual Technology							
Technology Transfer							
Suggested Practice							
Technology Transfer							
Middle Income Condominium							
Current Practice							
Usual Technology							
Suggested Practice							
Usual Technology							
Technology Transfer							
Low Income Condominium							
Current Practice							
Usual Technology							
Suggested Practice							
Usual Technology							
Technology Transfer							

Major barriers for the applications of new techniques according to the interviewees were; Lack of cost allocation, Poor mechanism of technology sourcing, transfer and management, Inadequate government or responsible parties' support and involvement, Lack of eco-friendly and poor waste management and drainage systems, Lack of public awareness and Lack of willing to transfer in to new methods.

It was concluded that if condominiums move to the new techniques by overcoming identified barriers and issues, it would be a user friendly environment for condominium residents with better safety & security and ventilation conditions.

Table 4: Current Practices and Suggestion for Ventilation Facility Improvements

Technology Management	**Technology**										
	Single-Sided Ventilation	Continuously Pressurized Corridor Ventilation	Balance Ventilation	Better indoor air quality through A/C	Cross Ventil ation	Stack Ventilation	Solar Wall	Solar Roof	HRV	ERV	Wind Catchers
Luxury Condominium											
Current Practice											
Usual Technology											
Technology Transfer											
Suggested Practice											
Usual Technology											
Technology Transfer											
Middle Income Condominium											
Current Practice											
Usual Technology											
Technology Transfer											
Suggested Practice											
Usual Technology											
Technology Transfer											
Low Income Condominium											
Current Practice											
Usual Technology											
Technology Transfer											
Suggested Practice											
Usual Technology											
Technology Transfer											

Through this research it is strongly recommended for the management parties or the responsible parties of the condominiums with recognizing the barriers and to move for new techniques to have better environment and more benefits. Further it will be beneficial to arrange awareness programs for the residents about new techniques or new approaches of the basic facilities. Expenditures should be allocated for the improvements of the basic facilities from the annual budget with proper planning to sustain in the long run. Further in macro scale it is required to arrange proper mechanism for technology sourcing and transfer by the government.

6. REFERENCES

Awbi, H., 2010. *Basic Concepts for Natural Ventilation of Buildings.* United Kingdom: University of Reading, Technologies for Sustainable Built Environments Centre.

Blayse, A., Karen, M. and Manley, 2004. Key Influences on Construction Innovation. *Construction Innovation,* 4(3), 143-154.

Building Technologies Energy and Environmental Solutions, 2005, October. *Energy Management for Condominiums* [online]. Available from: http://www.cci.ca/windsor/Resources/ARTICLES/CondoPresentationOct13.pdf [Accessed 8 May 2014].

Condobusiness, 2009. *Ventilation Options in High-Rise Condos* [online]. Available from: http://www.condobusiness.ca/Ventilationoptionsinhighrisecondos.aspx [Accessed 8 May 2014].

Cook, G., 2009, June. *Ventilation Options in High-Rise Condos* [online]. Available from: http://www.condobusiness.ca/Ventilationoptionsinhighrisecondos.aspx [Accessed 8 May 2014].

Dasanayaka, S. W. S. B., and Sardana, G. D., 2009. *Technology Issues in Pakistan's Leather Training SMEs,* 167-179.

Dickstein Associates Agency LLC, 2013. *The Importance of Condominium Safety Rules* [online]. Available from: http://www.dicksteininsurance.com/about-us/our-blog/the_importance_of_condominium_safety_rules [Accessed 8 May 2014].

Eskom, Wendy Poulton General Manager Corporate Sustainability, 2013. *Elements of Effective Technology Transfer and Stimulating Entrepreneurship.* Available from: http://www.oecd.org/science/inno/35791610.pdf [Accessed 8 May 2014].

Karajan, S., 2006. *Assessment of Demand and Supply of Condominium in Sri Lanka.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Kirthi, H., 2008. *New Act Needed for More Dynamic Forms of Condominium Ownership* [online]. Available from: http//www.thebottomline.lk/2008/04/02/L13.htm [Accessed 8 May 2014].

Kowshala, N., 2002. *Proliferation of Condominium Development.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

National Research Council, 1987. M*anagement of Technology: The Hidden Competitive Advantage*. Washington, DC: National Academy Press.

Resource Smart Business, 2010. *Natural Ventilation Systems* [online]. Available from: http://www.sustainability.vic.gov.au/resources/documents/natural_ventilation_technical_info_sheet.pdf [Accessed 8 May 2014].

Senaratne, S., Weddikkara, C. and Zainudeen, N., 2006. A Study into Land Supply and Demand for Property Development in Colombo. *Built-environment-Sri Lanka,* 07(01), 24-25.

Strawn, G. W., 1982. Technology Transfer. *Journal of Technology Transfer,* 06(2), 45-51.

Wisegeek, 2013. *What is Ventilation System?* [online]. Available from: http://www.wisegeek.com/what-is-a-ventilation-system.htm [Accessed 8 May 2014].

Yin, R., 1994. *Case Study Research Design and Methods*. 2nd ed. Newbury.

STRATEGIES TO ENHANCE SUSTAINABILITY OF PUBLIC PRIVATE PARTNERSHIP PROCUREMENT PROCESS FOR INFRASTRUCTURE DEVELOPMENT

Nilesh Agarchand Patil and Boeing Laishram*
Infrastructure Engineering and Management Division, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati, India

ABSTRACT

Public Private Partnerships (PPPs) have been used as one of the preferred modes for infrastructure development since the last two decades in India. The PPP programme in India, though, has stabilized significantly with lessons learnt from the experience of implementing PPP projects, but the PPPs in India still suffers from certain shortfalls which could be related to the failure to meet many aspects of sustainable development (SD) principles. One of the ways to overcome these shortfalls could to modify the procurement process so as to fulfil the principles of SD even through PPP route. The main aim of this paper is to develop a conceptual framework highlighting the strategies for integrating sustainability principles in procurement process of PPP projects.

Content analysis on existing literatures, research reports, and case studies on PPP projects has been adopted to first identify the shortfalls in PPP process and, secondly, examine the possible strategies from best practices being adopted in PPP projects executed all over the world. The preliminary framework on how to integrate the principles of sustainability is then conceptualized explaining how the formulated strategies can be integrated into PPP process. Finally, focused interviews with the key stakeholders of PPP projects have been undertaken to assess the feasibility of the preliminary framework.

The preliminary findings from the study indicate the opportunities to promote SD even through PPP route if procurement process is enhanced with respect to the following aspects by relooking the PPP process from the perspective of SD concepts and principles: stakeholder's participation, environment impact assessment, value for money analysis, user's charges and risk allocation policies, transaction and bidding cost, and bid evaluation criteria. The proposed framework will be a useful tool for the government to restructure the PPP procurement process in India to fulfil the SD goals, which are being currently pursued by the government rigorously.

Keywords: *Infrastructure Development; Procurement Process; Public Private Partnerships; Sustainability; Sustainable Development.*

1. INTRODUCTION

The Indian Government has adopted Public Private Partnership (PPP) route for development of infrastructure projects since the economic liberalization initiated in 90s. PPPs have become of the innovative routes for the governments to rehabilitate aging infrastructure and develop new facilities to bridge the demand-supply gap. PPP shave become an explicit procedure to achieve benefits such as optimal risk transfer, increased efficiency, access to advanced technology, and bring in innovation (Cheung, 2009). On the other hand, it has been observed that PPPs may result in construction of over-engineered and inefficient infrastructure, creating long-term indebtedness of municipalities, providing unequal access to service due to high user tariffs, postponement of investments in less profitable projects parts, and contract renegotiation in favour of private providers (Koppenjan and Enserink, 2009).

* Corresponding Author: E-mail - boeing@ittg.ernet.in.com

The PPP programme in India has stabilized significantly with lessons of experience of implementing infrastructure projects, but the PPPs in India still suffers from certain shortfalls which could be related to the failure to meet many aspects of sustainable development (SD) principles (PWC, 2005). Samuel and Oshani (2011) haves suggested that sustainability practices are present within PPP experience, but SD principles are largely absent from the theory and frameworks. Incorporating of SD principles in the procurement of infrastructure projects through PPP mode could lead to development of better infrastructure, bring more benefits to the better society and improve the quality of environment (Samuel and Oshani, 2012). One of the ways to overcome these shortfalls could be to modify the procurement process so as to fulfil the principles of SD even through PPP route. The main aim of this paper is to develop a conceptual framework highlighting the strategies for integrating sustainability principles in procurement process of PPP projects in India.

1.1. RESEARCH METHODOLOGY

The study used a mixed research methods to answer the various research questions relating to sustainable development promotion when infrastructure is developed through PPP route. A critical review of literature, research reports, and case studies on PPP projects were undertaken to answer the research question "*what are the areas of sustainable infrastructure development goals which are not fulfilled when infrastructure is procured through PPP route?*" For the critical review, content analysis methodology approach was used wherein the principles of sustainable development guided the critical analysis of PPP procurement process to identify the shortfalls from SD perspective. These identified shortfalls then guided formulation of preliminary framework of strategies on how to integrate SD principles in PPP process. This applicability of the preliminary framework was then evaluated through focused interviews as part of the research strategy to gain insights on the research question "*how to integrate sustainable development principles in PPP procurement process?*" The focused interviews with the key stakeholders developing PPP projects in Guwahati region of India have been undertaken to assess the feasibility of the preliminary framework.

2. PUBLIC PRIVATE PARTNERSHIPS AND SUSTAINABLE DEVELOPMENT

2.1. PUBLIC PRIVATE PARTNERSHIP PROCUREMENT PROCESS IN INDIA

PPP projects evolved through various phases while undergoing development from project concept to constructed facility. With respect to the PPP programme in India, the procurement process comprises of the four stages with respective deliverables. Table 1 depicts the outline of Indian PPP procurement process (PPP Cell, 2014).

Table 1: Phases of PPP Process in India

Phases	Deliverables
Identification	Strategic planning, Project pre-feasibility, PPP suitable check
Development	Full feasibility, PPP preparation and Clearance, Value for money (VfM) test
Procurement	Prequalification, Bid preparation, Bid evaluation, Contact finalization
Management	Construction / Operation, Contract management and Monitoring

2.2. PRINCIPLES OF SUSTAINABLE DEVELOPMENT

The principles of sustainability refer to abstract rules or guidelines that one can apply in order to achieve sustainable development. Various sets of principles of SD have been proposed in the past decades. Amongst the principles, the eight principles of sustainability formulated by Gibson *et al.* (2005) have been one of the commonly used principles for sustainability assessment. These principles have been used in various studies on infrastructure development as core criteria for sustainability assessment for urban development proposal (Morrison-Saunders and Hodgson, 2009); water governance regimes (Wiek and

Larson, 2012; Kuzdas *et al.*, 2014); and critical river basin infrastructures (Shah and Gibson, 2013). The eight sustainability principles postulated by Gibson are briefly explained in Table 2.

3. ANALYSIS OF PPP PROCUREMENT PROCESS – SD PRINCIPLES PERSPECTIVE

The process of procuring infrastructure projects through PPP route is examined to ascertain whether PPP mode of infrastructure development is leading to SD. The above mentioned eight principles of SD have been applied to all the phases of PPP project lifecycle, i.e. identification, development, procurement, and management. The processes and practices for PPP project procurement are critically reviewed to assess the extent to which it is promoting SD. A comprehensive literature review through content analysis of secondary data sources such as articles, reports, guides and online databases related to criticisms on PPPs for infrastructure development has been undertaken to identify the shortfalls.

Table 2: Principles of Sustainable Development

Principles	Description
Socio-ecological system integrity	Build human-ecological relations to establish and maintain the long-term integrity of socio-biophysical systems and protect the irreplaceable life support functions upon which human as well as ecological well-being depends.
Livelihood sufficiency and opportunity	Ensure that everyone and every community has enough for a decent life and that everyone has opportunities to seek improvements in ways that do not compromise future generations' possibilities for sufficiency and opportunity.
Intra-generational equity	Ensure that sufficiency and effective choices for all are pursued in ways that reduce dangerous gaps in sufficiency and opportunity (including health, security, social recognition, political influence) between the rich and the poor.
Intergenerational equity	Favour present options and actions that are most likely to preserve or enhance the opportunities and capabilities of future generations to live sustainably.
Resource maintenance and efficiency	Provide a larger base for ensuring sustainable livelihoods for all while reducing threats to the long-term integrity of socio-ecological systems by reducing extractive damage, avoiding waste, and cutting overall material consumption and energy use per unit of benefit.
Socio-ecological civility and democratic governance	Build the capacity, motivation and habitual inclination of individuals, communities and other collective decision-making bodies to apply sustainability requirements through more open and better informed deliberations, greater attention to fostering reciprocal awareness and collective responsibility, and more integrated use of administrative, market, customary and personal decision-making practices.
Precaution and adaptation	Respect uncertainty, avoid even poorly understood risks of serious or irreversible damage to the foundations for sustainability; plan to learn; design for surprise; and manage for adaptation.
Immediate and long-term integration	Apply all principles of sustainability at once, seeking mutually supportive benefits and multiple gains.

Table 3 shows the findings from the content analysis. The seven shortfalls identified from the analysis hamper sustainability of PPP projects from the perspective of key sustainability principles, namely, inefficient resource utilization and failure to promote socio-ecological system integrity; intra-generational inequality and lack of livelihood sufficiency and opportunity; failure to promote socio-ecological civility and demographic governance; and inadequate precautionary and adaptation measure.

4. STRATEGIES TO ACCOMPLISH THE PRINCIPLES OF SD

Strategies for SD are about making and implementing such choices, in a realistic, effective and lasting way. OECD (2001) defined the strategies for SD: "A co-ordinated set of participatory and continuously improving processes of analysis, debate, capacity strengthening, planning and investment, which seeks to

Table 3: Shortfalls in PPP Process Fails to Accomplish SD Principles

Shortfalls	Explanation	References	Deficient SD Principles
Inadequate environment impact assessment(EIA) and social impact assessment (SIA)	Current EIA and SIA activities for feasibility study are inadequate in ensuring promotion of project outcomes that are sustainable. EIA focuses all too often on acceptable impacts instead of optimizing the project for environmental, social and community benefits.	(Arce and Gullon, 2000; Arts and Faith-Ell, 2012; UNESCAP, 2006; Lorenzo, 2008)	Inefficient resource utilization and failure to promote socio-ecological system integrity
Inadequate whole life costing (WLC) methodology for VfM analysis	WLC methodology does not considered environmental and social externalities, and cost savings in VfM estimation. Risk model used in VfM analysis is very simple and outdated; and it fails to model the complex risk/reward profile of PPP project.	(Julie and Collins, 2004; Lockie, 2003; Samuel and Oshani, 2011; Samuel and Oshani, 2012; Curnow *et al.*, 2005; Carrillo *et al.*, 2008; PWC, 2005; PWC, 2008)	Inefficient resource utilization and failure to promote socio-ecological system integrity
Inadequate bid evaluation criteria for PPP procurement	Current bid evaluation criteria are in financial terms only, the private player tends to focus on maximizing returns and recover the investment cost by making crucial changes in the project. The bidding process should embed environmental and social safeguards/dimensions in their tender evaluation, supplier selection, and monitoring and contracting functions.	(Samuel and Oshani, 2011; Samuel and Oshani, 2012; Julie and Collins, 2004; Arts and Faith-Ell, 2012; Curnow *et al.*, 2005; Cheung, 2009; PWC, 2005)	Inefficient resource utilization and failure to promote socio-ecological system integrity
High tariff charges for infrastructure services	One of the most common complaints by the general public against PPP projects are the high tariff charged for the services provided by private sector. High tariff will make certain section of the society inaccessible to the infrastructure services and will fail to provide equal opportunity for growth and increase the gaps between the rich and poor.	(Cheung, 2009; Curnow *et al.*, 2005; Samuel and Oshani, 2011; Samuel and Oshani, 2012; Li *et al.*, 2005; WEF, 2013)	Intra-generational inequality and lack of livelihood sufficiency and opportunity
High bidding and transaction cost of PPP procurement preparation	The current bidding and transaction cost of PPP procurement preparation is six time higher than that of traditional procurement practice due to the lengthy negotiations in bidding process. Also, PPP projects engage professional services, which are highly costly, for structuring project deals.	(Albert *et al.*, 2010; Carrillo *et al.*, 2008; Cheung, 2009; Curnow *et al.*, 2005; Li *et al.*, 2005; PWC, 2005; PWC, 2008; Samuel and Oshani, 2011; Samuel and Oshani, 2012)	Intra-generational inequality and lack of livelihood sufficiency and opportunity
Lack of stakeholder's participation and public opposition	Public opposition has been reported as the main reason for failure of PPP projects in several instances. The main reasons for such failure, which are primarily connected with stakeholder's lack of awareness in the concept of PPP; insufficient education about PPP; and being denied access to detailed information contained in the consortium's PPP proposals.	(Gupta, 2011; Cheung, 2009; Arce and Gullon, 2000; Samuel and Oshani, 2011; Samuel and Oshani, 2012)	Failure to promote socio-ecological civility and demographic governance
Unbalance risk allocation and mitigation profile between public and private sector	The underlying norms of risk transfer and compensation for PPPs will need to be changed so that it can effectively serve as tools for SD. Also, the necessary precautionary measures could not be planned at the conceptual stage and the corresponding risks and risk mitigation mechanisms will not be in-built in the concession agreement (CA).	(Albert *et al.*, 2010; Cheung, 2009; Curnow *et al.*, 2005; Gupta, 2011; Samuel and Oshani, 2011; Samuel and Oshani, 2012; PWC, 2008)	Inadequate precautionary and adaptation measure

integrate the short and long term economic, social and environmental objectives of society through mutually supportive approaches wherever possible and manages trade-offs where this is not possible."

Plausible strategies on how to overcome the shortfalls were identified through content analysis of secondary data sources such as articles, reports, guides and online databases on best practices of promoting sustainable infrastructure development. Table 4 summarizes the final set of strategies to overcome the shortfalls and accomplish the requirement of SD principles.

The preliminary framework on how to improve sustainability of PPP projects is shown in Table 5. The framework indicates the point of interventions of the identified strategies in PPP lifecycle and which deliverables of PPP procurement process will be affected by the interventions.

Table 4: Strategies to Promote Sustainability of PPP Projects

Strategy to Achieve Broad SD Goals	References	SD Goal
Strategic environmental assessment (SEA) - Incorporate environmental and social (E&S) considerations into policies, plans and programmes of PPP project identification through SEA.	(Arce and Gullon, 2000; Arts and Faith-Ell, 2012)	Socio-ecological system integrity
Climate change considerations (CCCs) - Include the assessment of CCCs (GHG emission from project and climate change impact on project) into EIA of PPP project identification and development.	(Samuel and Oshani, 2012; UNECE, 2008)	Socio-ecological system integrity
Environmental-friendly and smart-growth technique (EFSGT) - Install and implement EFSGT technique in design of PPPs for contribute towards biodiversity conservation e.g. Green design through LEED, CEEQUAL, and BREEAM (rating tools).	(DOIT, 2010; USDOT, 2007)	Socio-ecological system integrity
Green accounting (GA) - Include E&S costs, and benefits (i.e. GA) in WLC estimation for VfM analysis through promoting to use renewable energy sources and cost effective technologies.	(Samuel and Oshani, 2012)	Resource maintenance and efficiency
Climate change parameters (CCPs) and long term environmental and social (E&S) impact - Include CCPs, and long term E&S impact in risk model of VfM estimation.	(Samuel and Oshani, 2012; UNECE, 2008)	Resource maintenance and efficiency
Life cycle assessment (LCA) - Adopt a LCA approaches using a materials calculator to quantify and compare materials lifecycle impacts and also recognizes use of materials that have environmental labels.	(UNECE, 2008)	Resource maintenance and efficiency
Green procurement (GP) - Promote GP through enhancement of procurement policy to invite that bid which uses innovative technologies to reduce pollution, climate change mitigation, and recycle of waste.	(UNECE, 2008)	Resource maintenance and efficiency
Environmental and social (E&S) criteria - Include the E&S criteria in bid evaluation through promoting private partners which complying the requirement of an 'Equator Principles' to assess E&S impact on project.	(Samuel and Oshani, 2011; UNECE, 2008)	Socio-ecological system integrity
Additional bidding criteria for energy efficient systems (EESs) - Include additional bidding criteria to promote utilization of EESs systems and various management techniques such as lean construction to minimize construction and operation and maintenance related wastes.	(USDOT, 2007; UNECE, 2008)	Resource maintenance and efficiency
Awareness through value analysis - Arrange comprehensive communication program to educate the public users about the necessity of improved services, as the new service saves their time and cost.	(DEA, 2010)	Intra-generational equality
Modified viability gap funding (VGF) mechanism - Enhance current government payments support system like VGF in India, which is currently limited to 40% of the total project cost.	(UNECE, 2008)	Intra-generational equality
Institute differentiated rates (IDRs) mechanism - Implement IDRs, specifically, adjust charges according to time, location and usage.	(UNECE, 2008)	Intra-generational equality
Relational contracting (RC) - Introduce the concepts of trust and reputation of RC in order to minimize procurement transaction costs through integrating principles of RC in PPP contract.	(Parker and Hartley, 2003)	Livelihood sufficiency and opportunity
Probity arrangements (confirmed integrity and honesty) - Interacting effectively with bidders during the tender process, consistent with appropriate probity arrangements through probity advisors.	(UNECE, 2008; WEF, 2013)	Livelihood sufficiency and

Strategy to Achieve Broad SD Goals	References	SD Goal
		opportunity
Flexibility to private sector for preparation of entire master plan for the project so that it promotes innovative and competitive bids.	(Mahalingam, 2010)	Livelihood sufficiency and opportunity
Special purpose company (SPC) - Establish a SPC, jointly owned by government, users and private developers as an institutional mechanism for development of projects.	(UNECE, 2008)	Socio-ecological civility and demographic governance
Building Information Modelling (BIM) - Adoption of BIM system for better communication tool for stakeholder's participation in decision making and provide greater clarity for all stakeholders across the project lifecycle.	(USDOT, 2007; WEF, 2013)	Socio-ecological civility and demographic governance
Partnering with urban local bodies (ULB) or NGOs - Encouraging community involvement through partnering with ULB /NGOs can play a key role in convincing the community on the benefits of PPP project	(Gupta, 2011; DEA, 2010)	Socio-ecological civility and demographic governance
Renegotiation mechanism (RM) - Include RM in model concession agreement (MCA) to address socio-political or economic changes which could be handled through inflexible contract model.	(Mahalingam, 2010)	Precautionary and adoption
Flexibility in MCA for climate change and disaster - Current MCA should have flexibility to address future unforeseen or unpredictable issues related to climate change, any disaster and risks	(UNECE, 2008)	Precautionary and adoption

Table 5: Preliminary Framework on Strategies for Deliverables of PPP Process

Code	Strategies enhance the sustainability	Deliverables	PPP Phase
STG-1	Strategic environmental assessment	EIA and SIA	Identification
STG-2	Climate change considerations into EIA		
STG-3	Environmental-friendly and smart-growth technique		
STG-4	Green accounting	VfM analysis	Development
STG-5	Climate change parameters and long term E&S impact		
STG-6	Life cycle assessment		
STG-7	Green procurement	Bid preparation and evaluation	Procurement
STG-8	Environmental and social criteria		
STG-9	Additional bidding criteria for energy efficient systems		
STG-10	Awareness through value analysis	User charges	Development
STG-11	Modified viability gap funding mechanism		
STG-12	Institute differentiated rates mechanism		
STG-13	Relational contracting	Bidding and transaction cost	Procurement
STG-14	Probity arrangements (confirmed integrity and honesty)		
STG-15	Flexibility to private sector for preparation of entire master plan		
STG-16	Special purpose company	Stakeholders participation	Development
STG-17	Building information modelling		
STG-18	Partnering with urban local bodies or NGOs		
STG-19	Renegotiation mechanism	Risk allocation	Procurement
STG-20	Flexibility in MCA for climate change and disaster		

5. FEASIBILITY OF FRAMEWORK – THROUGH FOCUSED INTERVIEWS

The feasibility of this preliminary framework formulated in previous stage has been evaluated through focused interviews. The focused interviews comprise of three sub-stages, namely respondent selection, interview protocol, and analysis of interview transcriptions.

5.1. RESPONDENT SELECTION

The targeted respondents are the practitioners involved in development and implementation of PPP projects. For the present study, the experts currently working in and around Guwahati region of India participated in the focused interviews. These experts can be categorized under three groups namely transaction advisors (TAs), officials from government/public sectors (GSs), and project managers from private sectors (PSs).

Sample size in qualitative research projects is determined using the concept of saturation (Miles and Huberman, 1994; Patton, 2002). Saturation occurs when new interviews do not provide additional data over previously conducted interviews and can be limited between 5 and 50 interviews, depending on the interview content and research focus (Patton, 2002). The six respondents have taken from two experts of each category mentioned above. Table 6 shows the details of respondents for each category. The experts are selected based on the criteria: Educational qualification; Position in the organisational hierarchy of the firm, and Number of years of experience relating to PPP procurement process for infrastructure projects in India. These criteria were based on the recommendations suggested by Hallowell and Gambatese (2010) for selecting experts. It could be observed that five out of six respondents having post-graduate degree (i.e. higher qualification). Five respondents are holding top level managerial position in their organisations (two directors, one senior manager, one project engineer, and one project manager) while the remaining one respondent is a middle level management executive (i.e. PPP expert). The experiences of the all respondents have been more than five years while some of them have up to ten years of experience in PPP project development.

Table 6: Demographic Information of Respondents

Code	Sector	Educational Qualification	Position in the Organisation	Experience in Years
TA-1	Consultant	Post Graduate Degree	Director	16-20 Years
TA-2	Consultant	Doctorate	Director	More than 20 Years
GS-1	Government	Post Graduate Degree	PPP Expert	6-10 Years
GS-2	Government	Post Graduate Diploma	Project Engineer	6-10 Years
PS-1	Private	Post Graduate Degree	Manager, Project Panning	6-10 Years
PS-2	Private	Post Graduate Degree	Senior Manager, Contracts	16-20ears

5.2. INTERVIEW PROTOCOL

The focused interview protocol has been designed to gain insights on respondent's understandings of the shortfalls in PPP process and feasible strategies that could be opted to overcome the shortfalls so as to facilitate fulfilment of SD goals. As part of the interview protocol, prior contact has been established with the respondents and the interview template that has been prepared to ensure that line of enquiry focuses on the strategies to overcome the shortfalls is also shared with them prior to the interview. The interview template comprises of three major sections. The first section has been designed to gather information about the qualification, and experience of the respondents in PPP project development. The respondents' opinion of appropriateness for various sustainability principles in PPP projects has been the focus of the second section. Lastly, in the final section, the opinion on suitability of the various strategies to overcome the shortfalls is sought from the respondents

5.3. ANALYSIS OF INTERVIEW TRANSCRIPTIONS

The interviews has been transcribed and analysed with the qualitative research program NVivo10 (QSR, 2014), a software program used in qualitative research to help store, organize, and analyse data (Lincoln and Guba, 1985). The transcriptions of word file and handwritten notes by each respondent have been uploaded into the program. Themes in the data have been coded through open coding under various tree nodes (shortfalls in PPP) and associated free nodes (strategies enhancing sustainability) of NVivo. Further analyse has been conducted to assess the level of agreement elicited by the respondents on feasibility of using the strategies to enhance the sustainability of deliverables in PPP process. The micro-interlocutor analysis - a new method of analysis for focused interview findings have been used wherein the consensus of the respondents is displayed in the form of a matrix (Onwuegbuzie *et al.*, 2009). Table 7 shows the matrix output showing how many respondents have provided substantive statement indicating feasibility of the concerned strategy or example suggesting a dissenting view. The acronyms written below Table 7 are used to define respondent's view on each strategy. It could be observed from the micro-interlocutor analysis that all respondents have expressed views highlighting feasibility of adoption of all the strategies (mentioned with acronym, A/SA), except the four instances wherein the respondents have disagreed (denoted with acronym, D/SD). The aggregated consensus of all the respondents' viewpoints for each strategy is displayed in the last column of matrix.

Table 7: Matrix for Assessing Level of Consensus in Respondents on Feasibility of Strategies

Strategies with Code	Interview Respondents						Aggregate Remark
	TA-1	TA-2	GS-1	GS-2	PS-1	PS-2	
STG-1	A	SA	NR	A	SA	A	A
STG-2	SA	SA	A	A	SA	SA	SA
STG-3	SA	SA	A	A	A	A	A
STG-4	A	A	A	A	SA	SA	A
STG-5	SA	D	SA	A	SA	A	SA
STG-6	A	A	A	A	A	A	A
STG-7	A	A	A	A	SA	A	A
STG-8	A	SA	SA	A	SA	A	SA
STG-9	A	SA	SA	A	SA	A	SA
STG-10	A	A	A	A	SA	A	A
STG-11	A	A	A	SA	SA	A	A
STG-12	A	A	SA	SA	SA	A	SA
STG-13	SD	SA	NR	A	SA	A	SA
STG-14	A	A	SA	SA	SA	A	SA
STG-15	SA	SA	SA	SA	A	A	SA
STG-16	SA	SA	SA	A	SA	A	SA
STG-17	A	A	A	SD	SA	A	A
STG-18	A	A	A	A	SA	A	A
STG-19	A	A	SA	A	SA	A	A
STG-20	A	A	SD	A	A	A	A

(Acronyms: A = Indicates agreement; D = Indicates dissent; SA = Provides significant statement or example suggesting agreement; SD = Provides significant statement or example suggesting dissent; NR = did not indicate agreement or dissent, i.e., non-response)

6. CONCLUSIONS

PPP has become a preferred mode for accelerated infrastructure development for the cash strapped governments in both developed and developing countries. PPP, though, brings in additionally of resources but PPPs are being criticised for unsatisfactory performance and these criticisms relate to the failure to promote sustainable development goals. Analysis of PPP procurement process from sustainability development principles perspective yields the key shortfalls, such as inadequate EIA and SIA, inadequate WLC methodology for VfM analysis, inadequate bid evaluation criteria for PPP procurement, high tariff charges for infrastructure services, high bidding and transaction cost, lack of stakeholder's participation and public opposition, and unbalance risk allocation and mitigation profile between public and private sector.

The strategies to overcome these shortfalls in order to promote satisfactory fulfilment of SD goals have been formulated into a preliminary framework. The key strategies are to replace EIA with SEA; include

E&S dimensions and green accounting in VfM analysis; introduce SPC, BIM and partnering with ULBs and NGOs in stakeholder participation for sustainable feasibility study, introduce RC mechanism and flexibility in preparation of master plan with probity arrangement. The feasibility of the preliminary framework has been tested through focused interview with stakeholders involved in PPP development in and around Guwahati region of India.

The framework gives an insight on various strategies to integrate SD principles in various deliverables of PPP procurement process and these strategies could become a useful tool for government on how to restructure PPP procurement process in India. However, the preliminary framework that has been derived from content analysis and preliminary interviews with local experts from Guwahati region need to be subjected to further study in order to increase the usefulness and enhance the applicability for practitioners.

7. REFERENCES

Albert, P.C., Lam, P.T., Chan, D.W., Cheung, E. and Ke, Y., 2010. Potential Obstacles to Successful Implementation of Public Private Partnerships in Beijing and the Hong Kong Special Administrative Region. *Journal of Management in Engineering*, 26(1), 30-40.

Arce, R. and Gullon, N., 2000. The Application of Strategic Environmental Assessment to Sustainability Assessment of Infrastructure Development. *Environmental Impact Assessment Review,* 20(3), 393-402.

Arts, J. and Faith-Ell, C., 2012. New Governance Approaches for Sustainable Project Delivery. *Procedia-Social and Behavioral Sciences*, 48(1), 3239-3250.

Carrillo, P., Robinson, H., Foale, P., Anumba, C. and Bouchlaghem, D., 2008. Participation, Barriers, and Opportunities in PFI: The United Kingdom Experience. *Journal of Management in Engineering*, 24(3), 138-145.

Cheung, E., 2009. *Developing a Best Practice Framework for Implementing Public Private Partnerships in Hong Kong.* Thesis (PhD). Queensland University of Technology.

Curnow, W., Jefferies, M.C. and Chen, S.E., 2005. Unsustainable Bidding Cost: Critical Issue for Public Private Partnerships. In: *Proceedings of conference on Public Private Partnerships: Opportunities and Challenges,* Hong Kong 22 February 2005. The Hong Kong Institution of Engineers (Civil Division) and The University of Hong Kong. 35-43.

DEA, 2010. *PPP Projects in India: Compendium of Case Studies.* New Delhi: Department of Economic Affairs, Ministry of Finance, Government of India.

DOIT, 2010. *Infrastructure Planning and Delivery: Best Practices Cases.* Canberra: Department of Infrastructure and Transport.

Gibson, R.B., Selma, H., Susan, H., James, T. and Graham, W., 2005. *Sustainability Assessment: Criteria and Process.*1st ed. London: Earthscan.

Gupta, A.P., 2011. *Governance Mechanisms for Infrastructure PPPs: Focus on India.* Thesis (MS), Massachusetts Institute of Technology.

Hallowell, M.R. and Gambatese, J. A., 2010. Qualitative Research: Application of the Delphi Method to CEM Research. *Construction Engineering and Management*, 136(1), 99-107.

Julie, H. and Collins, J., 2004. *PFI Meeting the Sustainability Challenge*. London: Green Alliance.

Koppenjan, J. F. M. and Enserink, B., 2009. Public Private Partnerships in Urban Infrastructures: Reconciling Private Sector Participation and Sustainability. *Public Administration Review,* 69(2), 284-296.

Kuzdas, C., Wiek, A., Warner, B., Vignola, R. and Morataya, R., 2014. Sustainability Appraisal of Water Governance Regimes: The Case of Guanacaste, Costa Rica. *Environmental Management*, 54(2), 205-222.

Li, B., Akintoye, A., Edwards, P.J. and Hardcastle, C., 2005. Perceptions of Positive and Negative Factors Influencing the Attractiveness of PPP/PFI Procurement for Construction Projects in the UK: Findings from a Questionnaire Survey. *Engineering, Construction and Architectural Management,* 12(2), 125-148.

Lincoln, Y.S. and Guba, E.G., 1985. *Naturalistic Inquiry*. 1st ed. London:SAGE.

Lockie, S., 2003. Briefing: Private Finance Initiative: The Lost Green Ticket? *Proceedings of the ICE-Engineering Sustainability,* 156(1), 11-12.

Lorenzo, S., 2008. *Environmentally Sustainable Urban Infrastructure:Outcomes of Recent UNESCAP Activities*. City of Ulsan: First Asia-Pacific Mayors' Forum on Environmentally Sustainable Urban Infrastructure.

Mahalingam, A., 2010. PPP Experiences in Indian Cities: Barriers, Enablers, and the Way Forward. *Journal of Construction Engineering and Management,* 136(4), 419-429.

Miles, M.B. and Huberman, A.M., 1994. *Qualitative Data Analysis: An Expanded Sourcebook*. 2nd ed. London: Sage.

Morrison-Saunders, A. and Hodgson, N., 2009. Applying Sustainability Principles in Practice: Guidance for Assessing Individual Proposals. In: *29th Annual Conference of the International Association for Impact Assessment,* Accra 16-22 May 2009. Accra: Impact Assessment and Human Well-Being, 1-6.

OECD, 2001. *The DAC Guidelines: Strategies for Sustainable Development.* Paris: Organisation for Economic Co-Operation and Development.

Onwuegbuzie, A.J., Dickinson, W.B., Leech, N.L. and Zoran, A.G., 2009. A Qualitative Framework for Collecting and Analyzing Data in Focus Group Research. *International Journal of Qualitative Methods,* 8(3), 1-21.

Parker, D. and Hartley, K., 2003. Transaction Costs, Relational Contracting and Public Private Partnerships: A Case Study of UK Defence. *Journal of Purchasing and Supply Management*, 9(3), 97-108.

Patton, M.Q., 2002. *Qualitative Research and Evaluation Methods*. 3rd ed. London: SAGE.

PPP Cell, 2014. *Public Private Partnership Toolkit* [online]. New Delhi, PPP Cell, Department of Economic Affairs. Available from: toolkit.pppinindia.com [Accessed 18 April 2014].

PWC, 2005. *Delivering the PPP Promise: A Review of Public Private Partnership Issues and Activity*. London: Price-water-house-Coopers.

PWC, 2008. *Infrastructure in India: A Vast Land of Construction Opportunity*. London: Price-water-house-Coopers.

QSR, 2014. *NVivo* [online]. Melbourne, QSR International. Available from: http://www.qsrinternational.com/default [Accessed 13 May 2014].

Samuel, C. and Oshani, P., 2011. *Sustainable Development: Is there a Role for Public Private Partnerships?* Ontario: International Institute for Sustainable development.

Samuel, C. and Oshani, P., 2012. *Harnessing the Power of Public Private Partnerships: The Role of Hybrid Financing Strategies in Sustainable Development.* Ontario: International Institute for Sustainable development.

Shah, S. H. and Gibson, R. B., 2013. Large Dam Development in India: Sustainability Criteria for the Assessment of Critical River Basin Infrastructure. *International Journal of River Basin Management*, 11(1), 33-53.

UNECE, 2008. *Guidebook on Promoting Good Governance in Public Private Partnerships.* New York and Geneva: United Nations Publication, United Nations Economic Commission for Europe.

UNESCAP, 2006. *Sustainable Infrastructure in Asia.* The Seoul: Seoul Initiative Policy Forum on Sustainable Infrastructure Seoul, United Nations Economic and Social Commission for Asia and the Pacific.

USDOT, 2007. *Case Studies of Transportation Public Private Partnerships in the United States.*Washington, DC: United States Department of Transportation.

WEF, 2013. Strategic Infrastructure Steps to Prepare and Accelerate Public-Private Partnerships. Geneva: World Economic Forum.

Wiek, A. and Larson, K., 2012. Water, People, and Sustainability: A Systems Framework for Analyzing and Assessing Water Governance Regimes. *Water Resources Management*, 26(11), 3153-3171.

STRENGTHENING THE SAFETY CULTURE IN RAW RUBBER PROCESSING STAGE THROUGH HUMAN CAPACITY BUILDING: A CONCEPTUAL FRAMEWORK

D.M.P.P. Dissanayake* and Nirodha Gayani Fernando
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Safety and health in the raw rubber processing stage has been a neglected subject, though this sector is still a major foreign exchange contributor to the national economy in Sri Lanka. Occupational safety and health concerns in raw rubber processing organisations have always been and continue to be of the utmost importance. Thus, establishing and strengthening of the safety culture is most critical in raw rubber processing environments with a high risk of health and safety concerns. The cause analysis for failings related to safety culture in raw rubber processing sector are varied and far reaching; with each issue coming into play at one critical point in time. However, most of the weaknesses are related with 'Human factors: How people feel (Heart and Mind)', 'What people do (Daily Action)'. Thus, developing of human capacities such as attitudes, behaviours, skills and knowledge etc. on this perspective will be an effective tool in addressing those failures and strengthening the safety culture in raw rubber processing sector. This paper therefore aims to develop a conceptual framework for strengthening the safety culture in raw rubber processing stage through human capacity building. A comprehensive literature review was used as the research methodology for this paper. Research findings illustrated that yet, like in any other employment sector, workers involved in raw rubber processing activity run an equal if not higher risk of being injured as a result of the type of work they do. Due to management and worker ignorance and rubber products manufacturing chemicals and bad work practices in some factories, serious hazards have been created and many accidents have occurred. Strengthening the safety culture is about more than removing hazards and establishing safety procedures. It is about working with people of the organisation to change their attitudes, behaviours and thoughts, and improve their situational awareness. The finding of this research incorporated into a conceptual framework which proposes a better working condition so that the safety culture can be strengthen.

Keywords: *Human Capacity Building; Human Factors; Raw Rubber Processing Stage; Safety Culture.*

1. INTRODUCTION

Safe and healthy workplaces help businesses and organisations to succeed and prosper, and also benefit wider society (Sukadarin *et al.*, 2012). Safety and health at work have traditionally been approached mainly by means of legislation and enforcement measures. Effective safety management in the twenty-first century involves paying attention to human factors as system components with as much potential to cause, or save, dangerous system states as technical components. By paying attention to human factors, highly reliable organisations can identify and capture potential hazards before they manifest as accidents. One method of achieving this is by measuring the state of safety through so-called 'leading' indicators such as safety culture (Yule, 2003).Therefore, companies are being encouraged to adopt a positive organisational safety culture in order to safeguard their operations against accidents and it is accepted as the number one priority (Clarke, 2003; Sukadarin *et al.*, 2012). In industries, like aviation, nuclear power, manufacturing and rubber processing this makes sense. Since safety and health in the raw rubber processing stage has been a neglected subject, strengthening a positive safety culture through paying attention on human factors is important.

* Corresponding Author: E-mail - piumi2d@gmail.com

For a good safety culture, involvement of human of the organisation together with their positive attitudes and beliefs, behaviours, knowledge and skills, past experiences etc. is indispensable. This is due to the fact that strengthening a strong safety culture is about more than removing hazards and establishing safety procedures. It is about working with human of the organisation to change their attitudes, behaviours and thoughts, and improve their situational awareness within the dynamics of today's world. Also, human resource as one of the most valuable resources in the organisation brings whatever the planned procedures, systems etc into reality. Therefore, capacitating the human to strengthen the safety culture in raw rubber processing stage is a timely requirement which will ensure the long term business continuity together with protection of employees and properties. Thus, in this study, capacity building is aimed towards capacitating the human for strengthening the safety culture in raw rubber processing stage.

2. RESEARCH METHOD

A comprehensive literature review was used as research methodology for this research paper. Literature review was carried out on a broader perspective with the purpose of getting familiarised with the subject areas of the research study while holding the focus on research problem. The background study took the attention of journal articles, online journals, e-books, web sites, electronic library data base and other publications. A conceptual framework for strengthening the safety culture in raw rubber processing stage through human capacity building was developed at the end by bringing in literal arguments**.**

3. 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 nuclear disaster in 1986 (Flin *et al.*, 2000). The investigation report by the International Nuclear Safety Advisory Group (INSAG) of the International Atomic Energy Agency (IAEA) identified that poor safety culture as one of the contributing factors to this worst nuclear power plant accident in history (INSAG, 1986 cited in European Agency for Safety and Health at Work, 2010) and which led to safety culture being defined as an organisational atmosphere where safety and health is understood to be, and is accepted as, the number one priority. From then on the concept of safety culture has been used more and more in safety research, particularly in high-risk industries. Safety culture is an abstract concept, giving researchers a large degree of freedom on how they understand these concepts and put them into practice (Havold, 2005). This implies that there is a lack of consensus on how the safety culture concept is understood, and now ideally accepted definition of the concept either (Guldenmund, 2010). In this context, following sub Sections 3.1 and 3.2 explore the relevant literature in the research arena with major focus is given on two areas: defining the safety culture and elements of safety culture.

3.1. DEFINING SAFETY CULTURE

Over the past years, the concept of safety culture has been studied by many researchers from different scientific backgrounds and disciplines. A distinction can be made between the approach taken by psychology-oriented research and the engineering-based approach (Antonsen, 2009). The psychological approach is interested specifically on how workers feel about and distinguish safety and safety management, and on their attitudes and behaviour regarding risks and safety. This psychological research refers more to the term 'safety climate' than to 'safety culture'. When it comes to the engineering approach, it is more focused and interested in the formal and managerial aspects and systems that have an influence on safety such as management systems, procedures, policies, control systems, etc.

Apart from this deviation between the psychological versus engineering perspective, safety culture can also be analysed from the viewpoint of organisational (culture) theory. For an example, Guldenmund (2010) considers safety culture as that part of organisational culture that is related to safety and risks. This is further emphersised by many researchers and they stated that safety culture is a subset of the corporate organisational culture that comprises workforce beliefs, attitudes, behaviours, norms and values, personal responsibilities as well as human resources features such as training and development with regard to safety (Sukadarin *et al.*, 2012; Clarke, 1999; Glendon and Stanton, 2000). 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
Cox and Cox (1991)	Safety culture is the ways in which safety is managed in the workplace, and often reflects the attitudes, beliefs, perceptions and values that employees share in relation to safety
Kennedy and Kirwan (1998)	An abstract concept, which is underpinned by the amalgamation of individual and group perceptions, thought processes, feelings and behaviours, which in turn gives rise to the particular way of doing things in the organisation. It is a sub-element of the overall organisational culture
Hale (2000)	Refers to the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems
Glendon and Stanton (2000)	Comprises attitudes, behaviours, norms and values, personal responsibilities as well as human resources features such as training and development
Guldenmund (2000)	Aspects of the organisational culture which will impact on attitudes and behaviour related to increasing or decreasing risk
Cooper (2000)	The product of multiple goal-directed interactions between people (psychological), jobs (behavioural) and the organisation (situational); while safety culture is 'that observable degree of effort by which all organisational members directs their attention and actions toward improving safety on a daily basis
Mohamed (2003)	A sub facet of organisational culture, which affects workers' attitudes and behaviour in relation to an organisation's on-going safety performance
Richter and Koch (2004)	Shared and learned meanings, experiences and interpretations of work and safety - expressed partially symbolically – which guide people's actions towards risk, accidents and prevention
Fang *et al.* (2006)	A set of prevailing indicators, beliefs and values that the organisation owns in safety
National Institute for Occupational Safety and Health (NIOSH) (2008)	Underlying organisational principles, norms, commitments and values related to the operation of safety and health, as well as its importance compared with other workplace goals.

Most of the definitions are relatively similar in the beliefs perspective, with each focusing, to varying degrees, on the way people think and behave in relation to safety. The definitions (see Table 1) adopted by Hale (2000), Glendon and Stanton (2000) and Cooper (2000) are the most practical, as they clearly outline the contents of safety culture. As explained in above, safety culture is about the way of managing the safety in the workplace and it is a combination of safety attitudes, beliefs, perceptions and values that employees share in relation to safety, safety behaviours and organisational environment, systems and procedures in relation to safety. Many researchers have been illustrated key elements to be considered when strengthening the safety culture. In this context, next section explores the elements of safety culture.

3.2. ELEMENTS OF SAFETY CULTURE

The concept of safety culture has been studied by many researchers from different perspectives. These perspectives include psychology-oriented approach and the engineering-based approach (Antonsen, 2009). The researchers who have defined the safety culture from *psychological approach*, mentioned that safety culture consist with psychological elements such as values, beliefs and perception and attitudes towards safety. For an example, the definition by Cox and Cox (1991) stated that safety culture reflects attitudes, beliefs, perceptions and values that employees share in relation to safety. The psychological aspects state how employees think and feel about safety and it is usually about winning over people's heart and minds.In *engineering approach*, researchers highlights the formal and managerial aspects such as management systems (Dissanayake and Fernando, 2014); procedures such as external and internal reporting procedures (Piers *et al.*, 2009; Gilbert *et al.*, 2012); policies (MacDonald *et al.*, 2000 cited Sukadarin *et al.*, 2012) and control systems safety evaluation, safety communication (Piers *et al.*, 2009; Dissanayake and Fernando, 2014) etc. as key elements of the safety culture.

When it comes to the study by Cooper (2000), he divided the safety culture into three elements which includes behavioural aspects in addition to the psychological and managerial aspects explained in above. Behavioural aspects discuss about what employees do in regards to safety and it includes their day-today activities towards safety in their working environment. This includes aspects such as Leadership (Reason, 1998); Supervisor subordinate relationship (Dissanayake and Fernando, 2014); Job satisfaction, Adequate equipments and its condition (Sawach *et al.,* 1999); Workmate's influence, Awareness - Safety training, Safety knowledge and Competency (Nishgaki, 1994; Garza, 1988; Davies and Tomasin, 1999; Sukadarin *et al.*, 2012); Personal responsibilities and Adaptability (Piers *et al.*, 2009). Psychological and Behavioural aspects directly link with human factors. The organisational/ managerial aspects cover the safety management systems that a company uses to set the guidelines for what people should do in various circumstances. Though organisational aspects directly discuss about 'what the organisation has', it indirectly links with human factors as organisational aspects guide people on what they 'should' do in relation to safety. Figure 1 depicts the all psychological, behavioural and organisational aspects discussed in above.

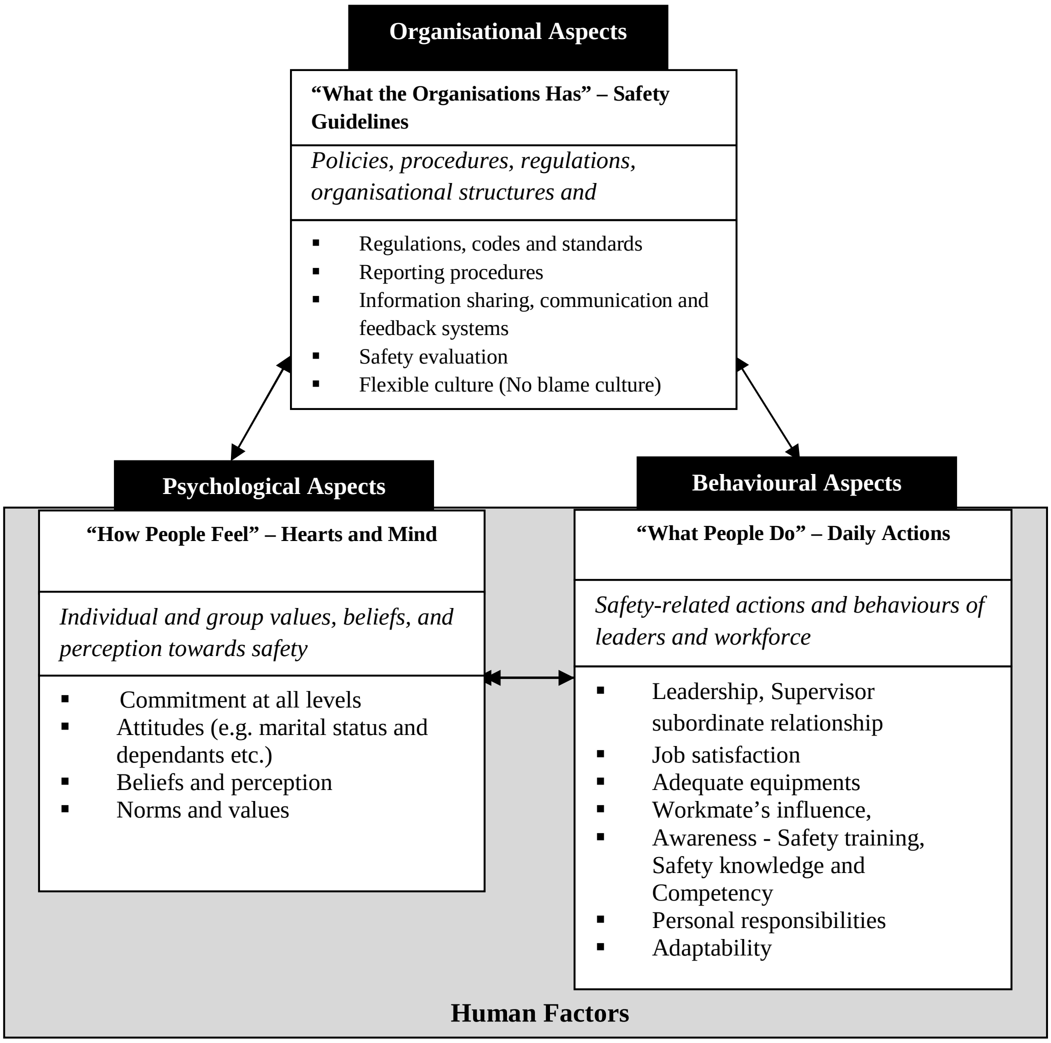


Figure 1: Elements of Safety Culture

4. IMPORTANCE OF STUDYING SAFETY CULTURE IN RAW RUBBER PROCESSING STAGE

The raw rubber processing sector as a heavy industry, it poses a number of health and safety risks to workers employed in that stage (Department of Census and Statistics, 2013). As an overall, the cause analysis for failings related to safety culture in raw rubber processing stage are varied and far reaching; with each issue coming into play at one critical point in time. As stated by Yogaratnam (2010), since a large number of unskilled and semi-skilled workers are employed in the raw rubber processing, many mechanical and chemical hazards exist. Not only that but also management and worker ignorance, negligent use of chemicals and pest and weed controlling and rubber products manufacturing chemicals, bad work practices, communication issues, prioritising cost-cutting and production above safety and poor competency of managers in risk/hazard management lead to create many serious accidents and hazards where about 15 percent of the total poisonings and deaths in Sri Lanka reported due to occupational accidents (Yogaratnam, 2010). Further, it causes a number of health and safety risks to workers employed in that stage. The main risks posed are from unguarded machinery in the factory and also many mechanical (i.e., rolls and centrifuges) and chemical hazards are exist in raw rubber processing which require strict safety controls and appropriate safety precautions during installation, use and maintenance, including attention to machine guarding (Alan, 2011). Since large quantities of chemicals are used as fertilizers and pesticides, many accidents have taken place among the workers, who are mainly estate labourers (Yogaratnam, 2010). Alan (2011) further highlights that proper concentration should be paid to the working area to slips, trips and falls. Employees should receive training in safe work practices and above findings highlight the lack of training on safe work practices. Generally, raw rubber processing involves mixtures of various chemicals which use to heat, pressure, and catalytic action during a variety of manufacturing processes. As a result, the work environment may be contaminated with dusts, gases, vapours, fumes, and chemical by products present (Centre for Disease Control and Prevention, 1993; Thompsons Solicitors, 2013). Therefore, workers may be exposed to these hazards through inhalation and skin absorption during rubber processing and product manufacturing.

The critical analysis of causes for failings related to safety culture in raw rubber processing stage show that said stage has been highlighted as having a higher rate of accidents than other similar industries. Simply, workers in this stage also having a high risk of being injured as a result of the type of work they do. Most of the weaknesses mentioned in above are related with ‘***Human factors: How people feel (Heart and Mind)’, ‘What people do (Daily Action)’.*** Thus, developing of human capacities such as attitudes, behaviours, skills and knowledge etc. on this perspective will be an effective tool in addressing those failures and strengthening the safety culture in manufacturing environment. This is further emphasized by Vecchio-Sudus and Griffiths (2004) as changing attitudes and behaviours of management and employees, ensuring their involvement and providing required training and seminars for them help to strengthen and further promote a safety culture. The next Section discusses about human capacity building and its importance in relation to strengthen safety culture in raw rubber processing stage.

5. HUMAN CAPACITY BUILDING AND ITS IMPORTANCE TO STRENGTHEN THE SAFETY CULTURE IN RAW RUBBER PROCESSING STAGE

Viewing human resources as human capital and beyond, the study argues that without human resources nothing can be accomplished, and without well-trained, well-developed, well-appreciated, and well-managed human resources, organisations can not establish the strong safety culture within it. As discussed in previous section, strengthening of the safety culture is about working with human of the organisation to change their attitudes, behaviours etc to improve to improve their situational awareness. Simply, it is to build their capacity towards strengthening the safety culture. The key words or concepts of capacity building with respect to the human aspects used in this section require some explanations.

According to Chapagain (2004, p.15), “capacity building is an approach to develop one’s own potentiality in order to enhance his/her performance or output”. He further stated that it is a response to the multi-dimensional such as organisational, intellectual, social, political, cultural, physical, financial etc. processes of change to bring intended outcome. The study by Farazmand, (2004) views capacity buildings mainly as an internal, local or domestic matter, where it directly relates to sustainable development and enhancement. Therefore, it is clear that the concept of capacity building is an essential component in development theory and practice, especially among various global, international and national originations such as World Bank, international donor agencies and civil societies (Pieterse and Donk, 2002). UNESCO (2006, p1), defines capacity building as 'process by which individuals, groups, organisations, institutions and societies increase their ability to perform (a) core functions, solve problems, define and achieve objectives and (b) understand and deal with development needs in a broad context and in a sustainable manner', adding that the focus of capacity building has changed from individual training to integration of individual capacities to institutions and systems. All these definitions and views on capacity building emphasise that capacity building is not a separate entity isolated from organisation's vision and mission. Chapagain (2004) further stated that it is always associated with day to day action to fulfil organisation's vision and mission. It provides an opportunity to understand strengths, weaknesses, threats and opportunities towards a resilient future through identification of broader issues around sustainable development of a particular programme, project or process, including unique cultural, social and ecological characteristics (Boyd and Juhola, 2009). Thus, levels of capacity building vary based on discipline and on the context within which it is applied, whilst activities and interventions may occur within and across capacity building levels/ dimensions.

Human resource development (individual and team), organisational development (organisations and relationships) and institutional and legal framework development are the three most important, linked levels or components of capacity building (Franks, 1999; Low *et al.*, 2001; UNESCO, 2006). Organisational development addresses elaboration of management structures, processes and procedures within organisations and maintaining relationships with other organisations and sectors, such as public, private and community (Low *et al.,* 2001; LaFord *et al.,* 2002; UNESCO 2006). Aspects related to institutional and legal framework development include legal and regulatory changes to enable organisations, institutions and agencies at all levels, in all sectors, to enhance their capacities (Low *et al.,* 2001; UNESCO, 2006). Considering about the human resource development, it is the process of equipping individuals with understanding, skills and access to information, knowledge and training, enabling effective performance (Low *et al.,* 2001; LaFord *et al.,* 2002; UNESCO 2006).

In this study, capacity building is aimed towards capacitating the human resources (Human resource development) to become reflective practitioners where they able to strengthen the safety culture of raw rubber processing stage. Human capacity building in this study is therefore, refers to building and enhancing a cadre of highly qualified, highly able, and highly motivated human resources at all levels with required skills, knowledge and capabilities to strengthen the safety culture raw rubber processing stage. Such a capability enables organisation to not only cope with and manage ongoing current challenges of safety culture but also to act well beyond by performing through anticipation, effective visions, proactive knowledge and skills, and self-corrective organisational behaviour. As stated by Eade and Williams (1995 cited Eade, 1997, p.23), "strengthening the human capacity to determine their own values, and priorities and to organise themselves to act on these, is the basis of development". Having identified the human capacity building as an important approach to strengthen the safety culture in raw rubber processing stage, next sections discuss how human capacity would be developed.

5.1. EXPECTED CAPACITY LEVELS: ASSESSING SAFETY CULTURE

Capacity gaps in this study show the differences between expected capacity levels and current level or else areas to be improved in order to move from its current safety culture maturity level to its desired future state or next safety culture maturity levels. Identification of desired capacity levels in terms of safety is an important task to be done at the early stage of the study. Accordingly, expected capacity levels in terms of safety culture was developed based on the literature discussed in Section 3.2 as elements of safety culture describe how the safety culture is comprised of and what sort of characteristics should be there to be a strong safety culture. Also, Fleming (2001) argues that an organisation's or installation's level of maturity is determined on the basis of their maturity on these elements. However, these elements (refer Figure 1) are at a fairly high level where they need to be expressed in more measurable terms. These are called as benchmark or indicators of expected capacity level in terms of safety. Each of these elements of safety culture is expressed in several safety culture indicators or as expected capacity levels in terms of safety as shown in Table 2.

Table 2: Expected Capacity Levels: Safety Culture Assessment

Element	Expected Capacity Levels	Author/ Year
Psychological Aspects		
Management concern	▪ Management's decision making with respect to safety ▪ Management's provision of adequate resources ▪ Developing safety policies ▪ Assigning safety responsibilities to personnel ▪ Importance of safety meeting	Cooper (2000) Piers *et al.* (2009) Sukadarin *et al.* (2012) Piyadarshani *et al.* (2013)
Perception of importance of safety (Values/ beliefs/ perceptions)	▪ Importance of safety issues ▪ Employees' concern for safety ▪ Importance of safety for business continuity	Piers *et al.* (2009) Sukadarin *et al.* (2012) Piyadarshani *et al.* (2013)
Prioritization of safety (Values/ beliefs/ perceptions)	▪ Priority of safety over profit and performance ▪ Investment of money and effort to improve safety	Sukadarin *et al.* (2012) Mills and Huberman (1994)
Behavioural Aspects		
Employee behaviour with respect to safety	▪ Prevention of accidents and incidents by employees/ Attention to safety protection by workers ▪ Unnecessary risk taking ▪ Maintaining close supervision of workers	Cheng *et al.* (2004) Jannadi (1996)
Job satisfaction	▪ Appreciation of work ▪ Acquirement of colleagues' respect by safe record	Molenaar *et al.* (2009).
Adequate equipment	▪ Access to equipment ▪ Condition of equipment	Sawacha *et al.* (1999)
Safety training	Awareness of job induced risk ▪ Awareness by management and employees of own risk on the job ▪ Awareness by management and employees of others' risk induced by the job Educating workers and supervisors in developing good safety habits Emergency training	Garza (1988) Nishgaki (1994) Jannadi (1996) Davies and Tomasin (1999)
Adaptability	Pro-activity to prevent occurrences ▪ Occurrences not the only input for safety improvement ▪ Autonomous searching of safety issues by employees Actions with respect to occurrences ▪ Actions upon reporting safety issues, incidents or accidents ▪ Follow-up of the improvements implemented Employee input ▪ Encouragement of employees to suggest improvements ▪ Assignment of right persons to solve problems	Piers *et al.* (2009)
Organisational Aspects		
Regulations, codes and standards	Establishing safety management system with adherence to legislation codes and standard	Piyadarshani *et al.* (2013)
Reporting procedures	Safety issues reporting system ▪ Perception of importance of safety issues reporting system ▪ Encouragement to report safety issues Willingness to use the reporting system ▪ Willingness to report minor incidents ▪ Possibility for anonymous reporting Consequences of safety reports	Pierset *al.* (2009) Gilbert *et al.* (2012)

Element	Expected Capacity Levels	Author/ Year
	▪ Appreciation of employees reporting safety issues ▪ Satisfaction with the way safety reports are dealt with	
Safety evaluation	Perception of evaluation ▪ Fair judgment after safety occurrences ▪ Clarity of evaluation system Evaluation of safety related behaviours ▪ Clear distinction between acceptable and unacceptable behaviour ▪ Consequences of reporting safety issue Passing of responsibility ▪ Acknowledgement of own errors by management ▪ Looking for scapegoat after safety occurrences	Piers *et al.* (2009)
Information sharing, communication and feedback systems	Availability of information ▪ Availability of work related information ▪ Clarity of instructions Communication of work related information ▪ Communication between different teams/ units ▪ Clarity about who shall communicate which work related information to whom Communication of safety related information ▪ Communication of safety issues to all employees ▪ Information of employees of changes affecting safety ▪ Conducting safety meetings for supervisors Information exchange about safety issues ▪ Talking about safety issues amongst employees ▪ Review of events	Piers *et al.* (2009) Molenaar *et al.* (2009) Hinze and Rabound (1998)

6. CAPACITY BUILDING APPROACHES TO SAFETY

Crisp *et al.* (2000), discuss two approaches of a top-down organisational approach and bottom-up organisational approach to capacity building. Emphasis in a top-down organisational approach is placed on policies or practices. Generally, senior management develops a top-down driven strategy on safety as part of an organisation's overall strategy for business or other mission. Safety management system is one of the key aspects, which includes safety performance measurement - both proactive and reactive, risk assessment and control, Human Resource Management (HRM) and safety culture (Glendon and Stanton, 2000). Safety culture comprises attitudes, behaviours, norms and values, personal responsibilities as well as such HR features as training and development. These factors contribute to human interventions.

This is common approach used by many of the organisations to establish safety within their workplace. However, safety and health in the raw rubber processing stage has been a neglected subject, though this sector is still a major foreign exchange contributor to the national economy in Sri Lanka. The literature findings further revealed that majority of health and safety issues have arisen due to human aspect (refer Section 4.2). Therefore, it requires analysis of these human behaviours to identify human development areas and develops their capacities accordingly to tackle this problem. Simply, it requires an operational approach. A bottom-up organisational approach can be used on this perspective as it is an operational approach where it addresses provision of skills, knowledge to staff and capacity building of workers and managers to proactively remediate issues (David, 2013). Further, as stated by Crisp *et al.* (2000), a bottom-up organisational approach is mainly focused on organisational and human capacity building. In this context, the bottom-up approach is used as an overall human capacity building approach with its immense scope (refer Section 7).

7. DEVELOPING THE CONCEPTUAL FRAMEWORK

By incorporating the main concepts discussed in above sections; elements of safety culture, human capacity building approaches and their relationships, the conceptual framework pertaining to this study is drafted as shown in Figure 2.

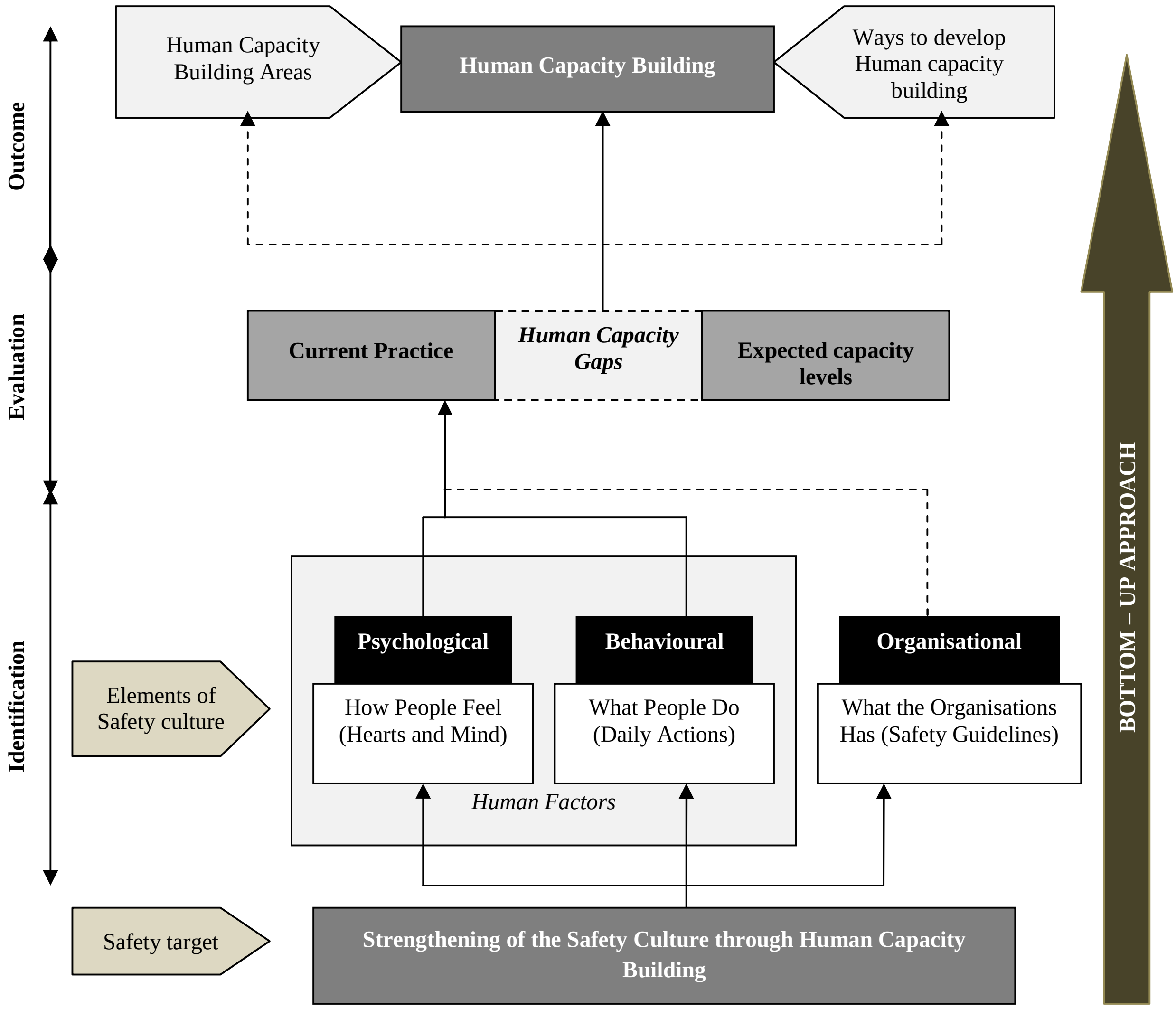


Figure 2: Conceptual Framework

Building and sustaining capacity requires organisational capacity as well as the expertise of individuals (Grisso *et al.*, 1995; Rist, 1995). As stated by Glendon and Stanton (2000), in a bottom up approach the driver may be a safety target or specific objective, such as accident prevention. In this study, it would be the 'strengthening the safety culture through human capacity building'. Safety culture comprises with three elements namely; organisational, behavioural and psychological factors as discussed in Section 3.2. In order to understand better how human interaction with tasks might lead to failings related to safety culture, both behavioural and psychological aspects should be analysed with compared to expected capacity levels. However, organisational aspects cannot be neglected at this level as it influence on human aspects and it guides human on what they 'should' do in relation to safety. The analysis of human failings will also help to identify human capacity gaps. Then, respective personnel should identify human capacity building areas that might have prevented the human error, or which could be implemented to prevent or reduce the likelihood of that error, are indicated. Simply, they should identify steps need to be taken in order to move from its current safety culture maturity level to its desired, future state or next safety culture maturity levels. These could be further training or changes to existing training, changes in procedures, changes in management or organisational policy**.**

8. CONCLUSIONS AND WAY FORWARD

This literature review aimed at developing a conceptual framework for strengthening the safety culture in raw rubber processing stage through human capacity building by bringing in literal arguments. Since health and safety concerns in raw rubber processing environment have always been and continue to be of the utmost importance, creating a positive safety culture is very important. Research findings revealed that creating a strong safety culture is about more than removing hazards and establishing safety procedures. It is about working with people of the organisation to change their attitudes, behaviours and thoughts, and improve their situational awareness within the dynamics of today's world. Also, literature findings disclosed that safety culture is mainly focus on the way people think and behave. Therefore, this highlights the importance of developing of human capacity in strengthening safety culture. A conceptual framework developed at the end of the literature review will be for strengthening the safety culture in raw rubber processing stage through human capacity building (refer Figure 2). Further, research proposed related this work could be developing methodological frameworks to gather empirical findings to test the validity of the conceptual framework.

9. REFERENCES

Alan, E., 2011. Rubber Tree Cultivation. *ILO Encyclopedia of Occupational Health and Safety* [online]. Available from: http://www.ilo.org/oshenc/part-xii/rubber-industry/item/388-rubber-tree-cultivation [Accessed 15 December 2014].

Antonsen, S., 2009. *Safety Culture: Theory, Method and Improvement*, UK: Ashgate Pub Co.

Centre for Disease Control and Prevention, 1993. *Special NIOSH Hazard Review Rubber Products Manufacturing Industry* [online]. Available from: http://www.cdc.gov/niosh/docs/93-106/ [Accessed 15 March 2014].

Chapagain, C.P., 2004. *Human Resource Capacity Building through Appreciative Inquiry Approach in Achieving Development Goals.* Dissertation (Doctoral). University of Madison.

Cheng, E.W.L., Li, H., Fang, D.P. and Xie, F., 2004. Construction Safety Management: An Exploratory Study from Department Of Building and Real Estate. *Construction Innovation*, 4, 224–229.

Clarke, S., 1999. Perceptions of Organisational Safety: Implications for the Development of Safety Culture. *Journal of Organisational Behaviour*, 20, 185–198.

Clarke, S., 2003. The Contemporary Workforce: Implications for Organisations Safety Culture. *Personnel Review*, 32(1), 40-57.

Cooper, M.D., 2000. Towards a Model of Safety. Culture. *Safety Science*, 36, 111–136.

Cox, S. and Cox, T., 1991. The Structure of Employee Attitudes to Safety - A European Example. *Work and Stress*, 5, 93-106

Crisp, B.R., Swerissen, H. and Duckett, S.J., 2000. Four Approaches to Capacity Building in Health: Consequences for Measurement and Accountability. *Health Promotion International*, 15(2), 99-107.

Davis, V. and Tomasin, K., 1999. *Construction Safety Handbook*. 2nd ed. Thomas Telford: New York.

Department of Census and Statistics, 2013. *Annual Survey of Industries (Final Report).*

Dissanayake, D.M.P.P. and Fernando N.G., 2014. Establishing a Positive Safety Culture in Rubber Manufacturing Sector: Human Factors. *World Construction Symposium 2014*, Colombo 20–22 June 2014.

Eade, D., 1997. *Capacity-Building: An Approach to People-Centred Development*. UK: Oxfam.

European Agency for Safety and Health at Work, 2010. *Mainstreaming OSH into Business, Luxembourg, Office for Official Publications of the European Communities* [online]. Available from http://osha.europa.eu/en/publications/ report s/mainstreaming_osh_business [Accessed 15 March 2014].

Fang, D.P., Chen, Y. and Louisa, W., 2006. Safety Climate in Construction Industry: A Case Study in Hong Kong. *Journal of Construction Engineering and Management,* 132(6), 573–584.

Farazman, A. 2000. Innovation in Strategic Human Resource Management: Building Capacity in the Age of Globalization. *Public Organisation Review: A Global Journal*, 4, 3–24.

Fleming, M. and Lardner, R., 1999. Safety Culture – the Way Forward. *The Chemical Engineer*, 6-18.

Flin, R., Mearns, K., O'conner, P. and Bryden, R., 2000. Measuring Safety Climate: Identifying the Common Features. *Safety Science*, 34, 177-192.

Franks, T., 1999. Capacity Building and Institutional Development: Reflections on Water. *Public Administration and Development*, 19(1), 51-61.

Garza, J., 1988. Analysis of Safety Indicators in Construction. *Journal of Construction Engineering and Management*, 124(4), 312-314.

Gilbert, Y.J.A., Ahonen L.M.W. and Lähde, A., 2012. *The Role of Safety Reports in Preventing Accidents: Key Points and Conclusions.* 4th ed. European Commission's Joint Research Centre and the Finnish Safety and Chemicals Agency (TUKES).

Glendon, A.I. and Stanton, N.A., 2000. Perspectives on Safety Culture. *Safety Science*, 34, 193–214.

Grisso, J.A., Christakis, E. and Berlin, M., 1995. Development of a Clinical Research Program in Women's Health. *Journal of Women's Health*, 4, 169–178.

Guldenmund, F.W., 2000. The Nature of Safety Culture: A Review of Theory and Research. *Safety Science*, 34, 215–257.

Hale, A.R., 2000. Editorial: Culture's Confusions. *Safety Science*, 34, 1–14.

Havold, J.I., 2005. Measuring Occupational Safety: From Safety Culture to Safety Orientation? *IOSH, Policy and Practice in Health and Safety*, 2005(1), 85-105.

Hinze, J. and Rabound, P., 1988. Safety on Large Building Construction Projects. *Journal of Construction Engineering and Management*, 114(2), 286–293.

Jannadi, M.O., 1996. Factors Affecting the Safety of the Construction Industry. *Building Research and Information*, 24(2), 108–111.

Kennedy, R. and Kirwan, B., 1998. Development of a Hazard and Operability-Based Method for Identifying Safety Management Vulnerabilities in High Risk Systems. *Safety Science*, 30, 249–274.

LaFord, A.K., Brown, L.B. and Macintyre, K., 2002. Mapping Capacity in the Health Sector: A Conceptual Framework. *International Journal of Health Planning and Development*, 17, 3-22.

Low, A., Tjongarero, A., Low, A. and Nambundunga, B., 2001. Donor Support to Human Resource Capacity Building in Nambia: Experience of Residential Technical Assistants Support for Workplace Learning and Assessment of Alternative Options. *Journal of International Development*, 13, 269-285.

Miles, M.B. and Huberman, A.M., 1994. *An Expanded Sourcebook – Qualitative Data Analysis*. 2nd ed. California: Sage publications Inc.

Mohamed, S., 2003. Scorecard Approach to Benchmarking Organisational Safety Culture in Construction. *Journal of Construction Engineering and Management*, 129(1), 80–88.

Molenaar, K.R., Park, J.I. and Washington, S., 2009. Framework for Measuring Coperate Safety Culture and Its Impact on Construction Safety Performance. *Journal of Construction Engineering and Management*, 135, 488-496.

National Institute for Occupational Safety and Health (NIOSH), 2008. *National Occupational Research Agenda: National Construction Agenda for Occupational Safety and Health Research and Practice in the U.S. Construction Sector* [online]. Available from: www.cdc.gov/niosh/nora/comment/agendas/construction /pdfs/ConstOct2008.pdf [Accessed 17 March 2014].

Nishgaki, S., 1994. Humanware, Human Error and Hiyari-Hat: A Template of Unsafe Symptoms. *Journal of Construction Engineering and Management*, 120(2), 421-441.

Piers, M., Montijn, C. and Balk. A., 2009. *Safety Management System and Safety Culture Working Group*. Netherlands: Dutch National Aerospace Laborator.

Pieterse, E. and Donk, M.V., 2002. *Capacity Building for Poverty Reduction*. South Africa: Isandla Institute.

Priyadarshani, K., Karunasena, G. and Jayasuriya, S., 2013. Construction Safety Assessment Framework for Developing Countries: A Case Study of Sri Lanka. *Journal of Construction in Developing Countries*, 18(1), 33-5.

Reason, J., 2000. Safety Paradoxes and Safety Culture. *Journal of Injury Control and Safety Promotion*, 7, 3–14.

Richter, A. and Koch, C., 2004. Integration, Differentiation and Ambiguity in Safety Cultures. *Safety Science*, 42, 703–722.

Rist, R. C., 1995. Postscript: Development Questions and Evaluation Answers. *New Directions for Evaluation*, 67, 167–174.

Sawacha, E., Naoum, S. and Fong, D., 1999. Factors Affecting Safety Performance on Construction Sites. *International Journal of Project Management*, 17(5), 309–315.

Sukadarin, E.H., Suhaimi, N.H. and Abdull, N., 2012. Preliminary Study of the Safety Culture in a Manufacturing Industry. *International Journal of Humanities and Social Science*, 2(4), 176-183.

Thompsons Solicitors, 2013. *Rubber Industry Health and Safety* [online]. Available from: http://www.thompsons.law.co.uk/workplace-illnesses-and-diseases/rubber-industry-health-and-safety.htm [Accessed 15 March 2014].

United Nations Educational, Scientific and Cultural Organisation, 2006. *Guide for Planning Education in Emergency and Reconstruction: Chapter 03-Capacity Building.* Paris: International Institute for Education planning.

Vecchio-Sudus, A.M. and Griffiths, S., 2004. Marketing Strategies for Enhancing Safety Culture. *Safety Science*, 42, 601– 619.

Yogaratnam, N., 2010. Safety, Health Issues in Rubber Sector. *Daily News,* 21 September.

Yule, S., 2003. *Senior Management Influence on Safety Performance in the UK and US Energy Sectors.* Thesis (PhD). University of Aberdeen.

SUITABILITY OF CRITERIA FOR SELECTING A DELAY ANALYSIS TECHNIQUE SUITABLE TO ANALYSE DELAYS IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA

E.M.K. Ekanayake*
Ministry of Infrastructure Audit, Oman

B.A.K.S. Perera
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Delays in construction projects are inevitable and they are the most critical factor that affects the cost of a construction project. They have to be analyzed comprehensively using appropriate techniques so as to identify their impacts. This study was carried out to find out, the delay analysis techniques (DAT) that are used most commonly in road projects in Sri Lanka, the extent of their usage, problems that arises when they are used and the criteria for selecting a suitable technique. The research methodology adopted involved an extensive literature review, interviews and a questionnaire survey. The most commonly used DATSs were identified through the literature review and by interviewing four practitioners. A questionnaire survey was carried out among a group of 60 professionals selected through purposive sampling. It was found that five types of delay analysis techniques are mainly used in Sri Lanka to determine the delays encountered in road projects and the most commonly used such technique is the as-planned vs as-built analysis while the least used is the window analysis. The non-availability of professionals to analyze delays is found to be the main problem and acceptance by courts and tribunals is the most important criteria (out of nine identified criteria) used in selecting a delay analysis technique.

Keywords: *As-Planned vs As-Built Analysis; Criteria; Delay Analysis Techniques.*

1. INTRODUCTION

Delay analysis techniques are models or methods agreed upon by experts in projects subsequent to practical experiments (Keane and Calettka, 2008). In order to claim damages due to a delay, the cause of the delay and the party responsible for it should be identified correctly as delays could be due to various reasons and there could be several parties responsible for them (Arditi and Pattanakitchamroon, 2006). Menesi (2007) has added that, the complexity of a construction project could make the delay analysis process also complicated.

Perera (2006) has stated that 80% of road projects in Sri Lanka undergo time and cost overruns thus facing high risks in terms of cost and time. The root cause of a delay and the party responsible for it have to be identified through appropriate methods. It is therefore necessary to find out criteria through which an appropriate delay analysis technique suitable for road construction projects in Sri Lanka could be selected and the impact of the delays evaluated.

The aim of this study is to identify the criteria that can be considered in selecting a delay analysis technique to analyze the delays in road construction projects in Sri Lanka. With this aim, the following research objectives were formulated:

- Identification of various types of DATs and examination of their advantages and disadvantages
- Determination of the extent of application of DAT

* Corresponding Author: E-mail - gayuqs@yahoo.com

- Identification of the problems of applying DAT
- Identification of the criteria for selecting a DAT

2. LITERATURE REVIEW

2.1. DELAY ANALYSIS TECHNIQUES THAT ARE USED IN THE CONSTRUCTION INDUSTRY

Delay analysis techniques are available in the industry in various forms with different titles. Since each DAT could be used in numerous ways, they can be easily manipulated (Keane and Calettka, 2008). Yang *et al.* (2012) have emphasized that one of the most difficult tasks in certifying a claim in respect of delays is to identify the cause of the delays and their effect on the project completion date as the methods and procedures available to analyze the delays are insufficient. Further, they have described that in construction projects with complex project schedules, the analysis is time consuming and inaccurate. Mohammed and Jafar (2011) have stated that the complexity of construction projects is the main factor that influences the selection of an appropriate delay analysis technique.

2.2. TYPES OF DELAY ANALYSIS TECHNIQUES

Arcuri *et al.* (2007), Baker (2014), Braimah (2013), Barry (2009), Delay and Disruption Protocol (2002), Enhassi and Jubeh (2009), Francis *et al.* (2014), Hegazy (2012), Menesi (2007) and Ng *et al.* (2004) have stated that the most commonly applicable DTAs in the industry were as planned v as built, time impact analysis, window analysis, impacted as planned and collapsed as built. Yang and Kao (2009) had identified nine additional delay analysis techniques namely, adjusted as built, as built but for, as planned but for, as built critical path, global impact technique, net impact technique, linear schedule analysis, snapshot analysis and isolated delay types. Therefore by reviewing past research, it can be concluded that the most commonly used DATs are as 'as planned v as built', 'time impact analysis', 'impacted as planned', 'window analysis' and 'collapsed as built'. A brief description of frequently used techniques is given below:

- **As planned v as built-** Baker (2014) has defined as planned v as build method as one that initially identifies the critical path of a project in the as planned programme. Thereafter all the delays that occur during project execution are inserted in to the as built plan to identify the critical path of the as built plan. The time difference between the completion dates of as-planned and as-built is the extended period.
- **Impacted as planned-**This is a technique similar to the as planned v as built where the difference in delays is inserted in to the as planned programme in chronological order. The time difference between the two critical paths is the additional time needed (Baker, 2014).
- **Time Impact Analysis-** This method is an improvement to the as planned v as built method and also to the impacted as planned method where the programme is updated whenever there is a delay. The critical paths of the as planned and as built are compared with each other to identify the delay and the project completion date is thereafter forecast (Francis *et al.,* 2014).
- **Window analysis-**This is very similar to the time impact analysis where the difference in a set of delays within a selected time frame (window) is analyzed. The programme is updated by accommodating the variances. The delay is forecast after analyzing one window. At the end of the project the total amount of time entitlement is estimated Society of Construction Law (2002).
- **Collapsed as built (But for Test)-**This is a modification to the as planned v as built method in which the employer's delay is subtracted from the as built plan (as built but for). The claimant could have completed the project by this date, if not for the defendant's delay making it necessary to extend the date of completion by the relevant number of days (Francis *et al.*, 2014).

2.3. *DELAY ANALYSIS PROCESS*

Barry (2009) has argued that in analyzing delay claims it is important to look at the Effect and Cause and not at the Cause and Effect. Majerowicz (2001) was of the view that delay analysis procedure is a process in which the original schedule and the as built schedule are compared with each other to identify the variances. He has explained the delay analysis process as shown below:

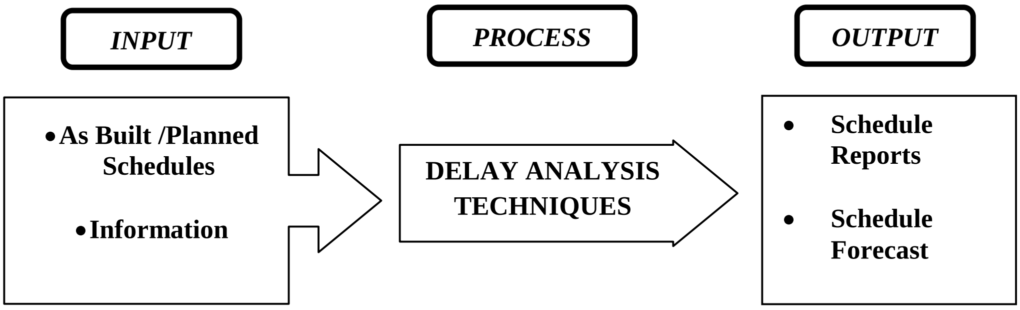


Figure 1: Delay Analysis Process

Figure 1 explains the delay analysis process consisting of an input process and an output process. Yang and Kao (2009) have stated that the identification of a suitable DAT is the first task to be considered by relevant parties before commencing the delay analysis process. They have further added that the selection of a suitable DAT will depend on factors such as the type of information available, time of analysis and the capabilities of the method, funds and effort. According to Hegazy (2012), delay analyzing procedures consist of Static Logic, Dynamic Logic, Model Methods, Addictive Methods and Subtractive Methods. The delay could however be agreed upon among the parties concerned but what would be the most difficult is to come to a compromise on the cost of the delay (Zack, 2002).

2.4. *CAUSES FOR DELAYS IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA*

Lawrence (2002), has stated that the best way to resolve a dispute in construction projects is for the parties to have a good understanding. Arbitration and other dispute resolution processes are time consuming, costly and are a threat to the business relationship between the contractor and the client. Therefore identification of causes for delays and acting early to minimize their effects will be beneficial to all stakeholders of a project.

As the number of road projects undertaken is increased, the delays and associated costs would also increase (National Construction Association Sri Lanka, 2013). Poor preliminary planning, inaccurate budgets, unrealistic time allocations, imprecise contract clauses and late payments are the reasons for the delays. Wijenayake (2014) was of the view that the road construction projects in Sri Lanka are delayed due to issues related to land acquisition, improper designs, poor financial management, political interference, and environmental pollution. Variation orders have caused delays incurring high losses. (Halwatura and Ranasinghe, 2013). Jeyarajah and Jayawardena (2011) have confirmed these findings stating that during their construction stage, 56% of road construction projects in Sri Lanka are delayed due to variations in quantities. They have further stated that improper designs, changes in the scope and specifications are the other causes of delays .Pathiranage and Halwatura (2010) reveal that road construction projects in Sri Lanka are affected due to financial incapability's, poor site management, adverse weather, scope changes, delays in receiving instructions, lack of resources and external influences. Late payments, shifting of utilities, cost escalations, design changes and late site possession are also caused for delays (Wijekoon and Attanayake 2012).

2.5. *IMPORTANCE OF IDENTIFYING A SUITABLE DAT FOR ROAD PROJECTS IN SRI LANKA*

The timely intervention and applicability of relevant and reliable methods to analyze the delays in a construction project will pave the way for eradicating or minimizing the disputes between parties to a contract (Lawrance, 2002). Pathiranage and Halwatura (2010) have stated that 56% to 88% of road construction projects in Sri Lanka experience time overruns whilst Perera (2006) has stated that 80% of road projects in Sri Lanka face the threat of time and cost overruns which in turn would have a bearing on the country's economy. The most vulnerable impact a construction delay can have for the country is for it to become a socio-economic problem (Wijekoon and Attanayake, 2012). A few professionals in Sri Lanka have attempted to resolve and manage accurately the delays in construction projects (Sudeha *et al.*, 2013). Most of them use ad hoc methods to evaluate the claims for time extensions which do not provide for estimating properly the actual impact of the delay on the project (Gunarathne, 2012). The accuracy of evaluating the delay claims is very low and consequently parties concerned have less confidence on the delay analysis processes used (National Construction Association of Sri Lanka, 2014). According to Priyantha *et al.* (2011), Sudeha *et al.* (2013), National Construction Association (2014), Halwatura and Ranasinghe (2013), Wijekoon and Attanayake (2012), Institute of Construction Training and Development (2008) and the Institute of Dispute Management Professionals (2013), the variations and cost overruns of road construction projects are on the rise. When there are variations in a contract, the contractor is entitled to claim for an extension of time and this it has to be evaluated accurately through an appropriate delay analysis technique. The failure to identify the party responsible for the delay will disrupt the construction process and their consequences will thus have to be borne by the public (Seboru and Atibu 2006). This is an area which has also not been adequately researched in Sri Lanka. Therefore, this research would emphasize the need to identify criteria for selecting appropriate delay analysis techniques for road construction projects in Sri Lanka.

3. RESEARCH METHODOLOGY

This descriptive study consists of three phases where primary and secondary data with qualitative and quantitative approaches were used. A comprehensive literature survey was carried out to identify various DATs used in road construction projects and their advantages and disadvantages. Interviews were conducted with four industry practitioners and a questionnaire survey was conducted to achieve the other objectives.

PHASE I: LITERATURE SURVEY

A comprehensive literature survey was carried out using peer reviewed journal articles, text books and periodicals (both print and electronic), theses and dissertations, reports, web pages, online publications and unpublished material. The literature survey helped to identify different delay analysis techniques that are used in the construction projects all over the world.

PHASE II: INTERVIEWS

Interviews were conducted with four professionals (practitioners) representing employers, consultants and contractors and who had experience in delay analysis techniques used in road construction projects in Sri Lanka refer table 1.

Table 1: Details of Interviewees

Details	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4
Profession	Engineer	Quantity Surveyor	Engineer	Engineer cum Lawyer
Designation	Project Director	Contract Specialist	Claims Specialist	Consultant
Experience (Years)	24	26	30	32

PHASE III: QUESTIONNAIRE SURVEY

Sixty questionnaires were distributed among professionals identified using purposive sampling technique and who were actively involved in delay analysis processes in road construction projects in Sri Lanka. Forty three of them responded to the survey.

3.1. DATA ANALYSIS

Data was verified completeness and accuracy by going through each questionnaire thoroughly and by running frequency distribution before being analyzed using SPSS data analyzing software. Frequency distribution was used to describe the extent of use of DATs in Sri Lanka. The data collected from the interviews was analyzed manually using grounded theory.

3.2. RELATIVE IMPORTANCE INDEX (RII)

The Relative Importance Index (RII) was used to rank the problems encountered in the application of DATs in Sri Lanka. It was also used to rank the criteria that are important in selecting a suitable DAT. The calculation of RII was done dividing the sum of weightings by the multiplication of the highest weight and the total number of respondents. Many researchers (Jeyamathan and Rameezdeen, 2006; Sumithiran, 2009; Sudeha *et al.*, 2013; Perera and Sudeha 2014) have identified RII as a data analysis technique for ranking the factors in identifying the most significant among them.

4. RESEARCH FINDINGS

4.1. TYPES OF DELAY ANALYSIS TECHNIQUES USED IN ROAD CONSTRUCTION PROJECTS

Five types of delay analysis techniques were identified in the literature recommended by the majority of authors. viz., Collapsed as built method, Window analysis method, As planned v as built method, Time impact analysis method and Impacted as planned method. The literature reveals that the techniques thus identified are used globally to analyze the delays in construction projects. The interviewees confirmed that the identified techniques are used to analyze the delays in road construction projects in Sri Lanka as well.

4.1.1. ADVANTAGES AND DISADVANTAGES OF THE IDENTIFIED TECHNIQUES

The advantages and disadvantages of the short listed techniques were identified in the second step of the first objective. As planned v as built and impacted as planned methods are simple, consume less time and are inexpensive. They are also very primitive and unreliable and could be easily manipulated and thus are not accepted by courts and tribunals. The Collapsed as built method is inexpensive, consumes less time, accommodates variations and is accepted by tribunals. Nevertheless it is also easy to manipulate and can analyze complex delays such as concurrent delays. Time impact analysis is reliable, accurate, difficult to manipulate and is accepted by tribunals. Furthermore, variations can be accommodated, contemporaneous updating is possible and the compensation can be categorized in terms of time and cost. However, it is expensive, complex, time consuming and need inputs from experts. Window analysis is also accurate, reliable, difficult to manipulate and is accepted by tribunals. Contemporaneous updating is possible and the compensation can be categorized in terms of time and cost. Yet, the accuracy can vary according to the selected time window and the set of delays within that window needs to be analyzed. This method is also expensive, time consuming and complex.

4.2. THE EXTENT OF APPLICATION OF DAT IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA

The second objective of this study was to determine the extent of application of DAT in road construction projects in Sri Lanka. Participants were requested to give the following information on the projects in which they were involved:

1. Name of the project
2. Whether the project was delayed
3. Whether the contractor claimed an extension of time
4. Whether an extension of time was granted to the contractor
5. Whether DATs were used for analyzing delays and if so their details.

The name of the project was requested to avoid duplication. Based on the information provided by the respondents, forty eight (48) road construction projects whose contract values exceeded Rs. 500 million were identified. Table 2 below describes the extent of application of DATs in these forty eight (48) projects.

Table 2: Extent of Using DATS in Road Projects in Sri Lanka

	No of Projects	Percentage
Delayed	32	66.7
Not Delayed	16	33.3
DAT is Used	28	87.5
DAT is not Used	4	12.5
As Planned v As Built	15	53.6
Impacted As Planned	5	17.8
Window Analysis	2	7.2
Time Impact Analysis	3	10.7
Collapsed As Built	3	10.7

Two thirds (32/48, 66.7%) of the selected road projects were reported as delayed. The respective contractors have claimed extensions of time in all of them. It is interesting to observe that more than fifty percent of the projects which used DAT, had used as planned v as built to evaluate the delays. However, the literature survey revealed that the delay analysis techniques most used globally is the collapse as built and window analysis methods whereas in Sri Lanka they were the least used. The extent of the use of DAT to evaluate the delays is 87.5% and as planned v as built is the most commonly used (with 53.4%) DAT in road projects in Sri Lanka.

4.3. THE PROBLEMS IN APPLICATION OF DAT IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA

Adjusting the organisational structure is one of the BIM strategies for the contractor. A BIM centre is separated from the former IT department. The problems that have an influence on the use of delay analysis as identified from the literature review and through interviews are as follows:

1. Small number of professionals involved in delay analysis
2. Use of ad hoc methods
3. Low accuracy in the evaluation of delay claims
4. Nonexistence of a requirement for delay analysis techniques to be mandatory
5. Preference given to backdoor settlements over others which are expensive and time consuming
6. Improper auditing of claims for extensions of time

These are listed in Table 3 which describes the importance of problems in the application of DATs in road construction projects in Sri Lanka as perceived by the study participants.

Table 3: Relative Importance of problems in the Application of DAT in Road Projects

Problems encountered in the application of DAT	**Employer/Consultant**		**Contractor**		**Overall**	
	RII	**Rank**	**RII**	**Rank**	**RII**	**Rank**
Shortage of professionals to analyze delays using DAT	0.704	1	0.658	1	0.684	1
Difficulty in collecting data for DAT	0.633	2	0.553	4	0.598	2
Lack of knowledge of the contractor on DAT	0.633	2	0.505	6	0.593	3
Lack of knowledge of the consultants on DAT	0.513	6	0.589	2	0.547	4
Poor reliability of the collected data	0.546	4	0.516	5	0.533	5
Lack of knowledge of the employer on DAT	0.530	5	0.463	7	0.500	6
Lack of facilities such as computers and software	0.388	7	0.558	3	0.463	7

According to Table 3, the shortage of professionals to analyze delays using DAT is the main problem (RII=0.684). Both the consultant/employer (RII=0.704) and the contractor (RII=0.658) have identified this as the main problem. It is interesting to observe that the consultant/ employer has ranked second the lack of knowledge of the contractor on DAT (RII=0.633) whereas the contractor has ranked second the lack of knowledge of the consultant on DAT (RII= 0.589). Consultant/ employer has identified difficulties in collecting data (RII=0.633, rank 2) and unreliability of collected data (RII=0.546, rank 4) as important problems in the application of DAT. Although the contractor has ranked the lack of facilities such as computers and software (RII=0.558) third, it has been ranked seventh by the consultant/ employer (RII=0.388). In the overall ranking (RII=0.463), it has been given a rank of 7 making it the last in the ranking.

4.4. *Identification of the Criteria for Selecting a Suitable Delay Analysis Technique in Road Construction Projects in Sri Lanka*

According to the literature review, the selection of a suitable delay analysis technique will depend on cost, time, accuracy, acceptability by courts and tribunals, reliability and complexity. During the interviews two other factors were also identified viz., the workability (contemporaneous) and acceptance by the parties concerned. Nine scenarios/ criteria identified in the literature and through the interviews are listed in Table 4. Through the questionnaire survey, the relative importance of these criteria was identified using a 10 point scale as described in Table 4.

Table 4: Importance of the Criteria for Selecting a Suitable DAT

Criteria that have to be considered in selecting a DAT	RII	Rank
Acceptability by courts and tribunals	0.953	1
Acceptability by relevant parties	0.886	2
Accuracy of the technique	0.828	3
Complexity of the analysis	0.781	4
Reliability of the technique	0.779	5
Inputs of experts	0.756	6
Workability of the technique	0.619	7
Cost of the analysis	0.488	8
Time taken for the analysis	0.477	9

According to Table 4, the acceptability by tribunals and courts has scored a RII value of 0.953 becoming the highest ranked and becoming the most important criteria to be considered in the selection of a suitable DAT. Acceptability by parties to the contract and the accuracy of the technique have been ranked second and third respectively scoring RII values of 0.886 and 0.828 respectively. The complexity of the analysis, reliability, inputs of the experts and the workability remain at moderate levels. According to the respondents, the cost and time of analysis are of low importance with their RII values being the lowest (0.488 and 0.477 respectively).

5. Conclusions and Recommendations

5.1. *Conclusions*

The delay analysis techniques available globally and their advantages and disadvantages were found through a comprehensive literature review. Consequently, fourteen delay analysis techniques were identified and the five techniques that are mostly used were: as planned v as built, impacted as planned, collapsed as built, window analysis and time impact analysis. Then the extent of use of DAT in road construction projects in Sri Lanka was found. Accordingly, the extent of use of DAT to evaluate the delays in the projects concerned was 87.5%. The as planned v as built method was the most used DAT. The order of use of the DATs is as planned v as built, impacted as planned, time impact analysis, collapsed as built, and window analysis.

Afterward, using the literature review, questionnaire survey and interviews, the problems of DAT when used in road construction projects in Sri Lanka were identified. The analysis revealed that the shortage of professionals to analyze time extensions using DAT is the main problem. However, the non-availability of computer software, accessories and other equipment was not a major problem in the delay analysis. The delay analysis techniques being not specified in contracts, the use of ad hoc methods by the parties concerned was identified as other critical problems. Finally, the criteria for selecting a DAT for road construction projects in Sri Lanka using literature review, interviews and questionnaire survey was identified. Accordingly, time taken for the analysis, cost, inputs required from experts, complexity, reliability, accuracy, acceptability by the tribunals and courts, acceptability by the parties to the contract and workability are the important criteria to be considered in selecting a DAT. The acceptability of the DAT by courts and tribunals is the most important criteria while the cost and time are the least important criteria.

5.2. RECOMMENDATIONS

The research reveals that there is a shortage of professionals to analyse delays in road construction projects in Sri Lanka and that the most important criteria is generally ignored in selecting a DAT. Therefore, it is recommended to increase the number of professionals who can use DAT and select an appropriate technique for the delay analysis. When a DAT is selected it is important to ensure that the selected technique is accepted by courts and tribunals. It is also important to introduce a pay item in the bill of quantities (BOQ) to recover the cost that is incurred in using delay analysis.

6. REFERENCES

Arcuri, F.J., Hildreth, J.C. and Tech, V., 2007. *The Principles of Scheduling Impact Analysis* (TR-07-03).Virginia, United States: Virginia Polytechnic Institute and State University.

Arditi, D. and Pattanakitchamroon, T., 2006. Selecting a Delay Analysis Method in Resolving Construction Claims. *International Journal of Project Management*, 24, 145-155.

Baker, K.R., 2014. *Presenting Delay Claims: Where is the Logic?* [online]. Available from: https://twiter.com/LormanEducation [Accessed 15 November 2014].

Barry, D., 2009. Beware of the Dark Arts Delay Analysis and the Problems with Reliance on Technology. In: *Society of Construction Law International Conference* [online], London. Available from: www.scl.org.uk [Accessed 10 November 2014].

Braimah, N., 2013. *Construction Delay Analysis Techniques* [online]. Available from: www.mdpi.com/journal/buildings [Accessed 07 December 2014].

Enshassi, A. and Jubeh, A., 2009. Delay Analysis Methods and Factors Affecting their Selection in the Construction Industry in Gaza Strip [online]. *Journal of Financial Management of Property and Construction*, 14(2), 126-151. Available from: http://dx.doi.org/10.1108/13664380910977592 [Accessed 08 December 2014].

Francis, J., Brennan, P.E., Michael, F. and D'Onofrio, P.E., 2014. *Techniques and Models for Assessing Delays* [online]. Available from: www.cpmiteam.com/Assessing Delays.html [Accessed 12 November 2014].

Gunarathne, Y.M.S.B., 2012. *Factors Affecting for Selection of Suitable Delay Analysis Technique for Sri Lankan Construction Industry*. Dissertation (BSc.). University of Moratuwa.

Halwatura, R.U. and Ranasinghe, N.P.N.P., 2013. Causes of Variation Orders in Road Construction Projects in Sri Lanka. *Journal of ISRN Construction Engineering* [online], 1-7. Available from: http://dx.doi.org/10.1155/2013/3816170 [Accessed 04 November 2014].

Hegazy, S., 2012. Delay analysis methodology in UAE Construction Projects. *PM World Journal* [online], 1(2), 1-17. Available from: www.pmworldjournal.net [Accessed 29 December 2014].

Institute of Construction Training and Development, 2008. *Sri Lanka Country Report* [online]. Available from: www.ictad.lk [Accessed 11 November 2014].

Institute of Dispute Management Professionals, 2013. *Dispute Management* [online]. Available from: http://www.idmp.lk/ [Accessed 10 November 2014].

Jeyakanthan, J. and Jayawardane, A.K.W., 2012. Mitigating Project Delays in Donor Funded Road Projects in Sri Lanka. *Journal of the IESL*, 45(1).

Jeyakanthan, J. and Rameezdeen, R., 2006. Skills and Competencies of Quantity Surveyors: The Case of Sri Lanka. In: Rameezdeen, R. and Senevirathne, I., eds. *Customizing the Quantity Surveyor to Face the Challenges in Year 2020*, Department of Building Economics, Moratuwa. 9-18.

Keane, P.J. and Calettka, A.F., 2008 .*Delay Analysis in Construction Contract*. United Kingdom: Blackwell Publishing Ltd.

Lawrance, G.H., 2002. Objectifying Claims on Extension of Time in Construction Contracts. *Journal of Institute of Engineers Sri Lanka*, 37(2).

Majerowiz, W., 2001. Schedule Analysis Techniques. In: *13th Annual International Integrated Programme, Management Conference.*

Menesi, W., 2007. *Construction Delays Analysis under Multiple Baseline Updates* [online]. Thesis (M.Sc.). University of Waterloo. Available from: http://www.scribd.com/doc/59763547 [Accessed 02 November 2014].

Mohammed, S.R. and Jafar, S.S., 2011. Construction Delay Analysis using Daily Window Technique. *Journal of Engineering,* 1(17), 186-198.

National Construction Association of Sri Lanka, 2014. *Report on Payment Delays in Sri Lankan Construction Industry.*

National Procurement Agency, 2006. *Procurement Guidelines* [online]. Available from: www.treasury.gov.lk [Accessed 02 November 2014].

Ng, S.T., Skitmore, R.M., Deng, M.Z.M. and Nadeem, A., 2004. Improving Existing Delay Analysis Techniques for the Establishment of Delay Liabilities. *Journal of Construction Innovation: Information* [online], *Process, Management*, 4(1), 3-17. Available from: http://eprints.qut.edu.au/archive/00004116 [Accessed 12 November 2014].

Pathiranage, Y.L. and Halwatura, R.U., 2010. *Factors Influencing the Duration of Road Construction Projects in Sri Lanka* [online]. Available from: http://dl.lib.mrt.ac.lk [Accessed 02 November 2014].

Perera, B.A.K.S. and Sudeha, H.M.C.K., 2014. Framework to Select the Most Suitable Delay Analysis Technique for Building Construction through a Consideration of Utility Factors. *Bhoomi the Planning Research Journal*, 3(2).

Perera, K.B.D., 2006. *Simulation Modeling for Time and Cost Overrun in Road Rehabilitation Projects in Sri Lanka.* Dissertation (BSc.). University of Moratuwa.

Priyantha, T.H.S., Karunasena, G. and Rodrigo, V.A.K., 2011. Causes, Nature and Effects of Variations in Highways. *Built Environment - Sri Lanka,* 1(2), 14-15.

Seboru, A. M., 2006. *An Investigation into Factors Causing Delays in Road Construction Projects in Kenya* [online]. Available from: http://www.uonbi.ac.ke/)www.textroad.com [Accessed 11 November 2014].

Rider of Construction Law, 2002. *Delay and Disruption Protocol* [online]. Available from: http://www.scl.org.uk/resources [Accessed 10 December 2014].

Sudeha, H.M.C.K., Perera, B.A.K.S. and Illankoon, I.M.C.S., 2013. *Utility Factors Affecting for Selecting Delay Analysis Technique.* In: Senevirathne, L.D.I.P and Sandanayake Y. G., eds. *Second World Construction Symposium on Planning, Designing and Building for Tomorrow*, Sri Lanka. 473-482.

Sumithiran, Y., 2009. *A Mature Profession of Quantity Surveying in Sri Lanka*. Dissertation (BSc.). University of Moratuwa.

Wijekoon, S.B. and Attanayake, A.M.C.T.K., 2012. *Study on the Cost Overruns in Road Construction Projects in Sri Lanka* [online]. Available from: http://dl.lib.mrt.ac.lk [Accessed 11 December 2014].

Wijenayake, T., 2014. *Delays and Escalating Cost in Road Construction* [online]. Available from: http://www.ftlk [Accessed 08 December 2014].

Yang, J. B., Huang, K. M., Chen, C.M. and Liu, S.H., 2012. Implementing Schedule Delay Analysis Methodology on Project Management System. In: *14th International Conference in Computing in Civil and Building Engineering,* Moscow, Russia.

Yang, J.B. and Kao, C.K., 2009. Review Delay Analysis Methods: A Process Based Comparison. *The Open Construction and Building Technology Journal*, 3, 81-89.

Zack, J.G., 2002. Calculation and Recovery of Home/Head Office Overheads. *Journal of Cost Engineering Council*, 1-4.

SUITABILITY OF GOVERNMENT BID EVALUATION PROCEDURE FOR BUILDING PROJECTS IN SRI LANKA

D.M.G.A.N.M. Sumanarathna* and B.A.K.S. Perera
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

In Sri Lanka, a Contractor is selected through a bid evaluation procedure in construction projects and this is be a crucial step in the implementation of the project. The most frequently used bid evaluation procedure in Sri Lanka is the Government Bid Evaluation Procedure (GBEP), the Government being the client in most of the projects. Although GBEP is referred to in government publications, it has so far not been analysed in detail. This study therefore was conducted to identify the suitability of GBEP to local building projects.

Firstly, a literature synthesis and a desk study were carried out. The degree of use of GBEP identified from the literature synthesis was validated through semi structured interviews which also identified the advantages, disadvantages and limitations of GBEP.

The analysis reveals that a well-defined procedure, proper documentation, possibility of selecting the lowest evaluated bid are the major advantages of GBEP while the absence of a minimum eligibility criteria for preliminary bid evaluation, adjustments done by the evaluator, low accuracy of the Engineer's Estimate and non-consideration of the optimum bid are its major disadvantages and/or limitations. Suggestions are made to overcome the disadvantages and limitations. Flexibility on ICTAD registration, making allowance for discounts for variations, introduction of standard formats for reporting and prohibition of adjustments by the evaluator will enhance the transparency and accountability of GBEP.

Keywords: *Construction Industry; Contractor Selection; Engineer's Estimate; Government Bid Evaluation Procedure; Tender Evaluation.*

1. INTRODUCTION

The construction industry is quite complex in that it has both new projects and renovation projects (Wills and Ashworth, 1992). Fellows *et al.* (2002) state that having two separate stages for the design and construction is a unique characteristic of this industry. Before any construction work is undertaken, a suitable contractor has to be selected (Holt, 2010) through a tendering process (Janaka, 2011). Holt (1998) states that this process consists of two stages, pre-qualification and tender evaluation. During tender evaluation (TE), tenders of pre-qualified contractors are evaluated (Wong *et al.*, 2001).

In Sri Lanka, several TE procedures are being used (Aluvihare, 1998) and the GBEP published by the National Procurement Agency (NPA) is one of them (NPA, 2006a, NPA 2006b). According to NPA (2006) the purpose of the GBEP is to determine the lowest evaluated bid that is substantially responsive. The GBEP has four major stages, i.e preliminary examination of bids, detailed evaluation and comparison of bids, post qualification verification and writing the bid evaluation report. It can be applied whenever open and selective tendering methods are used for the selection of a contractor (NPA, 2006).

Therefore, to successfully execute a construction project, tender evaluation procedure should be strong and strict. This paper aims to identify the suitability of exiting GBEP in Sri Lanka and the scope will be re-measurement type building projects. The aim is achieved through studying the GBEP, identifying its degree of usage, identifying its advantages, disadvantages and limitations and suggesting solutions for identified disadvantages and limitations.

* Corresponding Author: E-mail - nipunisumanarathne@gmail.com

2. GOVERNMENT BID EVALUATION PROCEDURE OF SRI LANKA

GBEP of Sri Lanka was officially implemented in 1996 through the General Treasury by the Ministry of Finance and Planning when the Government issued guidelines on tender procedures (General Treasury, 1996). When in 1997, the General Treasury was made the National Procurement Agency (NPA), a revised version of the guidelines on the tender procedure was introduced (NPA, 2006). As stated by the Ministry of Finance and Planning (1997), the Government has published a procedure for tendering (bidding as used in Sri Lanka) especially for public sector projects. GBEP in Sri Lanka has four major stages as set out in the NPA Procurement Guidelines (2006) which are; preliminary examination of bids, detailed evaluation and comparison of bids, post qualification verification and writing bid evaluation report.

This very first stage of the bid evaluation process is preliminary examination of bids which eliminates the bids that do not meet the minimum standards or requirements given in the bidding document (NPA, 2006). All bids received before the dead line for submission of bids are considered for the preliminary bid evaluation and the Procurement Entity (PE) has to establish reasonable criteria for the elimination of bids that do not meet the stated requirements (NPA, 2006). During the second stage; detailed evaluation and comparison of bids, all substantially responsive bids are evaluated to determine the lowest evaluated bid. A systematic and logical sequence is stated in the NPA Procurement Manual to carry out this stage (NPA, 2006). Post qualification verification; the third stage has become important when there is no requirement for pre-qualification (NPA, 2006). North American Development Bank (NADB) (2012) recommends this highly for uncomplicated building contracts. Pre-qualification does not offer much advantage at this stage as its purpose is only to determine whether the lowest responsive evaluated bid can meet the contractual requirements. The final stage; writing bid evaluation report is carried out after the confirmation of the lowest responsive bid (NADB, 2012). Once the bid evaluation is completed, the PE has to prepare a bid evaluation report using standard formats (NPA, 2006).

The level of usage of GBEP in Sri Lanka is high since it is necessary to follow government bidding procedure for the public sector projects (Abeysinghe, 2006). Further, the Government is the largest client of the local construction industry, with 73% of its total investment (Central Bank of Sri Lanka, 2012) in 2012 being on construction related activities. Colombo Page (2013) has confirmed that the Government's public sector investment was 5.9% of the GDP. As per the Department of Census and Statics (2011), the degree of use of GBEP in Sri Lanka is also high, as most public sector projects are in the construction sector.

The exiting GBEP has several disadvantages and limitations. The main disadvantage is being the 'Winner's Curse'. According to Abeysinghe (2006), 'Winner's Curse' occurs when a contract is awarded to the lowest responsive bidder whose bid price has a high estimating error. Jayasena and Uhanowitage (2008) define 'Winner's Curse' as the situation when a winning contract either carries negative profits or below average profits. Moreover, Abeysinghe (2006) state that, Winner's Curse makes construction firms insolvent. A contractor may also try to compensate his poor cash flow through the Winner's Curse, by submitting claims that cause post contract difficulties to clients (Jayasena and Uhanowitage, 2008).

Abeysinghe (2006) has argued that there are disadvantages and limitations of GBEP other than 'Winner's Curse'. Eriksson and Westerberg (2001) discussed that GBEP has a disadvantage of producing conflicts. Ngobeni (2001) mentioned that corruption may exist during tender evaluation. Expert opinions also indicate the necessity to examine the suitability of GBEP. Watt *et al.* (2009) have mentioned that many experts and academic institutions have made suggestions for contractor selection and evaluation. Mahdi *et al.* (2002), Rajaie *et al.* (1997) and Turskis (2008) stated that the only criteria for selecting a contractor should not be the fact that he has submitted the lowest responsive bid. The strict bid evaluation procedures followed in other countries have encouraged the researcher to explore the suitability of the existing GBEP. The Republic of Kenya gives preference to best value for money and not the lowest responsive bid (Public Procurement Oversight Authority, 2009). In South Africa, Finland and UK, it is the most advantageous bid that is selected (Ngobeni, 2001; Tikkanen and Kaleva, 2011 and Holt *et al.*, 1995). Construction industry requirements also make it necessary to examine the suitability of the existing GBEP. According to 2013 Annual Report of the Central Bank and the report of the Colombo Page (2013), the largest client of the construction industry in Sri Lanka is the Government. ICRA Lanka

(ICRA Lanka Limited) and IMaCS (ICRA Management Consulting Services Limited) (2011) as well as Amarapathy (2013) state that with the end of the war the construction activities initiated by the Government have increased during the last five years. Hence, there is a need to follow both the NPA guidelines and GBEP, as most of the construction projects are funded by the Government. In addressing the requirements of literature as well as the industry, the existing GBEP has to be examined and updated. To achieve these purposes, the qualitative approach was chosen for this study. The methodology to analyse suitability of GBEP is discussed in detail in the following section.

3. Research Methodology

Social constructionism was adopted as the research philosophy of the study, and a qualitative approach was used to assess subjective data (expert opinions). A desk study, preliminary interviews and semi structured interviews were used to collect data.

The desk study was carried out mainly by referring to the Procurement Manual, Procurement Guidelines and the Government Tender Procedure published by the NPA. Its objective was to analyse GBEP and divide its stages in to sub stages. Thereafter, four preliminary interviews were conducted mainly with experts in consultancy organisations to validate the outputs of the desk study. Semi structured interviews were used as the third data collection technique. The interview guidelines validated through preliminary interviews, were followed in conducting ten semi structured interviews with experts, who have had long experience and vast knowledge on GBEP. The software program NVivo 10 developed by QSR (Qualitative Solutions and Research Ltd.) was used for this research as it could handle rich text based data and analyse same in detail. The details of the desk study, preliminary interviews and semi structured interviews and their outcomes are given below.

4. Research Findings

Research findings are discussed under four main headings, i.e study of GBEP, identification of the current degree of use of GBEP, advantages, disadvantages and limitations of GBEP and expert suggestions.

4.1. Studying Government Bid Evaluation Procedure

In studying and identifying the advantages, disadvantages and limitations of GBEP and making suggestions, it is convenient to divide it into stages and sub stages. Table 1 indicates the stages identified through the desk study.

Table 1: Sub Stages of GBEP Identified through the Desk Study

Main stage	Sub Stages
1.0 Preliminary bid evaluation	Checking preliminary requirements
	Identifying deviations
2.0 Detailed bid evaluation	Excluding VAT, contingencies and provisional sums
	Correcting arithmetical errors
	Applying discounts
	Adjusting for omissions
	Adjusting for deviations
	Adjusting for the delivery period
	Adjusting for inland transportation
	Computing operational and life cycle costs
	Converting to common currency
	Domestic preferences
	After sales services
	Examining unbalanced bids
	Comparing with Engineer's Estimate (EE)

	Rejecting all bids
	Seeking clarifications during evaluation
	Studying alternative bids
	Identifying the lowest evaluated bid
3.0 Post qualification verification	Checking technical feasibility
	Checking financial feasibility
4.0 Writing the bid evaluation report	

Subsequent to the desk study and the validation process, 'Adjustment for delivery period' and 'Adjustment for inland transportation' were removed from the sub stages as they were found not to be relevant to the scope of the study. Table 2 below shows the profile of the participants of the preliminary interview all of whom were from the construction industry.

Table 2: Profile of the Participants of the Preliminary Interview

Interviewee Code	Designation	Years of Experience	Category of Organisation	Type of Organisation
A	Chairman	40	Consultant	Private
B	Director	20	Consultant	Private
C	Deputy General Manager	18	Consultant and Contractor	Government
D	Chief Quantity Surveyor	18	Consultant and Contractor	Government

4.2. IDENTIFYING CURRENT DEGREE OF USE OF GOVERNMENT BID EVALUATION PROCEDURE

The objective of this section is to identify the degree of use of GBEP in building projects in both public and private sectors. Hence, ten semi-structured interviews were conducted and Table 3 presents the profile of the interviewees. Accordingly, it was found that the current of usage of GBEP is high and it confirmed the literature findings.

Table 3: Profile of Participants of Semi Structured Interviews

Interviewee Code	Designation	Years of Experience	Category of Organisation	Type of Organisation
E01	Deputy General Manager	18	Consultant and Contractor	Government
E02	Chief Quantity Surveyor	18	Consultant and Contractor	Government
E03	Director	20	Consultant	Private
E04	Project Manager	35	Client	Government
E05	Senior Quantity Surveyor	16	Consultant and Contractor	Government
E06	Asst. Director	28	Regulatory body	Government
E07	Asst. General Manager	30	Client and Consultant	Government
E08	Chartered Quantity Surveyor	12	Consultant and Contractor	Government
E09	Contracts Manager	19	Consultant	Private
E10	Commercial Director	22	Project Manager	Private

Percentage Use of Government Bid Evaluation Procedure

Even though GBEP is not adapted 100% in public and private sector construction projects, its degree of use is comparatively higher as shown by Figure 1.

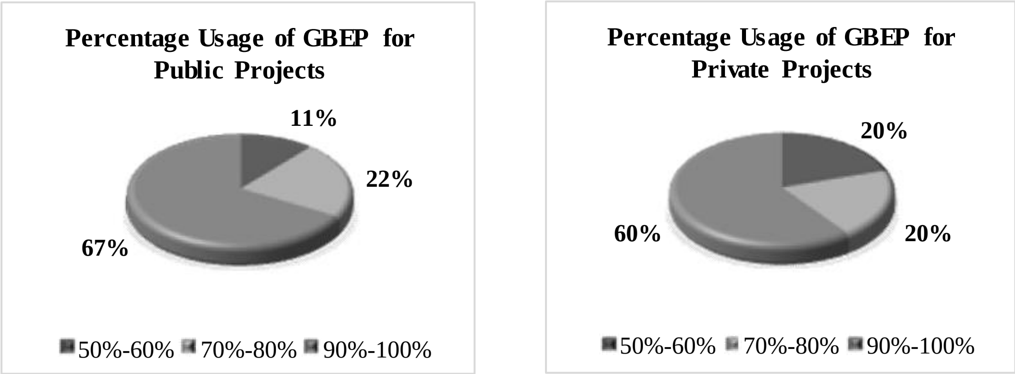


Figure 1: Percentage Usage Ranges of GBEP

Percentage of Deviations from Government Bid Evaluation Procedure

The extent of deviation from GBEP is higher in the private sector as shown by Figure 2.

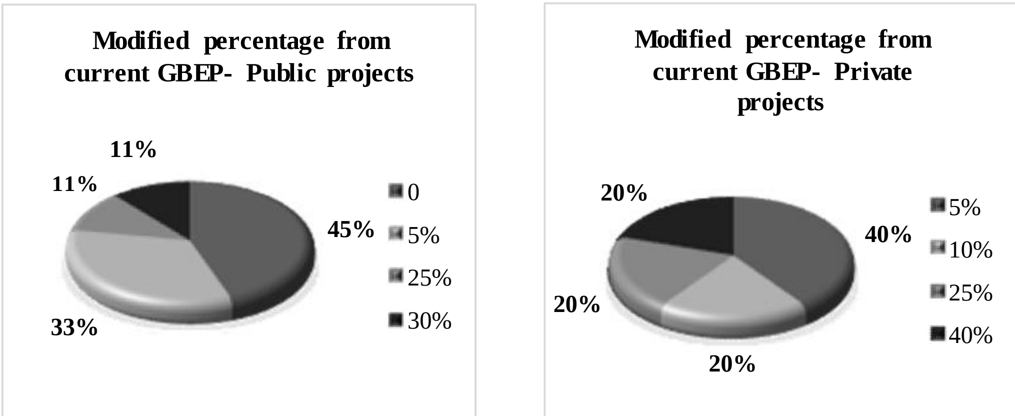


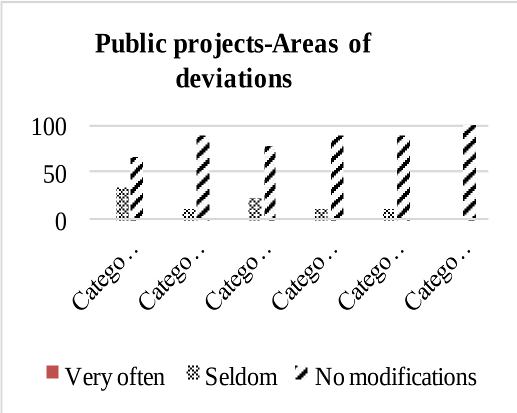
Figure 2: Modified Percentage from Current GBEP

Deviations from Government Bid Evaluation Procedure

The areas of deviations are shown in Table 4 and Category 1 is found to be the most deviated area and Category 6 the least deviated area. Furthermore, the figure 2 shows the percentage deviations of public projects and the private projects under the scale of 'very often, seldom and no modifications' and the considered areas of deviations are shown by the Table 4.

Table 4: Areas Deviated from GBEP

Areas	Category
Extension of bid validity	1
Categorization of deviations	2
Preliminary bid evaluation	3
Detailed bid evaluation	4
Post qualification verification	5
Determination of substantially	6



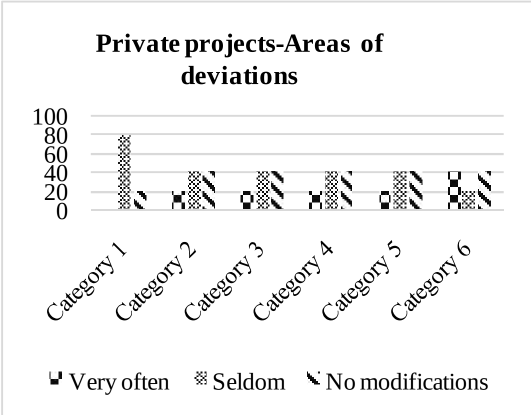


Figure 2: Percentage Deviations from GBEP

Reasons for deviating from Government Bid Evaluation Procedure

While GBEP is used strictly in state sector construction projects, ad-hoc bid evaluation procedures are used in private sector projects. Public accountability is a major requirement of the public sector whereas client's satisfaction is the primary concern of the private sector which can therefore afford to deviate from GBEP.

4.3. Advantages, Disadvantages and Limitations of Government Bid Evaluation Procedure

The advantages, disadvantages and limitations of each sub stage organised using NVIVO 10 coding structures are summarised in Tables 5, 6, 7 and 8.

Preliminary Bid Evaluation Stage

Table 5: Advantages, Disadvantages and/or Limitations of GBEP

Sub Stage	Advantage/s	Disadvantage/s and/or Limitation/s
Checking preliminary requirements	▪ Short listing of bids is possible ▪ Form of bid, validity of bid and power of attorney could be checked	▪ Not all qualifications can be checked ▪ Setting up of a minimum qualification criteria is not possible ▪ ICTAD registration could be made mandatory ▪ Level of authority given to the Bid Opening Committee (BOC)
Identifying deviations	▪ Non availability of historical data could be considered as a minor deviation ▪ All areas of deviations could be addressed	▪ It is possible to be flexible in respect of bid validity ▪ It is not possible to be flexible with bids that provide shorter construction periods than what is specified

Detailed Bid Evaluation Stage

Table 6: Advantages, Disadvantages and/or Limitations of GBEP

Sub Stage	Advantage/s	Disadvantage/s and/or Limitation/s
Excluding VAT, contingencies and provisional sums	▪ Reasonable when • they have not been quoted by bidders • this does not create differences among bidders • they are not required for evaluation • they are not contractual	
Correction of arithmetical errors	▪ Bid price could be considered as the governing amount ▪ Words over figures could be considered to avoid manipulations ▪ Form of bid could be adjusted in re-measurement type projects	▪ Corrected bid price could be considered as the governing amount ▪ Amount quoted in the BOQ could be considered as the governing amount ▪ Words over figures cannot be considered when the corrected bid price is taken as the bid price
Application of discounts	▪ It is beneficial to the client ▪ It is similar to with what is set out in World Bank and Asian Development Bank bid evaluation guidelines	▪ Applicability for variations is not mentioned ▪ Mal functions could be possible ▪ Establishing and mentioning of the applicable parameters could be avoided
Adjustment for omissions	▪ Items which are not quoted could be covered by rates quoted for other items ▪ Clarifications will not be permitted when certain items have not been quoted ▪ Rejection of bids is possible if critical items have not been quoted for	▪ Average prices could be amended because of unquoted items ▪ Bids could be rejected without seeking rejection clarifications ▪ Applicability of the Invitation to bids (ITB) clause
Adjustments for departures	▪ Clarifications could be sought in the absence of historical data	▪ Adjustments could be done by the Technical Evaluation Committee (TEC)
Operational and Life Cycle Costing (LCC)	▪ This will be applicable to only certain components of building projects ▪ This will be applicable only in building projects where there is a considerable quantity of Mechanical, Electrical and Plumbing (MEP) components	▪ This will not be applicable for re-measurement building projects ▪ A common system for evaluation will not be available ▪ An evaluation format will not be available
Conversion to common currency	▪ Mean of the selling and the buying prices could be considered ▪ Prejudices could be avoided ▪ This is similar to other bid evaluation guidelines ▪ A reference is possible	▪ It will not be possible to convert to Sri Lankan Rupees ▪ It will be possible to quote in foreign currencies ▪ This will not be applicable to public re-measurement type projects as foreign bidders will not be involved
Domestic preferences	▪ Local bidders are encouraged ▪ The percentage 15% is sufficient ▪ National construction industry is promoted	▪ Quality of output is disregarded ▪ The percentage 15% is too high
After sales services	▪ This is applicable to mechanical components of the buildings ▪ Maintenance is available after the Defects Liability Period (DLP)	▪ This is applicable only to design and build projects ▪ Maintenance is considered only during DLP ▪ Minimum standards are mentioned in the bidding document
Examination of	▪ Separate methods are available	▪ There will be high reliance on EE

unbalanced bids	for projects of different scales ▪ Provision is available for obtaining higher performance security	▪ It will be possible to obtain a higher performance security
Comparison with Engineer's Estimate (EE)	▪ A basis for evaluation will be available ▪ It will be possible to deviate from EE ▪ A validation process is available ▪ ICTAD price indices could be considered ▪ Dependence on the evaluator or the accuracy of EE could be avoided	▪ There will be high reliance on EE ▪ There will be dependence on the accuracy of the EE ▪ There will be dependence on the evaluator ▪ A proper EE validation procedure is not available ▪ There will be a possibility of rejecting bids which have deviated considerably from EE ▪ An ICTAD standard is not available ▪ A reasonable margin is not available ▪ The schedules of rates could be non-logical ▪ There is no proper procedure for appointing the TEC ▪ Price fixing committees are not available ▪ Trend analysis for evaluation is not available
Rejection of all bids	▪ A reasonable level of authority is vested with the client ▪ Saving of time and cost is possible ▪ Negotiations will not be possible during evaluation	▪ Shortcomings of the procurement strategy will be highlighted ▪ Consultants can avoid liability ▪ All bids could be rejected unreasonably due to the absence of effective tendering ▪ All of the bids could be rejected due to unethical behaviour of bidders
Clarifications during evaluation	▪ Historical data could be clarified ▪ Price modifications will be disallowed ▪ This will beneficial for emergency projects	▪ This will take a long time ▪ It will not be possible to avoid unethical clarifications completely
Alternate bids	▪ This will be beneficial to the client ▪ Acceptance will not be mandatory when quality is substandard	▪ This will not be applicable for re-measurement projects ▪ Quality could get reduced ▪ Only the lowest bidder will be successful ▪ Bidder will not be able to submit more than one bid security
Identifying the lowest evaluated bid	▪ Only the lowest bidder having qualifications will be identified ▪ Winner's curse could be avoided through a higher performance security and an accurate EE	▪ Winner's Curse could be present ▪ Lowest will not always be the best ▪ The term 'responsiveness' will not be very clear

Post Qualification Verification Stage

Table 7: Advantages, Disadvantages and/or Limitations of GBEP

Sub Stage	Advantage/s	Disadvantage/s and/or Limitation/s
Checking technical feasibility	▪ Separate stages will be available for short listing and detailed verification	▪ There will be repetition of work ▪ Verifying the legal history will not be possible ▪ New contractors will not be able to enter the industry ▪ A procedure to verify the validity of the submitted details will not be available ▪ There will be a requirement for experience in similar work during previous five years
Checking financial feasibility	▪ Separate stages will be available for short listing and detailed verification	▪ There will be repetition of work ▪ A formula for the annual turnover will be available

Writing of the Bid Evaluation Report Stage

Table 8: Advantages, Disadvantages and/or Limitations of GBEP

Advantage/s	Disadvantage/s and/or Limitation/s
▪ Non-disclosure of the evaluation report to bidders ▪ A Standard format will not be necessary as; • following the guideline will not be mandatory • the report could vary from project to project	▪ A standard format will not be available ▪ Submission of technical literature and specifications will not be mandatory ▪ There will be insufficient input from the Quantity Surveyor

4.4 EXPERT SUGGESTIONS

Expert suggestions were collected on each sub stage also as the general comments. Preliminary bid evaluation and establishment of a minimum qualification criteria were suggested for the first stage while ICTAD registration and bid validity were considered as minor deviations. For the detailed bid evaluation stage, it was suggested to consider as the governing amount, the quoted bid price or the corrected bid price whichever is lower, setting out parameters for applying discounts, making provision for variations, obtaining an express understanding for unquoted items before rejecting a bid, avoiding the increase of the average prices for comparison purposes to account for unquoted items, avoiding adjustments by the TEC/evaluator, allowing bidding in foreign currencies and evaluation by using lowest fluctuated currency and/or in Sri Lankan rupees, reducing domestic preference from 15% to 4%, setting out criteria for after sales services, not requesting higher performance security in case of unbalanced bids, rejecting unbalanced bids or informing bidders to re-price, increasing the accuracy and reliability of EE and establishing a reasonable margin for the comparison of bids, establishing an accurate procurement strategy to avoid rejection of all bids, rejecting all bids when unethical behaviour of bidders is disclosed, introducing novel clarification procedures, evaluating all alternative bids and identifying the lowest evaluated optimum bid. Checking the legal history of bidders and the validity of details submitted by them, reducing the requirement for experience in similar work in the preceding three to five years, establishing separate criteria to check the capability of new contractors and adjustments to annual turnover formula are the suggestions made for the post qualification verification stage. Similarly, suggestions made for the final stage of writing the bid evaluation report, include the introduction of standard formats, getting the evaluator to justify his decisions and calculating the annual turnover. Further, it is suggested to make mandatory the requirement for technical literature and specifications and to have more input from QS to the report.

As the general suggestions, it is explained that the appointment of members to the TEC should be transparent and that their qualifications should be well established. Majority of them should be technically qualified personnel. It is suggested to remove the authority devolved to Provincial Councils. The relevant Minister should clarify the decision pertaining to the award of the contract. The submission of the construction program and the method statement should be made mandatory. It is found that the Winner's Curse exists because of the inaccuracies in the EE and due to evaluation errors. The selection of the lowest evaluated bid also results in the Winner's Curse. There is corruption because of the slowness of various processes that require documentation. As GBEP is a well-defined procedure, the risk of conflicts is less. GBEP provides transparency to a certain extent and promotes competition. Its final outcome is to determine the lowest responsive bidder.

5. CONCLUSIONS AND RECOMMENDATIONS

There are four stages of GBEP, i.e preliminary bid evaluation, detailed bid evaluation and comparison of bids, post qualification verification and writing the bid evaluation report. The degree of its use in both the public and private sectors was identified separately for convenience and it is confirmed that almost all organisations in the two sectors use GBEP with or without deviations from the existing procedure.

Advantages, disadvantages and/or limitations of each sub stage of GBEP were identified in general. Thereafter, reliable expert suggestions were collected to improve the bid evaluation procedure. Minimum qualification criteria, making clarifications in an accepted manner, checking the validity of details submitted by bidders, identifying the lowest evaluated optimum bid, using standard formats wherever possible, justifications provided by the TEC/evaluators for each and every evaluation decision, making necessary calculations and submitting necessary evidence etc., are the critical suggestions made.

The industry practitioners and regulatory and legal bodies in the construction industry are advised to appoint bid evaluation authorities in a transparent manner having a majority of technically qualified members. It was suggested to remove the authority devolved to Provincial Councils to maintain consistency. The need to clarify the final decision with the TEC by the relevant Minister was discussed with a view to increasing the transparency of the bid evaluation procedure. One recommendation was to make the construction program and method statement mandatory to increase the accuracy and the reliability of bids even though this information is not contractually required.

These recommendations if implemented, would improve the quality and the standard of the construction industry. Hence, it is recommended that the stake holders consider these recommendations.

6. REFERENCES

Abeysinghe, U.S., 2006. *The Reliability of Consultant's Estimate.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Aluvihare, A., 1998. *Evaluation of Tenders for Design and Build Contracts.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Amarapathy, A.M.P., 2013. *E-Tendering Framework for Public Construction Procurement in Sri Lanka.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Central Bank of Sri Lanka, 2013. *Annual Report 2012*. Colombo: Central Bank of Sri Lanka.

Colombo Page, 2013. *Sri Lanka Invests 5.9 Percent of GDP in Public Projects Last Year* [online]. Available from: http://www.colombo page.com/archive_13A/Jun18_1371 571382CH.php [Accessed 14 January 2014].

Department of Census and Statistics, 2012. *Survey of Construction Industries 2011*. Colombo, Sri Lanka

Eriksson, P.E. and Westerberg, M., 2011. Effects of Cooperative Procurement Procedures on Construction Project Performance: A Conceptual Framework. *International Journal of Project Management*, 29(1), 197-208.

Fellows, R., Langford, D., Newcombe, R. and Urry, S., 2002. *Construction Management in Practice* [online]. 2nd ed. United Kingdom: Blackwell Science Ltd. Available from:

http://k126.fsv.cvut.cz/predmety/126ymcc/ymcccmin practice [Accessed 14 February 2014].

General Treasury, 1996. *Guidelines on Government Tender Procedure Part I Government Procurements*. Colombo 1: General Treasury.

Hampson, K., and Kwok, T., 1997. Strategic Alliances in Building Construction: A Tender Evaluation Tool for the Public Sector. *Journal of Construction Procurement*, 3(1), 28-41.

Holt, G., 2010. Contractor Selection Innovation: Examination of Two Decades 9 [online]. *Construction Innovation*, 10(3), 304-328. Available from: http://www 10.1108/14714171011060097 [Accessed 14 February 2014].

Holt, G. D., 1998. Which Contractor Selection Methodology. *International Journal of Project Management*, 16(3), 153-164. Available from: http://ac.els-cdn.com/S0263786397000355/1-s2.0-S0263786397000355-main.Pdf?tid=d8c83b10-8b1b-11e3-9c6c-00000aab0f26&acdnat=13912439267030f0912f 4e81a6caa588779d8b0298 [Accessed 14 February 2014].

Holt, G. D., Olomolaiye, P. O. and Harris, F. C., 1995. A Review of Contractor Selection Practice in the UK Construction Industry [online]. *Building and Environment*, 30(4), 553-561. Available from:

http://ac.els-cdn.com/036013239500008T/1-s2.0-036013239500008T-main.pdf?_tid=04ebedd0-8b1d-11e3b191- [Accessed 18 February 2014].

ICRA Lanka and IMaCS, 2012. *Survey of Construction Industries 2011* [online]. Available from: http://www. icralanka.com/Sri%20Lanka%20Construction%20-%20Sept%2015%20final.pdf [Accessed 18 February 2014].

Janaka, W.R.G.C., 2011. *Evaluation Contractor Pre-Qualification Process in Sri Lankan Construction Industry.* Unpublished Dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Jayasena, H. S. and Uhanowitage, R., 2008. The Effect of Winner's Curse on Post-Contract Management [online]. In: *International Conference on Building Education and Research*, *Building Resilience*, 1559-1565. Available from: http://www.academia.edu/1239834/The_Effect_of_Winners_Curse_on_Post-Contract_Management [Accessed 18 February 2014].

Mahdi, I. M., Riley, M. J., Fereig, S.M. and Alex, A. P., 2002. Multi-Criteria Approach to Contractor Selection [online]. Engineering, Construction and Architectural Management, 9(1), 29-31. Available from: http://www.emeraldinsight.com/journals.htm?articleid=1657470 [Accessed 18 February 2014].

Ministry of Finance and Planning of Sri Lanka, 1997. August. *Guidelines on Government Tender Procedure Part1: Government Procurements* [online]. Colombo. Available from: https://www.google.lk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&ved=0CDAQFjAB&url=http %3A%2F%2 Fww.treasury.gov.lk%2Fsinhala%2Fimages%2Fdepts% [Accessed 10 February 2014].

National Procurement Agency, 2006. January. *Procurement Guidelines: Goods and Works* [online]. Colombo: Author. Available from: http://www.treasury.gov.lk/depts/publications/ProcurementGuidelines2006 _amded12June.pdf [Accessed 10 February 2014].

National Procurement Agency, 2006. *Procurement Manual* [online]. Colombo. Available from: http://www.treasury.gov.lk/depts/pfd/publications/ProcurementManual200620060817withSup8.pdf [Accessed 10 February 2014]

Ngobeni, S., 2001. *An Analysis of the Tender Process in National Government in South Africa* [online]. Dissertation (B.Sc.). North-west University. Available from: http://dspace.nwu.ac.za/bitstream/handle/10394 /7596/NgobeniS.pdf?sequence=2 [Accessed 14 February 2014].

North American Development Bank, 2012. *Bid Evaluation Procedures* [online]. United States. Available from: http://www.nadbank.org/pdfs/procurementdocs/Bid_Eval_Procedures.pdf [Accessed 10 February 2014].

Public Procurement Oversight Authority, 2009. *Procurement Manual for Works*. The Republic of Kenya.

Rajaie, H., Hazrati, A. and Rashidi, A., 1997. Evaluation of Construction Contractors in Developing Countries Using Fuzzy SAW Method [online]. In: *International Conference on Computing in Civil and Building Engineering*. 1-11. Available from:http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/ pf142 .pdf [Accessed 10 February 2014].

Tikkanen, I. and Kaleva, H., 2011. Contract Award Procedures and Award Criteria in the Catering Services in Finland. *British Food Journal*, 113(8), 952-964. Available from: http://10.1108/00070701111153805 [Accessed 10 February 2014].

Turskis, Z., 2008. Multi-Attribute Contractors Ranking Method by Applying Ordering of Feasible Alternatives of Solutions in terms of Preferability Technique. *Technological and Economic Development: Baltic Journal on Sustainability*, 14(2), 224-239.

Watt, D. J., Kayis, B. and Willey, K., 2009. Identifying Key Factors in the Evaluation of Tenders for Projects and Services [online]. *International Journal of Project Management*, 27(1), 250-260. Available from:

http://ac.els-cdn.com/S0263786308000409/1-s2.0-S0263786308000409-main.pdf?_tid=da6bb49a-8b1d-11e3 -8daa-00000aab0f27&acdnat=1391244788_7ae5222eb99b932b6f38033bc58752f7 [Accessed 14 February 2014]

Willis, C. J. and Ashworth, A., 1992. *Practice and Procedure for the Quantity Surveyor.* 9th ed. UK: Mackays of Chatham PLC.

Wong, C.H., Holt, H.D. and Harris, P., 2001. Multi-Criteria Selection or Lowest Price? Investigation of UK Construction Clients' Tender Evaluation Preference. *Engineering, Construction and Architectural Management*, 8(4), 257-271.

SUPERVISION OF FABRICATION OF PRECAST STEEL FIBRE REINFORCED CONCRETE (SFRC) SEGMENTAL LINING

George Varghees*
C@nspecs Pte Ltd., Singapore

ABSTRACT

Precast reinforced concrete (RC) segments have been widely used to construct tunnels for mass rapid transit lines in Singapore. However, the reinforcement bar cages are labour intensive to fabricate and install in moulds. Then the cages must be adjusted in moulds to achieve minimum cover at critical locations such as bolt sockets and cover to external face. Supervision has to be tight to achieve good quality segments.

However, with the use of steel fibre reinforced concrete (SFRC), steel reinforcement bars have been eliminated. Steel fibres are added during the batching of concrete. Concrete is then poured in moulds and compacted. Compaction is done by using external vibrators mounted on moulds. For downtown line stage 3 contract 933, SFRC segments were used as tunnel lining. C@nspecs Pte Ltd supervised the production of SFRC segments in the factory.

This paper outlines the quality control tests done on the fresh and hardened concrete.

Keywords: *Precast Reinforced Concrete; Steel Fibre Reinforced Concrete (SFRC).*

1. INTRODUCTION

In densely built cities of today, the mass rapid transit is the best mode of urban transportation. Generally the transit lines are built underground to avoid congestion on surface. Tunnel boring machines (TBM) are used to bore the tunnels. Generally precast reinforced concrete tunnel segments are used as lining and they form the permanent tunnel to carry the railway line. Steel reinforcement bar cages are labour intensive to fabricate, install and supervise.

As the tunnels are built for a life span of 120 years, it is important that the reinforcement bars remain protected by providing the minimum cover of 40mm from the external surface. In the long term, any water seepage or chloride attack will corrode the reinforcement bars thus affecting the design life span of tunnel. SFRC eliminates the necessity of providing steel reinforcement bars and helps to provide a durable tunnel.

2. SFRC MIX DESIGN AND BATCHING

Coarse aggregate, fine aggregate and steel fibre, cement and silica fume are mixed dry for about 90 seconds. Polypropylene (PP) fibres are then added and mixed for 5 seconds. Water and admixture are added and mixed for another 15 seconds. Final mixing is done for another 10 seconds before discharging to the delivery bucket.

Concrete strength is specified as 60 N/mm^2. Mix design is done by precaster and confirmed by trial mix. Contract 933 PS-20.2.1 specifies that steel fibre reinforcement shall be deformed steel fibre produced by cold drawn wire. Steel fibres shall be for structural use in concrete (Group 1) complying with EN 14889-1 with aspect ratio 50 to 80. Minimum length of steel fibres shall be 50mm and tensile strength shall be

* Corresponding Author: E-mail - gv@conspecspl.com.sg

1000 MPa. Steel fibres shall be uniformly distributed in concrete and shall not tend to form fibre balls during batching and mixing. Steel fibre dosage was 40 kg/cubic metre.

Polypropylene (PP) fibres are added to the concrete mix to make it fire resistant. Contract 933 PS-20.2.2 specifies that polypropylene fibres shall be 100% virgin polypropylene monofilament fibre containing no reprocessed materials. The PP fibres shall comply with EN 14889-2 (Class 1a). Nominal cross-section diameter of PP fibres shall be between 18 microns to 20 microns and nominal length between 6mm to 12mm. The melting point of PP fibres is 160^{o}C +-10%. Minimum PP fibre dosage is 1.0 kg/ cubic metre.

Coarse and fine aggregate used shall not be alkali reactive. Mortar bar tests are done to determine whether aggregate is alkali reactive. According to ASTM C1260, aggregate shall be with marginal reactivity, expansion <0.2%. Sieve analysis is done weekly to ensure grading.

Cement used is Portland cement. Pulverised Fuel Ash (PFA) is added to cement to make it low-heat. Silica fume is added to the mix to make it denser. Portland cement, PFA and silica fume together form the binder. Total binder content is 370 kg/m^3 to 400 kg/m^3. Approved super plasticizer is added in the design mix to improve workability. Water cement ratio is generally 0.35.

3. Steel Fibre Reinforced Concrete Properties

Contract 933 PS-20.4 specifies the characteristic compressive cube strength as 60 N/mm^2 and characteristic tensile splitting strength as 4.5N/mm^2. Characteristic limit of proportionality (LOP) value, $f_{R,1}$ and $f_{R,4}$ are 4.2 N/mm^2, 2.8N/mm^2 and 1.4N/mm^2 respectively.

4. Confirmation of Mix Design by Trial Mix

Cement Three batches of trial mix are conducted. Average cube compressive strength at 28 days shall be 70 N/mm^2. Three samples are tested for Rapid Chloride Permeability before production starts.

Contract 933 PS-20.7 gives the acceptance criteria for trial mix as follows:

Trial Mix and Acceptance	
Three steel fibre content tests on fresh concrete	EN 14721:2005
Three slump tests on fresh concrete	EN 12350-2:2000
Three density tests on fresh concrete	EN 12350-6:2000
Three air content tests on fresh concrete	EN 12350-7:2000
Twelve cubes for compressive strength testing, at 28 days	EN 12390-3:2002
Twelve cylinders for compressive strength testing, at 28 days	EN 12390-6:2000
Twelve prisms for compressive strength testing, at 28 days	EN 14651:2005

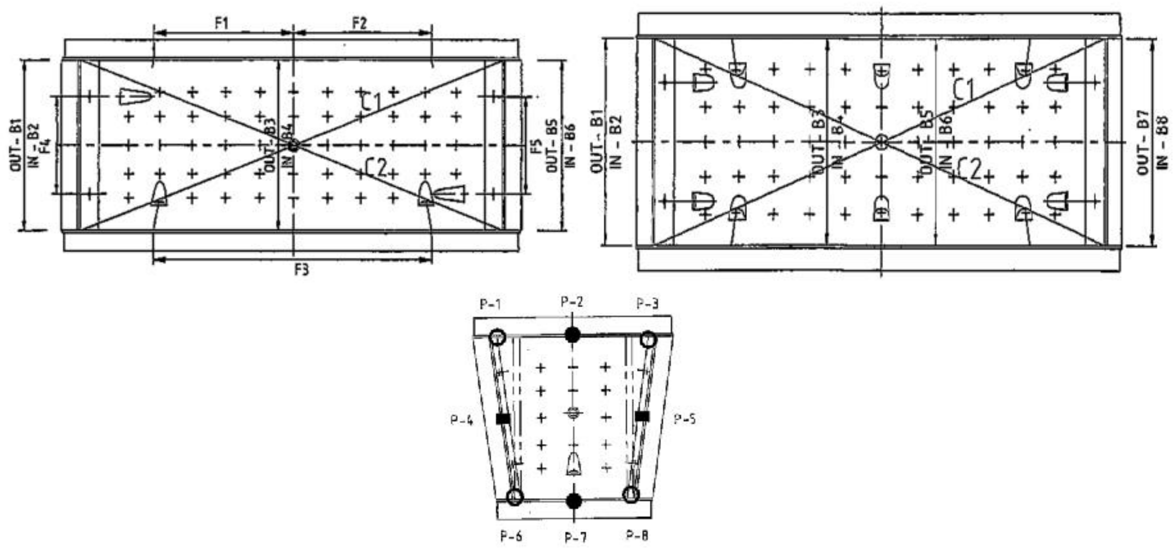
Contract 933 PS-20.7.3 gives the compliance criteria as follows:

The average steel fibre content > proposed steel fibre dosage minus 5%. Average slump value shall be within 20 mm or 25% of the designed slump value. Compressive strength of each cube tested > specified characteristic strength. Average compressive cube strength (from all 3 batches) > specified characteristic strength + 10 N/mm^2. Tensile splitting strength of each cylinder tested > specified characteristic strength. Average tensile splitting strength (from all 3 batches) > specified characteristic strength +1.5 N/mm^2.

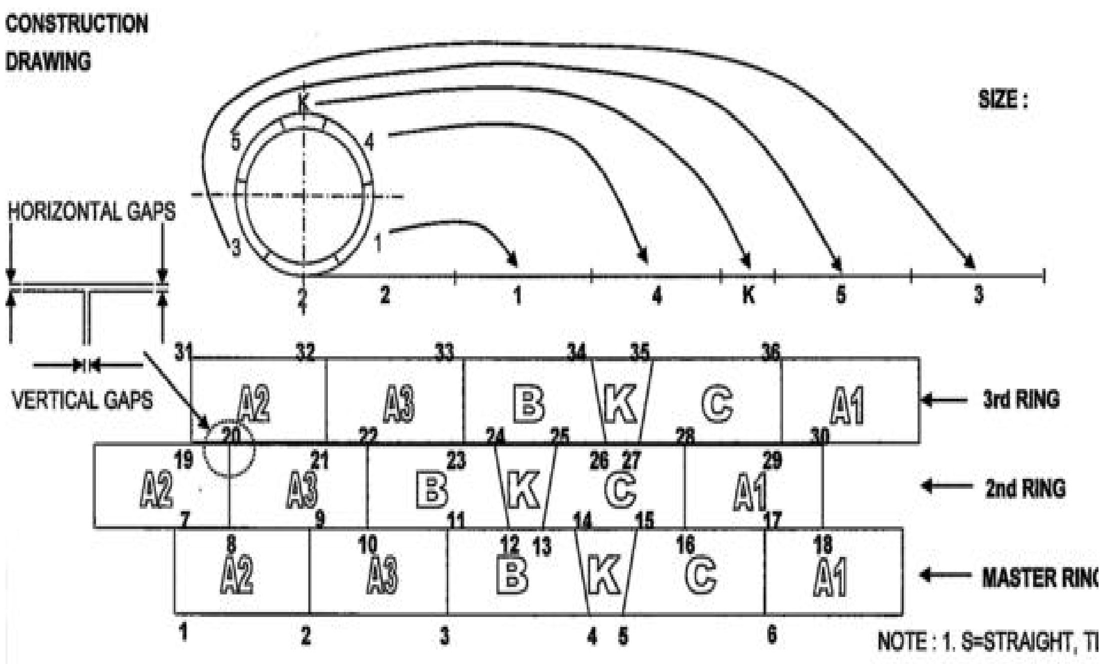
The limit of proportionality (LOP) value of each prism tested > specified characteristic value. Average limit of proportionality (LOP) value (from all 3 batches) > specified characteristic strength +1.8 N/mm^2. $F_{R,1}$ value of each prism tested > specified characteristic value. Average $f_{R,1}$ value (from all 3 batches) > specified characteristic strength +1.2 N/mm^2. $F_{R,4}$ value of each prism tested > specified characteristic value. Average $f_{R,4}$ value (from all 3 batches) > specified characteristic strength +0.6 N/mm^2

5. Moulds Used

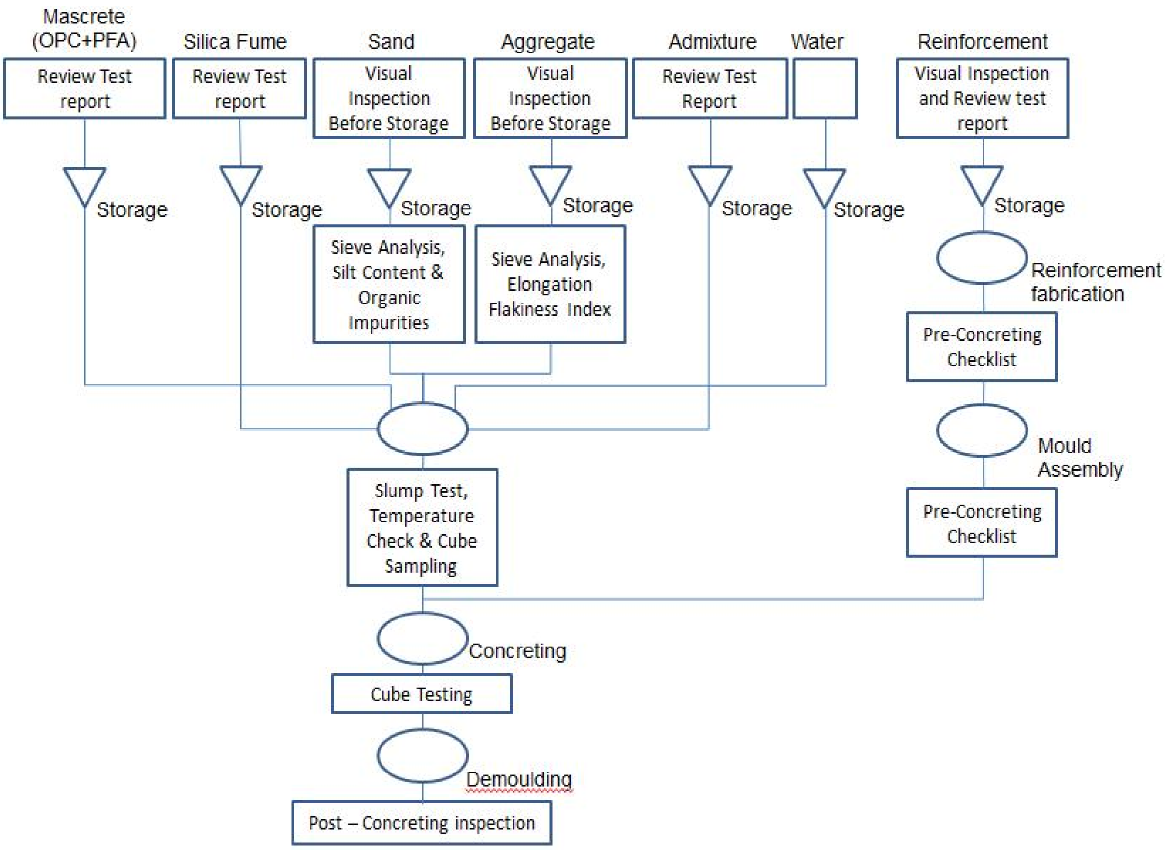
Mould dimension checks are done by independent Inspector before production and one cycle per every 100 casts.



Master ring / trial ring shall be assembled before production commences and checked for internal diameter, vertical and horizontal gaps etc.



The flow chart of production quality control is given below:



6. INSPECTION AND TEST PLAN

Activity / Particular	Standards / Frequency	Acceptance Criteria	Document Verified
Mascrete (OPC + PFA)	OPC – SS 26 PFA – BS 3892	Temperature < 75˚C	DO Mill Certificate
Silica fume	SS 26	-	DO Test Certificate
Sand (Sieve Analysis) Silt Content & Test for Organic Impurities	SS 31, SS 73	Max % by mass passing 75µm sieve – 3%	-
Check sand moisture before batching	-	Water for batching will be compensated to take into account the moisture content	-
Coarse aggregate Sieve analysis Flakiness & Elongation Index	SS 31, SS 73	% by mass passing 75µm sieve < 1 < 35%	Test report
Admixture	SS 320	-	Test report
Water	BS 3148	-	Test report
Calibrate concrete batching plant (in-house)	Monthly	Load Cells ± 3%	Calibration report
Calibrate concrete batching plant (external party)	Annually	± 3%	Calibration report
Calibrate concrete	Annually	± 3%	Calibration report

Activity / Particular	Standards / Frequency	Acceptance Criteria	Document Verified
cubes compression machine (external party)			
Maintenance of lifting equipments	3 months	Maintenance certificate to be current	Reports - catalogues
Check mould	Each mould before concreting	Check whether mould is clean, demoulding oil applied	Mould supplier specs, pre-concreting inspection form
Batching concrete	Mix design (daily)	Grade 60	Mix design verification from computer
Slump test	SS 78	For every batch of concrete	Slump test record
Concrete test cubes	M&W Specs Cl 11.8.3	For every batch	Cube compression test report
Cube tests	M&W Specs Daily	Demoulding – 10 N/mm^2 7 Days – Indicative 28 Days – 60 N/mm^2	Test Report
Pre-pour inspection	Before pouring concrete	Concrete Cover +5mm / – 0mm Check all cast-in-items are fixed	Inspection form
Demoulding	Each cast segment	Compressive Strength 10 N/mm^2	Cube test result
Curing	Each segment	Intrados sprayed with curing compound Extrados and sides (coating)	-
Inspect segment for defects / damage	Each segment	Check for non-conformance & damages	NCR
Wet Film Thickness	Wet film gauge 1 segment / day	200 microns	Post concreting check list
Dry Film Thickness	Elcometer paint inspection gauge 1 segment / day	Min 200 microns	Test Report
Pull-Out Adhesion Test	Elcometer adhesion tester (ASTM D 4541) Once a week for first month; subsequently 1:150 rings	Min 1.5 N/mm^2	Test Report
Rapid Chloride Permeability Test	ASTM C 1202 First 100 rings, 1:20 rings Subsequently1:150 rings	Average 700 coulombs or better < 1000 coulombs	Test report
Check dimensions of segment	As per specifications 1 :100 segments	Thickness +3/-1mm Width +/- 1mm	Segment dimension checklist
Check mould dimensions	Manufacturer specifications. Before project starts; subsequently every month	Specified tolerances by manufacturer	Mould dimension check report
Lifting Socket	Specifications 2 tests before production subsequently 1:2000 segments	FS of 3 against design pull-out force	Test report
Matching and interchangeability test	LTA Specs Every set of mould	LTA Specifications	Ring assembly & gap checklist
Storage of segment	Daily	Segments turned and stored with intrados face upwards	-
Delivery of Segments	Every load	28 days strength > 60 N/mm^2, no damages, ensure that segments are secured properly and stable	Delivery Order

7. SAMPLING AND TESTING OF SFRC DURING PRODUCTION

Contract 933 PS-20.8 specifies the following:

Fibre content testing shall be done on fresh concrete. One steel fibre content test is to be done per production day. Steel fibre content > proposed steel fibre dosage minus 20%. Tensile splitting strength tests are conducted on hardened concrete for 2 cylinders at 28 days for every 4 rings.

Average tensile splitting strength from any 4 consecutive tests shall be > characteristic tensile splitting strength + current margin. Tensile splitting strength from any individual test shall be > characteristic tensile splitting strength – current margin. Current margin = 1.64 x standard deviation

Flexural strength tests are done on hardened concrete for 2 prisms at 28 days for every 12 rings. Average LOP value from any 4 consecutive tests shall be > characteristic LOP value + current margin. LOP value from any individual test shall be> characteristic LOP value – current margin. Current margin = 1.64 x standard deviation

Average $f_{R,1}$ value from any 4 consecutive tests > characteristic $f_{R,1}$ value + current margin. $F_{R,1}$ value from any individual test > characteristic $f_{R,1}$ value – current margin. Current margin = 1.64 x standard deviation.

Average $f_{R,4}$ value from any 4 consecutive tests > characteristic $f_{R,4}$ value + current margin. $F_{R,4}$ value from any individual test > characteristic $f_{R,4}$ value – current margin. Current margin = 1.64 x standard deviation.

8. CURING OF SFRC AND POST-CONCRETE INSPECTION

All precast concrete segments shall be cured using moist curing, curing compounds or curing at elevated temperature. For steam curing, minimum and maximum temperature is 55°C and 67°C respectively inside the curing chamber. Curing period is from 6 to 7 hours before segments are de-moulded.

Post-concreting inspection is done by visual inspection to check for defects and surface finish. Common defects seen are cracks, honeycomb, concrete chipped off / spalled off etc. Segments with cracks or honeycomb are rejected whereas segments with chipped off edges are repaired according to the specification.

9. CONCLUSIONS

SFRC segments are a better alternative to reinforced concrete segments using conventional reinforcement bars. These segments help to reduce the labour employed in the factory and good quality control can be achieved in production. Production cycle can be shortened which will then increase the production capacity of the precast yard thus achieving higher productivity and savings in cost.

SUSTAINING THE FUTURE WITH LEGACY: A CASE STUDY ON THE UK GOVERNMENT CARBON EMISSION TARGETS 2025 AND LONDON OLYMPICS 2012

G.A.G.R. Godawatte*
School of Engineering and Built Environment, Glasgow Caledonian University, United Kingdom

ABSTRACT

The UK Construction 2025 Strategy states that the UK construction industry should be the world leader in sustainable construction by 2025. The Government views sustainable construction as an opportunity for growth within the UK as the industry seeks new markets across the globe. Mega projects such as the London Olympics 2012 and Glasgow Commonwealth Games 2014 have been viewed by Government as important drivers for innovation and an opportunity for demonstrating good practice to the wide industry. Lessons are emerging from these projects and have been incorporated into the development of the Government's vision for Construction 2025 with a view to further delivering sustainability in product and practice, but also with a view to establishing capacity. This paper mainly focuses on evaluating the Carbon Emission Reduction targets set by the UK Government in order to be in line with the current Sustainable Development practices. The study also includes an analysis of the Legacy set out by London Olympics 2012 which achieved a number of successful outcomes in terms of Sustainable Construction and Procurement. However, a number of traditional barriers within the construction industry are argued to be restricting the ability to progress the construction agenda at the rate intended. The evidence show that the UK is well within the Carbon Emission Reduction targets and the legacy from the London 2012 Olympic Games should provide for better construction practices in the future, provided that they are used in the correct context, and embraced by the key stakeholders from the outset.

Keywords: *Carbon Emissions; Construction; London Olympics; Sustainable Development; UK Government.*

1. INTRODUCTION

'Climate change', 'Carbon emissions', 'Renewable energy sources', 'Waste', 'Green construction' have become the 'hot topics' in the present world gaining the attention of every single person on the planet with regard to Sustainable development. The UK government has identified the construction industry as a major industry in terms of delivering the UK national carbon emission targets and achieving the sustainable development in a broader spectrum. The construction industry is set to face new challenges in line with the new government strategy for construction: 2025, and a change of the vision and strategies for construction is expected as far as sustainable development is considered. The UK construction vision: 2025 targets mainly to develop new plans for sustainability and waste reduction in the UK construction sector and become the world leader in sustainable construction by 2025. There have been significant changes and improvements in government policies and legislation on the construction industry to stay in line with sustainable practices. Major issues such as climate change, carbon emissions, and energy usage have made a significant impact on the construction and related industries and have raised public awareness on these issues. The UK government has made an important decision to make changes to the current practices however; this has been a challenge due to various traditional, technical, and economic barriers (Thomson and El-Haram, 2011).

Both Latham (1994) and Eagan (1998) reports suggested that there is a need for a change in vision, strategies and overall thinking and decision making in the construction process. Since the industrial

* Corresponding Author: E-mail - gimhan.godawatte@yahoo.com

revolution there has been a significant change in human living style, technology and innovations. There have been periods where the governments had to make changes in policies and legislation to overcome potential threats. Issues such as global warming, climate change, carbon emissions and energy usage have shown that there is a need for a 'sustainable development' to retain resources for the future generations.

In the UK recent government action plans and strategies such as Sustainable Development Strategy (2005), Sustainable Communities Act (2007), the Climate Change Bill (2009) and Low Carbon Transition Plan (2009) etc. show a need for setting up policies for driving construction industry towards sustainable development (Thomson and El-Haram, 2011). According to Ding (2008) the construction industry is a major industry that causes impacts on the environment ranging from high consumption of resources during construction and operation, to the environmental pollution. Also Vanegas (2003) has identified construction industry has the responsibility and potential to become a major participant in carbon reduction targets and ultimately drive towards the wider principles of sustainable development made.

2. CARBON EMISSIONS AND UK GOVERNMENT TARGETS

Carbon emissions and climate change have been the most significant threats to humankind as far as the future is concerned. Depending on the emissions there is a threat of rising global temperature by between 1.4ºC and 5.8ºC between 1990 and 2100 (HM Government, 2005). Reduction of emissions should be accompanied with the support of constructing zero-carbon homes and business premises that consume less energy (HM Government, 2007). According to BRE (2003) buildings are responsible for 50% of the emissions if all the energy is used in constructing, occupying and operating the building. Rohracher (2001) mentions that about 40% of energy consumption and about 25% of material ecological load is carried by the construction of buildings. Although there are visible signs and evidence to prove that the UK government has taken actions to overcome the potential threats, Hall *et al.* (2006) argues that sustainability is given a low priority and the government has yet to make a significant contribution and impact on driving construction towards sustainability.

In accordance with the Kyoto protocol the UK government has set targets to:

- Reduce UK greenhouse gas emissions by 12.5% below base year (1990) levels over the period of 2008 – 2012.
- Reduce UK carbon dioxide (CO_2) emissions by 20% below base year (1990) levels by 2010.

In addition to the above targets the government is committed to reduce at least 80% of the UK carbon dioxide (CO_2) emissions by 2050 compared to the levels in 1990 (Figure 1) and achieve real progress by 2020. Figure 1 shows the estimated Carbon Emissions Reduction targets from 1993 to 2050. However, it mainly concentrates only on CO_2 emissions rather than the Carbon emissions as a whole. For regular review and to advise the government on the optimum pathway to the 2050 carbon emission targets a Climate Change Committee was established under the Climate Change Bill (2009). Further, the Carbon Reduction Commitment (CRC) is responsible to mandate the large commercial and public sector organisations to reduce carbon emissions by at least 1.1 MtC / year by 2020 (HM Government, 2008)

The UK Government has set out a policy stating that new homes should be zero-carbon from 2016 and respectively from 2016, 2018 and 2019 all new schools, public sector non-domestic buildings and other non-domestic buildings will also expected to be zero-carbon (HM Government, 2008). Also the Government has issued the Approved Document L1A and L2A (Conservation of fuel and power) to provide practical guidance for energy efficiency requirements of the Building Regulations. The main purpose of Approved Document L is to calculate and ensure CO_2 emissions rate from the building as built, is the same to the Target CO_2 Emissions Rate (TER), set as a target by the Building Regulations (Approved Document L1A, 2010).Also there is a Sustainable Development Commission formed to independently assess the role and the performance of the UK government organisations against the targets of the sustainable development.

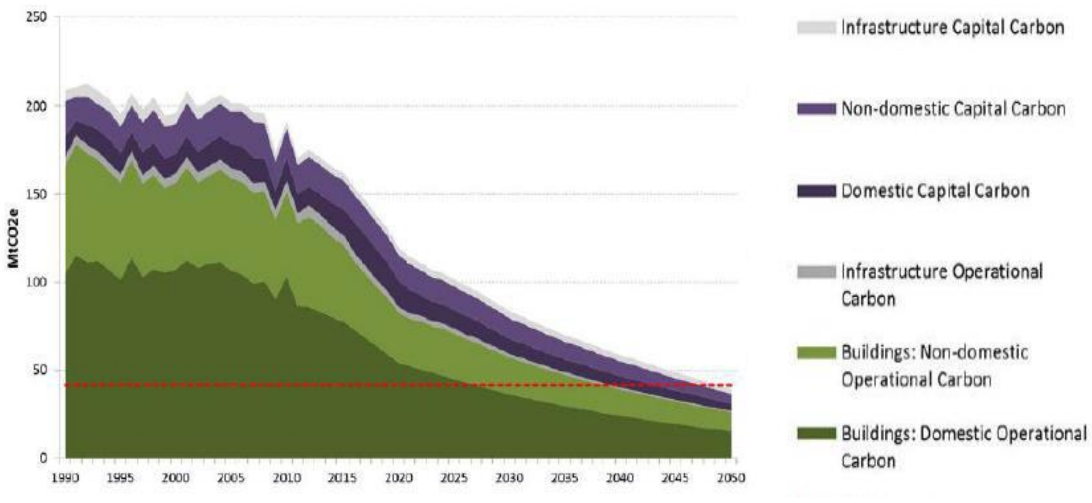


Figure 1: Carbon Emissions Target for 2050
Source: Green Construction Board (2013)

The latest statistical evidence and projections show that UK is well inside the limits to meet Kyoto targets (HM Government, 2009). However, still there are certain actions have to be taken in order to achieve the 2010 carbon dioxide (CO_2) reduction goal. According to the estimate carried out by Climate Change Programme (CCP) in year 2011 showed that only about 14.8% of carbon dioxide emissions were reduced in year 2010 compared to the initially predicted 1990 levels (20%). This clearly shows that the government should take additional actions and procedures in order to stay in line with the carbon emission targets. Also Rees (2009) argued that the government has failed to address the true scale of problems other than implementing policies and regulations. There is a need for a rethink of construction in order to change the processes and traditional and cultural barriers. The government should be involved on these aspects to change the image of the general public and make them aware of what is happening. Bringing in policies one after another would not achieve the ultimate success of any agenda but a mind winning process is required to retain the targets. Rees (2009) also mentioned that there is a need for a cultural shift to address the traditional barriers of implementing sustainability from the inception to the delivery of a project.

3. RESEARCH METHODOLOGY

Research design is the systematic process of converting identified research questions into the realistic research project in order to answer the questions (Yin, 2009). This simply means that there should be strategies, methods, and techniques involved in the process of answering the research questions to make the research viable.

Research approaches can be interpreted and described in various ways depending on the type of research question and area. This research paper has adapted the Case study method as the suitable research approach based on the Legacy of London 2012 Olympics. Case study research has become an extremely common research strategy for inquiry within property and construction research in the current research trend among researchers. Case study research involves the study of an issue explored through one or more cases within a bounded system (Yin, 2009). Case study research therefore naturally lends itself to built environment research themes.

This paper has selected Documentation/Archival records as the data collection and analysis method for the case study. Documentation/Archival records method refers to the data that been already published by someone else (Barakat, 2009). This is also known as “Secondary data”. Many researchers have mentioned that secondary data is considered as the data being reused in a different context. The main data for the case study were collected with reference to the various Government and UK Olympics Committee publications on London Olympics 2012. The analysis of the data takes the form of a qualitative critical review than a quantitative analysis. A critical review of the information was required in order to evaluate the outcomes of the London Olympics 2012 project in terms of sustainability. The evaluation includes major sustainability themes including procurement, selection of materials, supply chain, and carbon emissions. The analysis of the case study is presented in the next section.

4. CASE STUDY: LEGACY OF LONDON 2012 OLYMPICS FOR A SUSTAINABLE FUTURE

Following the completion of the London 2012 Olympics and Paralympics Games the attention has turned to ensuring that an effective legacy from the games is provided. This legacy takes a number of different forms, from an obvious sporting and health legacy through to playing an active role in the future regeneration of the Stratford and East London in a physical and socio-economic sense.

According to the LOCOG (2013) the Olympic park represented the biggest construction project in Europe and the UK Government has been keen from the outset to stress its importance in providing a legacy for driving improvement within the construction industry both in terms of product and process. The park represented a number of high profile sports facilities (stadium, swimming pool, indoor arena etc.) and an athlete’s village. These were planned to realise a number of ambitious sustainability targets in terms of environmental targets (e.g. energy, contaminated land, reuse of building materials, waste generated); but also number of economic targets (e.g. reducing cost and ensuring multiplier affects) and social targets (e.g. related to health and safety, creation of apprenticeships and local employment). In the two years since the games has finished a number of reports have emerged to evaluate the legacy of the Games, and many have focused heavily on the legacy for the construction industry with emphasis on Sustainable Construction. Indeed, the lessons have helped to shape the UK Governments Construction 2025 vision and strategy for growth.

During the bidding process London Olympics’ bid team affirmed their commitment to form the vanguard of sustainable development standards, whilst correspondingly creating a lasting sustainable legacy benefiting local communities and securing economic growth by concentrating on the extensive regeneration of East London (LOCOG, 2013). It was the responsibility of the Olympic Delivery Authority (ODA) to reflect this pledge into the delivery of infrastructure, venues and facilities within budget and time constraints. The ODA engaged with a comprehensive suite of expertise including; Government Organisations, NGO’s and industry as well as the local community to develop ambitious, yet achievable, sustainability targets for each project associated with the programme. In 2007 the ODA published the Sustainable Development Strategy placing the onus on the project teams to meet its firm criteria. Sustainable procurement of materials was integrated into the framework’s procurement policy and from the outset; there was an emphasis on responsible sourcing of materials, use of secondary materials, minimizing embodied impacts and the use of healthy materials (DEFRA, 2013).

According to the European Commission (2013), sustainable concrete supply for the extensive site was identified to be a significant means to alleviate the environmental impact of development. Concrete remains the most predominant building material supplied to the UK construction industry and the cement constituent accounts for around 2% of UK CO_2 emissions with an average embodied carbon content of 830kg CO_{2e}/tonne (AECOM, 2011). Coupled with a significant environmental and social impact in the sourcing, extraction and distribution of aggregate to batching plants and construction sites, it soon becomes apparent the carbon footprint of concrete processing is substantial (European Commission, 2013). During the design phase, it was estimated that 500,000m^3 of ready-mix concrete and a parallel 1 million tonnes of aggregate would be required for construction of the Olympic venues and the subsidiary infrastructure. The ODA evaluated supplier credentials with a thorough tender process and a balanced score-card approach in which sustainability made up 20% of the assessment (in comparison to a typical average of around 5%) only appointing a company whom demonstrated a sustainability commitment (European Commission, 2013).

Furthermore, the ODA identified innovations within the supply chain and coordinated contractor-supplier communication to create a sustainable concrete process which included use of recycled aggregate (22%), efficient design, extensive testing of sustainable mixes and sustainable freight methods (i.e. rail transport and construction of a site batching plant to reduce transport emissions). This contributed to an approximate saving of 50,000 tonnes of embodied CO_2 and 70,000 vehicle movements to the site, not to mention the 289,000 tonnes reduction in quarried aggregate (European Commission, 2013).

Whilst much of the focus has been given to the methods of construction and the systems put in place for a sustainable method of construction to be achieved, the defining measurement of the sustainability of construction and thus the legacy of the Olympic Park (and surrounding area) will be its adaption and subsequent re-use from sports stadia and infrastructure into a revitalized part of East London - the best endeavours of constructing the Olympic Park in the most sustainable manner would have little effect if the development plan did not extend any further than the hosting of the games – note the state of the Olympic stadia and parks built for the Athens Olympics, which had an effective life of the games and have since fell into disrepair (Hackney Council, 2013).

According to Davies (2012) the development of the Olympic Park, the associated area, and the improvements to the transport and infrastructure allowed for complete urban regeneration of former industrial areas of London, which had laid derelict or in disuse for a number of years prior to the winning of the Olympic bid. As part of the bid document the development for the Olympics heralded to extend beyond that of the 2012 games by providing East London with a revitalized community which could further develop and grow. Whilst the building for the games instigated the regeneration of the area, the initial step of providing the sustainable legacy from London 2012 has been in the reallocation of the sports stadia / venues / elements that were developed for the games. Of the eight venues constructed all have been listed for re-use

- Olympic Stadium – to be utilized by West Ham FC
- Media Centre – now occupied by BT Sport
- Arcelor Mittal – tourist attraction
- Eton Manor Sports Park – location for the 2015 Hockey World Championship
- VeloPark / Copperbox / Aquatics – arenas for public use, providing affordable facilities

This has ensured that funding and investment remains in the area, which in turn supports business and development, and provides residents with amenities within the area. In addition to the re-use of the stadia the Athletes Villages have been adapted to form the first in a series of new communities, providing over 2750 homes in the area demarked as East Village, of which occupation has since commenced.

A further good example of the UK Government’s sustainability agenda being promoted is through the delivery of the athlete’s village. The village not only provides affordable housing in London; it also provides housing that is fit for purpose and can be easily adapted in the future through the design of the housing which meets lifetime homes standards (Davies, 2012). Post Games, this allows the properties to be easily adapted and will future proof the properties at the design stage to ensure the buildings meet the future needs of tenants and owners; which could be argued will have a positive effect on increasing the buildings lifespan. HM Government (2008) state that design is a key features of the sustainability strategy and therefore incorporating well designed buildings that can be adapted to meet future needs is an excellent example of the Government’s agenda being promoted through the Games.

Within the design element of the strategy HM Government (2008) provide an action point to deliver all publically funded housing to lifetime home standards. Good design is said to include ‘sustainable’ and ‘adaptable’ properties (HM Government, 2008, p.14) which ties back to the building lifecycle of the village. The legacy of the Games village will provide homes that are easily adaptable should residents have any health or mobility issues later in life. This could be through the means of a supported joist for the provision of a future hoist, or an aperture between floors which would allow a through floor lifts to be installed, allowing easy access to all levels of the properties. The Olympic Park Legacy Company (2012) have compiled a report on the importance of inclusive design for the village which provides their vision for inclusive design to ‘…an approach that considers the widest possible audience, addressing the needs of people who have traditionally been excluded or marginalized by mainstream design practices.’ A key point to this is addressing the needs of people, which also ties back to the UK sustainable strategy in terms of adaptability.

In conclusion the London 2012 Olympic Games and in particular the Olympic Park have provided a lasting legacy to the area which continues today through the continued use of the buildings and surrounding areas as detailed this has been achieved through foresight in planning and securing new users of the buildings prior to the games commencing. In terms of promoting sustainability throughout the industry, it is clear to see that the games as a whole was an achievement for the industry however, it is uncertain as to how much of a knock-on effect this has had on the rest of the industry with many major construction companies still only concerned with the immediate demands with regards to sustainability of their client who inevitably pays them.

5. CONCLUSIONS

Through mega projects such as London 2012 the UK sustainability agenda has shown a new direction to the construction industry of UK as well as the world. The government has already identified the construction industry as a key participant of achieving the sustainable development targets in future. Contribution of various parties is essential to achieve the carbon emission targets by 2050. Government could influence the process but it is the duty of the general public to accept the changes for a better future. As an industry, construction sector is accused for high energy and resource consumption and according to Myers (2005) there are several important initiatives that have been implemented by the government specifically on the construction industry.

According to the London Olympics sustainability plan (2011) the London 2012 construction was the largest construction project in Europe. Legacy provided by this project has got many direct and indirect impacts on the Sustainable Construction agenda in the UK. The overall planning and procurement process was a key indicator of the success of the project. As per the guidelines given by the Office for Government Commerce the selection of a procurement route is based on the primary consideration of obtaining value for money. According to the Final Report of the IOC Coordination Committee (2013), some of the major achievements were:

1. Creation of Olympic park – This was the largest new urban parkland in Europe in 150 years. Various state-of-the-art engineering and architectural solutions were used in the construction stage, and polluted soil and waterways were cleaned and most of the waste was recycled and re-used in new constructions.
2. Centrepiece Olympic stadium - According to the report this was the lightest, most sustainable and most adoptable stadium ever constructed and was able to show how games can respond to important themes such as sustainability. The athletics track was retained after the games providing a landmark venue for athletes of all levels.
3. Measurement of carbon footprint – According to the report this project was the first large scale project to measure its carbon footprint over the entire period of the project and achieved a Carbon footprint saving percentage of 66%. The construction works contributed 44% of the savings. Also London 2012 was the first games to commit and deliver a zero landfill waste target.
4. Inspiration for a sustainable management system – This project set an inspiration for the development of a sustainable management system standard for events, and was eventually introduced as a national standard – BS 8901.

At the initial brief of the procurement process 'sustainability' was identified as a key performance indicator of the project in terms of achieving value for money. The most significant decision in the procurement process was that 'sustainability should not be sacrificed in favour of lower prices.' The main focus on procuring suppliers was on local sourcing and 70% of the suppliers were small and medium sized organisations.

Even though this project has had some significant achievements there were few demerits during the procurement process. The Lessons learned reports (LOCOG, 2012) of the project indicate that: "LOCOG often faced a challenge when balancing the need to satisfy its clients' expectations with the need to meet its budget objectives."

Satisfying the client and the other stakeholders is a must to ensure the success of any project. This project specifically aimed at achieving its sustainability goals but often failed to comply with the objectives when managing the financial aspects of the project. The budget considerations delayed the procurement and planning process which eventually delayed the progress of construction and had a negative impact on the delivery schedule. Therefore the government has a responsibility to review the actual gains of the project rather than discussing the sustainable practices on its own.

Through this case study it is evident that achieving carbon emission reduction targets will be a significant achievement of the UK construction industry along with the energy industry and the government but success of each construction project should also be reviewed as far as sustainability is considered. Being successful in achieving a zero-carbon target does not mean a project, industry or a nation is sustainable in all aspects. It will depend more on the mind-set of the general public and the parties actively engaged in the construction activities. The government should be able to identify and understand the actual gap between the problem and the required solution and set more realistic goals for the construction industry in order to become the world leader in sustainable construction by 2025. And finally that would give a clear answer to the question “whether construction industry has demonstrated a significant step forward in transforming social, economic and environmental features into one that is ‘Sustainable Development’?.

6. REFERENCES

AECOM, 2011. *Zero Carbon Non-Domestic Buildings*, London: Department for Communities and Local Government, UK.

Andranovich, G., Burbank, M.J. and Heying, H.C., 2001. Olympic Cities: Lessons Learned from Mega-Event Politics. *Journal of Urban Affairs*, 23(2), 113-23.

Approved Document L1A, 2010. *Building Regulation, Conservation of Fuel and Power.* sl.: Department of Communities and Local Government, UK.

Barakat, T.A.H., 2009. *A Hybrid Model of Communication and Information Management in Mega Construction Projects in Dubai using a New Critical Success Factor Approach*. Thesis (PhD). Loughborough University.

Building Research Establishment, 2003. *Carbon Dioxide Emissions from Non-domestic Buildings 2000 and Beyond*. BRE: Watford.

Davies, L.E., 2012. Beyond the Games: Regeneration Legacies and London 2012 [online]. *Leisure Studies,* 31(3), 309-337. Available from: http://dx.doi.org/10.1080/02614367.2011.649779 [Accessed 13 October 2014].

DEFRA, 2013. *London 2012 Olympic and Paralympic Games The Legacy: Sustainable Procurement for Construction Projects – A Guide* [online] Available from:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224038/pb13977-sustainable-procurement-construction.PDF [Accessed 15 October 2015].

Ding, G.K., 2008. Sustainable Construction - The Role of Environmental Assessment Tools. *Journal of Environmental Management*, 451–464.

Egan, J., 1998. *Rethinking Construction, Construction Task Force Report for Department of the Environment, Transport and the Regions*. London: HMSO.

European Commission, 2013. *GPP in Practice: Supply of Sustainable Concrete at the London Olympics* [online]. Available from:

http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue23_Case_Study52_Olympics_concrete .pdf [Accessed: 20 October 2014].

Hackney Council, 2013. *Hackney: A Legacy from 2012*. London: Hackney Design, Communication and Print.

Hall, M., Purchase, D., 2006, “Building or Bodging? Attitudes to Sustainability in UK Public Sector Housing Construction Development”. *Wiley Inter Science*, 205–218.

HM Government, 2005. *Securing the Future: Delivering UK Sustainable Development Strategy*. London: DEFRA.

HM Government, 2008. *Strategy for Sustainable Construction*. London, UK: SFC.

HM Government, 2009. *Carbon Plan*. London: DEFRA.

HM Government, 2009. *Climate Change Bill*. London: DEFRA.

HM Government, 2013. *Industrial Strategy: government and industry in partnership*. London, UK: Construction 2025.

International Olympic Committee, 2013. *Olympic Legacy*. March 2013 [online]. International Olympic Committee. Available from:

http://www.olympic.org/Documents/Olympism_in_action/Legacy/2013_Booklet_Legacy.pdf [Accessed 11 October 2014].

Latham, M., 1994. Constructing the Team: Joint Review of Procurement and Contractual Arrangements in the UK Construction Industry. London: HMSO.

LOCOG, 2012. *Final Report of the IOC Coordination Commission*. London: LOGOC.

LOCOG, 2012. *Learning legacy Lessons learned from planning and staging the London 2012 Games*. London: LOGOC.

LOCOG, 2013. *London 2012 Olympic Games Official Report Volume: 3* [online]. Available from: http://www.olympic.org/Documents/Reports/Official%20Past%20Games%20Reports/Summer/ENG/2012-RO-S-London_V3_eng.pdf [Accessed: 15 October 2014].

Myers, D., 2005. A review of construction companies' attitudes to sustainability. *Construction Management and Economics*, 781–785.

Olympic Park Legacy Company, 2012. *Inclusive Design Strategy: Creating Inclusive Neighbourhoods In The Future Queen Elizabeth Olympic Park* [online]. Olympic Park Legacy Company. Available from: http://www.londonlegacy.co.uk/media/Inclusive-Design-Strategy-Jan-2012_reduced-size.pdf [Accessed 17 October 2014].

Rees, W., 2009.The ecological crisis and self-delusion: implications for the building sector. *Building, Research & Information*, 37(3), 300-311.

Rohracher, H., 2001. Managing the Technological Transition to Sustainable Construction of Buildings: A Socio-Technical Perspective. *Technology Analysis & Strategic Management*, 137-150.

Sustainable Construction Taskforce, (2001). Reputation, Risk and Reward: the Business Case for Sustainability in the UK Property Sector. DTI, London.

Thomson, C.S. and El-Haram, M., (2011). Exploring the potential of sustainability action plans within construction projects. In: *27th Annual ARCOM Conference*, Bristol, UK 5-7 September 2011. Association of Researchers in Construction Management, 1085-1094.

Vanegas, J. A., 2003. Road map and principles for built environment. Environmental Science Technology. *American Chemical Society*, 37, 5363-5372.

Yin, R.K., 2009. *Case Study Research: Design and Methods.* Canada: Sage Publications.

TEAM WORKING IN ROAD MAINTENANCE FUNCTIONS FOR SUSTAINABLE CONSTRUCTION IN SRI LANKA

H.G.N. Premakanthi
Department of Building Economics, University of Moratuwa, Sri Lanka

Sepani Senaratne*
School of Computing, Engineering and Mathematics, University of Western Sydney, Australia.

ABSTRACT

Road maintenance is a continuous process that ensures a proper road network with safe and comfortable riding facilities are available to the road users. Among the few research studies on road maintenance, most of them suggest better contractual arrangements to improve road maintenance performance. This paper takes a different stance by looking into the team working aspects of road maintenance teams and suggesting avenues to improve team performance for sustainable road maintenance in general. Literature lacks in discussing how teams perform in road maintenance activities. Hence, the aim of this research was to explore how team working takes place in road maintenance functions and how to improve team-working towards sustainable road maintenance in Sri Lanka. The case study research approach was selected for this study. Accordingly, three case studies with three Executive Engineer's Divisions within the Road Development Authority were undertaken. The findings revealed how maintenance personnel worked as teams during different phases of road maintenance. However, several areas needed improvement as suggested in the paper. These findings will be useful for performance improvements of road maintenance activities in general.

Keywords: *Case Studies; Road Maintenance; Team Performance; Team Working.*

1. INTRODUCTION

Researchers all over the world have highlighted the significance of teams in organisational perspective (Fisher *et al.*, 1997; Mendelsohn, 1998). Many of them explored the nature and function of team working (Peter and Bamberger, 2009), learning capability (Hubber, 1999; Murry; Moses, 2005) and many other qualities of teams. Working as a team in an organisation results in increased productivity (Moses and Stahelski, 1999). Bacon and Blyton (2003) indicated that teamwork has a greater positive impact upon both organisational performance and human resource outcomes.

The concept of "teamwork" is very much appropriate for the construction industry as the construction of a product is a collective effort of professionals (Senaratne and Hapuarachchi, 2009). According to Cornick and Mather (1999, p.5), "construction itself probably generated the earliest examples of team work." Various authors have highlighted the importance of teamwork in construction projects". For example, Danston and Reed (2000) have reported that the improved teamwork among design team reduced design costs. In addition, team building approaches in projects reduce the total project cost (Albense, 1994). Also, Chan *et al.* (2001) have shown that improved team performance in construction projects increased participants' job satisfaction.

The importance of teamwork in construction is not just limited to the design and construction stages. It is equally important in the maintenance stages. Albert (1998) emphasised that if the top-level objectives of the maintenance strategy are to be accomplished, they ought to be cascaded into team and individual goals. However, as Albert (1998) showed, the effectiveness of the maintenance function has become a major management issue.

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

In particular, the effectiveness of the road maintenance function has become a major management issue (Richard *et al.*, 2000) as road maintenance is an essential activity (Oliver, 2002; Klockow and Hofer, 1991). For example, well-maintained roads support national and local economies by ensuring that freight and businesses can move efficiently and safely (Guptha, 2008). Further, the way of life now depends substantially on the availability of the road networking. Also, various acts of Parliament place legal obligations on road authorities to maintain their roads in a safe condition, and to ensure that maintenance operations are carried out safely.

Typically, the road maintenance function is perceived to be confined to the tactical role of maintaining, servicing and fixing facilities already in place. With such a perception, road maintenance is often regarded as an expense account and a popular target for cost reduction programmes. Although the budgets for these maintenance activities are planned prudently, based on the engineer's estimate, changes usually occur in the work plans after the maintenance work starts (Shrestha *et al.*, 2014). Albert (1998) revealed that maintenance is not only a tactical matter, but also it has a strategic dimension covering issues such as design of facilities and their maintenance programmes, upgrading the knowledge and skills of the workforce, and deployment of tools and manpower to perform maintenance work. It was noted that recent research on road maintenance focuses on suggesting alternative contractual arrangements (for example see, Lam and Gale, 2014; Costello *et al.*, 2014; Shrestha and Shrestha, 2014) rather than the internal team performance. A maintenance team generally performs this maintenance task. However, less evidence found in literature emphasising teamwork issues of such maintenance teams, particularly, in road maintenance teams. Identifying this research gap, the key research question that this study addresses is “How team working takes place in road maintenance functions?” The literature findings related to this question are discussed next.

2. KEY FINDINGS FROM THE LITERATURE

2.1 THE CONCEPT OF MAINTENANCE

Various authors have explored their ideas regarding the concept of maintenance in management literature. Among those authors, Liyanage and Kumar (2003) have explained the evolution of maintenance concept. Accordingly, prior to the early 1900s, maintenance was considered as a necessary evil. When technology was not in a state of advanced development, there was no alternative for avoiding failure, and the general attitude to maintenance was, “it costs what it costs.” With the advent of technological changes and after the Second World War, maintenance became as an important support function for production and manufacturing. During 1950-1980, with the advent of techniques such as preventive maintenance and condition monitoring, the maintenance cost perception changed to: “it can be planned and controlled.” Today maintenance is considered as an integral part of the business process and it is perceived as: “it creates additional value” (Liyanage and Kumar, 2003). However, maintenance is normally perceived to have a poorer rate of return than any other major budget item.

Many authors have defined maintenance in management literature. According to European Standard EN 13306, maintenance is defined as the combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore it to, a state where it can perform a required function. In this sense, a combination of generic maintenance activities or actions that are repeated and transforms input into output may be seen as a maintenance process (Campbell and Jardine, 2001). Hence, the repetitiveness is an important characteristic of the maintenance process, since it distinguishes the process from a project or a linear description of cause and effect without any feedback (Soderholm *et al.*, 2007).

The maintenance process can be related to the four phases of the common Deming’s Improvement Cycle (Plan-Do-Study-Act) as follows: Maintenance Planning (Plan), Maintenance Execution (Do), Functional Testing (Study), and Feedback (Act). In the Maintenance Planning phase, several inputs such as information about the health of the current system and maintenance documentation are needed to prepare the maintenance plan. In the Maintenance Execution phase, main input is the maintenance plan while maintenance environment, maintenance documentation, and the actual availability of time, personnel, and resources are all needed for successful execution. The purpose of Functional Testing is to test the function of an item, in relation to some requirements. Functional Testing may be performed continuously, or periodically during scheduled checks, in order to establish the current health of the system and the actual need for maintenance. The Feedback after execution phase should pass mainly from Functional Testing to Maintenance Planning and Maintenance Execution phases. In all these phases, a team of personnel perform the required maintenance tasks and the next section explores the concept of team in maintenance.

2.2. TEAM WORKING IN MAINTENANCE

Various researches have defined the term "team" in various ways. Amongst these definitions, the following given by Katzanbach and Smith (1993) is the one commonly cited: "a team is a small number of people with complementary skills, who are committed to a common purpose, performance goals and approach for which they hold themselves mutually accountable". Teams and teamwork is an area long being studied in different context and fields. However, there are very few attempts on studying teams in maintenance context.

Hambleton (cited Knapp and Mahajan 1998) developed a manpower-planning model for maintenance personnel considering different maintenance areas for forecasting the maintenance team, such as areas (technical and/or geographical), craft-type (fitter, welder, etc.), training levels (experience), and sub-contracted and in-house employees. This can be taken as one way of categorising different teams in maintenance.

In addition, maintenance teams can be described as permanent teams. Panteli and Dibben (2000) explained about permanent teams in maintenance against the most common temporary teams. The notion of a permanent team describes the situation where there is continuity in the membership of the group; that is, where a particular group of people regularly addresses ongoing issues such as maintenance (Townsend *et al.*, 1998). This is different to a temporary team, which is characterised by discontinuity, exists only to accomplish a specific task, and then disassembles. On the other hand, maintenance teams can be regarded as self-managed teams, as they have day-to-day responsibilities and take action on their problems (Appelbaum, 1999). When the skills, talents and energy of individuals are combined and weaknesses mitigated, then the team members find the key to maximum productivity. However, there is a dearth of literature, which explores team working in maintenance.

As per general management literature, several key features were identified that applies to maintenance teams. In management literature, Crocker (1999) has explored about the human nature in maintenance, "Humans, alas, are fallible. They have emotions, get tired, lose concentration and become distracted." Hence, leadership is not an exception in maintenance activities. Similarly, communication plays a key role in team working of any teams. In addition, Knapp and Mahajan (1998) highlighted the need to have the right number of workers with the right capabilities in the right maintenance areas in maintenance jobs. Thus, team composition and their capabilities are two key aspects that relate to better team performance. Further, the importance of trust in holistic and middle management is emphasised and is seen as very relevant to maintenance teams. According to Hartenian (2003), team training and experiences positively correlate with team knowledge, skills and abilities in maintenance team. In fact, as Bamber *et al.* (2002) argue, modern maintenance engineers are expected to contribute to the continuous improvement of operations in working teams.

In summary, even though the importance of project teams are discussed by various authors in the past, the function of teams involved in road maintenance and the performance of road maintenance teams have not appreciated sufficiently in the management literature. It is important to understand how they work as teams in real-life scenarios. Identifying this research gap, road maintenance teams operating in Sri Lanka was chosen for this research as described next.

3. RESEARCH METHODOLOGY

According to Easterby-Smith *et al.* (2002), 'Interpretivism' is one key research philosophy, which believes that the reality is subjective and interior to the people. When considering the research question of this research, it is obvious that this study needs a vigilant observation of human interactions and behaviours. This particular issue forces the researcher to assume that the reality, which the research problem seeks, is within the people. Hence, interpretivism research philosophy was adapted in this research.

A suitable research approach had to be selected to deal with the research problem, after defining the research philosophy. The research problem in this study is "how the teams perform in road maintenance functions in Sri Lanka." According to Yin (2003), the case studies are appropriate when the research problem is "how" and "why" type of questions. Yin (2003), further stressed that the case studies can be very useful when little is known about a particular phenomenon. In this research, too, the knowledge on the research area is very little or almost nil, due to scarcity in maintenance related teamwork research. Hence, case study approach was selected for this research study.

The cases (road maintenance teams) were selected from the Road Development authority (RDA) only, because the RDA is the major functional road maintenance organisation in Sri Lanka, which operate island-wide. Moreover, the composition of the maintenance team varies based on the maintenance methods adopted. Therefore, this study is focusing on roads only. Direct labour system is the most popular method in carrying out road maintenance in Sri Lanka. In this, an engineer will take a lead role while a number of other personnel such as Technical Officer (TO) and Technical Assistant (TA) involve in the management team. In addition, there are work supervisors (WS) who directly supervise labour gangs. These personnel together belong to one Executive Engineer's (EE) division. Three such teams were selected from RDA. Interviews were conducted with three key participants of each team; namely, Executive Engineer, Technical Officer (TO) and Technical Assistant (TA). A brief description about the selected three cases is given in Table 1.

Table 1: Brief Description about the Selected Cases

Case	Case A	Case B	Case C
Type	Road maintenance team in RDA-Western province	Road maintenance team in RDA – Southern province	Road maintenance team in RDA – Sabaragamuwa province
Number of km	171 km	287km	273km
Number of Depots	4	3	3
Number of Members	EE - 01 TOs - 04 TAs. - 04 WSs - 11	EE - 01 TOs - 04 TAs. - 08 WSs - 12	EE - 01 TOs - 01 TAs. - 02 WSs - 10
Number of Labours	**100**	**172**	**106**

The interview data were then mapped though cognitive mapping concepts to draw conclusions. These case study findings are presented and discussed next.

4. RESEARCH FINDINGS

Initially, the empirical phase looked into the four maintenance phases and how members work as a team in each phase, starting from the planning phase. The Road Maintenance Manual (Road Development Authority, 1989) highlighted that the Executive Engineer is the key person responsible for the planning, programming, organising and carrying out all operations on road maintenance. However, in the studied cases all key participants act as a team in the planning stage. For example, the Executive Engineer of the Case C stated, "*I personally think that teamwork is very important at the planning stage, because we have limited funds and resources. Hence, we have to select priority items considering the urgency of attending. For that, we have to discuss each and every item. Then only we can perform well*". This was the case in the execution phase too. Most of the members who were interviewed in the study were in the road maintenance teams for many years and they were well experienced. Almost all the interviewees believed that the team is a must at the execution phase of road maintenance works.

Road maintenance should be carried out while the service is provided to the users. Therefore, testing of work done is carried out at the same time of execution of work. The Technical Assistant of the Case A explained this, "*most of the time, road maintenance works are tested during the execution. So TO, TA and WS who are at the execution are involved for this testing. EE will involve later to confirm the work is in order.*" Hence, it cannot be seen as a team activity fully. Similarly, the interviewees viewed that feedback is a two-way process rather than a team activity. The Technical Assistant of the Case A mentioned, "*feedback of our team is in moderate level. However, feedback is essential because team members can understand the success level of the work they have done through feedback. Team members always seek team leader's feedback after most of the work*." The Executive Engineer in Case A further indicated, "*in my team feedback level is very good up to Technical Assistant level. However, Work Supervisors are not skilled enough for that. However, the member's feedback is essential for the maintenance work.*" Hence, it is apparent that both parties (leader and subordinate) are expecting feedback from each other's.

Next, the empirical study looked into team working features in the selected road maintenance teams as discussed next.

Team Composition -Teams studied were quite similar in terms of team composition but vary in size. As per the Executive Engineer in the Case A, "*team consisted of various people who are normally involved in road maintenance activities. My present team consists of Executive Engineer, Technical Officers, Technical Assistants, Work Supervisors and maintenance labourers. This composition is ideal for road maintenance works*." In some Executive Engineer's Divisions, there is an additional Engineer to help EE, due to the physical spread of the area under the EE's Division. For example, EE's office in the Case B is 106 kms away from the boundary of the EE's Division. Therefore, to avoid management difficulties, one additional Engineer was allocated. Also, Case B comprised of several TOs to assist the team as some of the non-maintenance works were also assigned to them such as road improvement works.

The empirical study has identified that the road maintenance teams are of varying team sizes. Cases, which were selected in this study, consisted of varied number of team members in both supervisory level and labour level. Case A and Case B have higher number of members in those teams in supervisory level where as, Case C has less number of members in the team. Executive Engineer in Case A noted, "*Actually the size and the structure of the teams are highly influenced, when attending the wide range of scheduled activities. As far as this team is concerned, the structure is ok but the size is not enough. Due to the less attendance of labour less output can be gained*." In Case C, in which the team size is further less in labour level, its Executive Engineer indicated that the number of labourers in his team should be increased.

Capabilities of the Team - The empirical data disclosed that in road maintenance teams, the capability of team is significantly governed by the competencies and skills of each member. For example, the Executive Engineer of the Case C indicated, "*individual's capability is very important as road maintenance is a hardworking activity and skill is also required. But in some areas, we cannot get required skills as expected because some team members are not interested to develop their skills*." Capabilities are important in urgent situations, for example, the Executive Engineer in Case B indicated, "*relevant to the work to be carried out, there should be at least one capable man to do it. If there are no skilled personnel we have to hire people*."

Leadership within the Team - All the members in the case studies perceived Executive Engineer as the team leader of the team. Most of the interviewees stated that the Executive Engineer as the team leader who coordinated the day-to-day activities, overlooked and supported well for the successive performance of road maintenance. However, it was found that their leadership role is significantly governed by the organisational conditions. For example, the Technical Officer in Case B indicated, "*Team leader and the team have to follow all the financial and administration regulations and conditions, which were declared by the parent organisation. Therefore, there are conditions and limits when implementing the maintenance activities. For procedures of maintenance, we have to follow the guidelines of the RDA specifications. However, some freedom is there within the above limits.*" Therefore, it is evident that in road maintenance teams, the leader's role was controlled by the organisational conditions up to some extent and hence, the importance of the leadership role on team performance is affected.

Trust within the Team - Generally, teamwork was seen between members. Executive Engineer of Case A further described, "*I think, members do well in their teamwork, because they help each other when one has more work, interchange materials if the other do not have them and so on.*" Trust was highly regarded in road maintenance teams. Supporting this statement, Technical Officer of Case C stated that "*To develop the maintenance performance, trust between individuals is important, because the team is dispersed and most of the works are material related works. If there is no trust, some malpractices can occur.*" It was observed that Executive Engineer as team leader of road maintenance teams intervened to develop trust between team members, as the parent organisation has no proper mechanisms. Technical Officer in Case A confirmed this, "*actually the team leader is fully devoted to improve trust between team members. He always arranges some social entertainment activities among team members. Through that he believes to improve trust.*" Technical Officer of Case C stated, "*trust cannot be artificially built-up. It should be developed in individual's mind emotionally based on the behaviour of another party*." Hence, leader's qualities and the behaviours had significantly affected building trust between the team and the leader.

Team Communication - Case study findings showed how lack of proper communication mechanisms affected road maintenance activities in certain urgent repairs. This was made further difficult due to geographically dispersed setting. The Technical officer of Case B stated, "*our team, most of the time, dispersed within some considerable area under road maintenance, which is not like other machine or building maintenance. So the communication is quite difficult.*" However, interviewees agreed that they generally followed the proper channel of communication. Almost all the members highlighted that the behaviours and attitudes of team members affect communication within the road maintenance teams. For example, age of the members, educational background and family background found to have an effect on how they communicate, especially when extending to labourer's level.

Training and Development - The teams highlighted this area as needing attention. Most of the members who were interviewed in this study have positive interest to participate in training programs, but the parent organisation had not paid much attention to arrange field-training programs at least for the Executive Engineers. Due to the unavailability of Executive Engineer camps, they do not have opportunity to discuss their problems and achievements. Therefore, there is lack of consistency between EE's divisions in terms of procedures and policies. Thus, different divisions face a similar problem in different ways. Therefore, the need for keeping past records and sharing experiences were highlighted by the empirical study. All above findings are summarised in Figure 1 to depict holistically the key findings from the case studies. The next section put forth key conclusions of this study.

5. CONCLUSIONS

The aim of this study was to explore how team working takes place in road maintenance functions and how to improve this towards sustainable road maintenance in Sri Lanka. This was approached through studying three case studies from Road Development Authority in Sri Lanka. The empirical findings revealed that the process of road maintenance is fairly a cyclical process where maintenance execution and functional testing phases are overlapping. Even though, the process of road maintenance was carried out by teams, there were some phases such as planning and functional testing where not all the members needed to involve. However, it was noted that the key members were involved, in particularly at the planning phase. Further, it was also evident that the team involvement is necessary in the execution phase.

Team members in road maintenance teams depicted good team working especially in emergencies. It was evident that in the selected road maintenance teams, even if they do not have enough members, at emergencies, they could manage such situations favourably due to collective efforts. Generally, these teams were quite similar in team composition with very few key members at the supervisory level. Even though, the Executive Engineer was considered as the leader of the team, his role was significantly governed by the organisational conditions and regulations. Nevertheless, most of the leaders have taken efforts to play their role to enhance team performances by supporting, coordinating, facilitating and keeping good relationship with members. To this extent, building trust within the team was highly regarded by the leaders and the other team members. In terms of communication, despite fewer facilities most of the teams followed proper channels. Team dispersion was seen as the most influential barrier while age, educational and family backgrounds also affected communication within road maintenance teams. Further, lack of field training was highlighted by the case study participants and need for consistency in terms of practices and procedures in between different maintenance teams within the same organisation.

Based on above key findings following can be recommended for better team working practices in road maintenance activities. It is also important for the road maintenance team leadership to be knowledgeable about the process of road maintenance and determine what type of resources and support will be required to the team based on the specific challenges faced in each phase. Support from organisation level for team building activities is seen as important as individual teams and leaders are conditioned by organisation rules and policies. In particular, more opportunities for knowledge sharing are important, as there was less connection between different teams who encounter similar problems. To this end, recording lessons learned and wider dissemination of these at organisational level and knowledge building though training and development are also highly relevant. Hence, future studies could look into knowledge sharing opportunities between different road maintenance teams

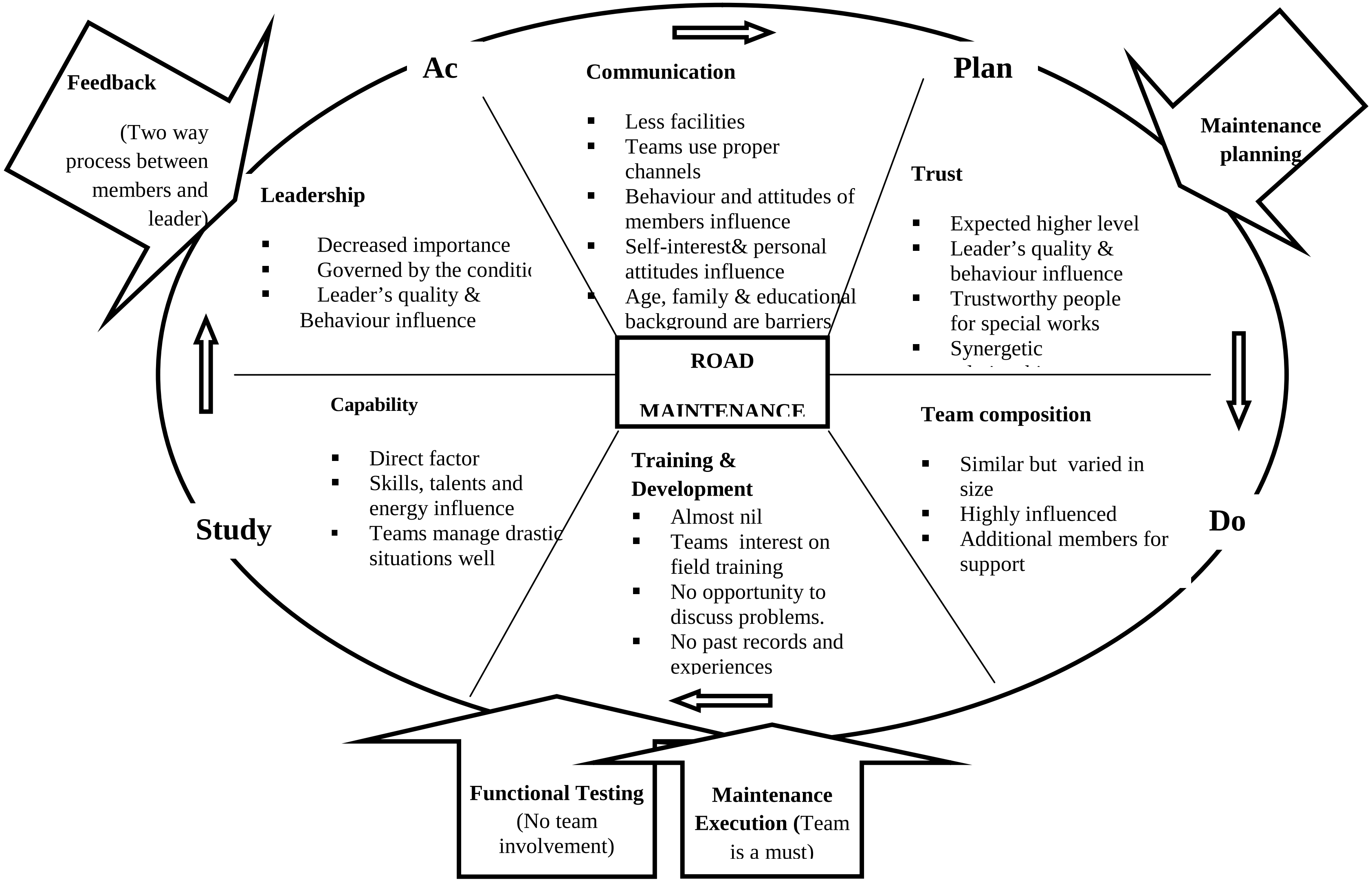


Figure 1: Road Maintenance Team Performance Process Based on Case Studies

6. REFERENCES

Albense, R., 1994.Team Building Process Key to Project Results. *Journal of Management in Engineering,* 10(6), 36-44.

Albert, H.C. and Tsang, 1998. A Strategic Approach to Managing Maintenance Performance. *Journal of Quality in Maintenance Engineering*, 4, 87-94.

Appelbaum, S. H., Rethune, M. and Tannenbaum, R., 1999. Downsising and the Emergence of Self- Managed Teams. *Participation and Empowerment; An International Journal*, 7(5), 109-130.

Bacon, N. and Blyton, P., 2003. High Road and Low Road Team working: Perception of Management Rationales and Organisational and Human Resource Outcomes. *Human Relations*, 53(11), 1425-1458.

Bamber, C., Sharp, J. and Hides, M., 2002. The Role of The Maintenance Organisation in an Integrated Management System. *Managerial Auditing Journal*, 17(½), 20-25.

Campbell, J.D. and Jardine, A.K.S., 2001. *Maintenance Excellence: Optimising Equipment Life-Cycle Decisions*. New York: Marcel Dekker.

Chan, A.P.C., Tam, C.M. and Ho, D.C., 2001.Effect of Inter organisational Teamwork on Project Outcome. *Journal of Management in Engineering*, 17(1), 34-40.

Cornick, T. and Mather, J., 1999. *Construction Project Teams: Making Them Work Profitably*. London: Thomas Telford Publishing.

Costello, S. B., Smith, N. E., Henning, T. F. P. and Hendry, M., 2014. Towards Measuring Road Maintenance Efficiency and Effectiveness in Local Authorities. *Road and Transport Research: A Journal of Australian and New Zealand Research and Practice*, 23(2), 3-14.

Crocker, J., 1999, Effectiveness of Maintenance. *Journal of Quality in Maintenance Engineering*, 5(4), 307-313.

Danston, P.S., and Reed, A.G., 2000. Benefits of Small Projects Team Initiative. *Journal of Construction Engineering and Management*, 126(1), 22-28.

Easterby–Smith, M., Thorpe, R. and Lowe, A., 2002. *Management Research: An Introduction*. London: Sage publications.

Fisher, S.G., Hunter, T.A. and Macrosson, W.D.K., 1997. Team or Group? Managers' Perceptions of the Differences. *Journal of Managerial Psychology*, 12(4), 232-242.

Guptha, D.P., 2008. Maintenance Management Tools for Rural Roads. In: *PIARC Seminar on Road Asset Management*, Chandigarh, India 19-21 March 2008.

Hartenian, L.S., 2003. Team Member Acquisition of Team Knowledge, Skills, and Abilities. *Team Performance Management*, 9(1/2), 23-30.

Hubber, G. P., 1999. Facilitating Project Team Learning and Contributions to Organisation Knowledge. *Creativity and Innovation Management*, 8(2), 70-76.

Katzenbach, J.R. and Smith, D.K., 1993. The Discipline of Teams: What Makes the Difference between a Team that Performs and One that Doesn't?. *Harvard Business Review*, 11-20.

Klockow, S. and Hofer, W., 1991. Improvement of Road Maintenance Practices in Developing Countries, *Transportation Research Part A*, 25(2-3), 113-120.

Knapp, G.M. and Mahajan, M., 1998. Optimisation of Maintenance Organisation and Manpower in Process Industries. *Journal of Quality in Maintenance Engineering*, 4(3), 168-183.

Lam, T. and Gale, K., 2014. Highway Maintenance: Impact of Framework Agreements on Contractor Performance. *Engineering, Construction and Architectural Management*, 21(3), 336-347.

Liyange, J.P. and Kumar, U., 2003. Towards a Value-Based View on Operations and Maintenance Performance Management. *ournal of Quality in Maintenance Engineering*, 9(4),.333-350.

Mendelsohn, R., 1998. Teamwork Key to Productivity. *Journal of Management in Engineering,* 18(4), 22-25.

Murry, P. and Moses, M., 2005. The Centrality of Teams in the Organisational Learning Process. *Management Decision*, 43(9), 1186-1202.

Moses, T.P. and Stahelski, A.J., 1999. A Productivity Evaluation of Teamwork at an Aluminum Manufacturing Plant. *Group and Organisation Management*. 24(3), 391-412.

Oliver, J.E., 2002. *Highways.* 4th.ed. London.

Panteli, N. and Dibben, M.R., 2000. Repositioning Interpersonal Trust within Virtual Teams. In: *10th Annual Conference of Business Information Technology Management: E-Futures*, Manchester 1-2 November 2000.

Peter, A. and Bamberger, 2009. Team –Based Reward Allocation Structures and the Helping Behaviors of Outcome – Interdependent Team Members. *Journal of Managerial Psychology*, 24(3), 239-251.

Richard, C.M., Peter, T.S.E., Ling, L. and Francis, F., 2000. Enhancement of Maintenance Management through Benchmarking. *Journal of Quality in Maintenance Engineering*, 6, 224-240.

Road Development Authority, 1989. *Road Maintenance Manual*. Baththaramulla, Sri Lanka: Ministry of Highways.

Senaratne, S. and Hapuarachchi, D.U.A., 2009. Construction Project Teams and their Development: Case Studies in Sri Lanka. *Architectural Engineering and Design Management*, 5, 215-224.

Soderholm, P., Holmgren, M. and Klefsjo, B., 2007. A Process View of Maintenance and its Stakeholders. *Journal of Quality in Maintenance Engineering*, 13(1), 19-32.

Shrestha, K., Shrestha, P. and Kandie, T., 2014. A Road Maintenance Management Tool for Rural Roads in Kenya. *Construction Research Congress 2014*, 289-298.

Shrestha, P. and Shrestha, K., 2014. An Evaluation of Current Practices of Road Maintenance Contracting Methods. *Construction Research Congress 2014*, 1408-1417.

Townsend, A.M., Demarie, S.M. and Hendrickson, A.R., 1998.Virtual Teams: Technology and the Workplace of the Future. *Academy of Management Executive*, 12(3), 17-29.

Yin, R.K., 2003. *Case Study Research: Design Method.* 3rd ed. London: SAGE Publications Ltd.

THE LEGAL FRAMEWORK FOR DESIGN LIABILITY IN BUILDING INFORMATION MODELLING

Thilina Laksiri Dissanayake*, Himal Suranga Jayasena and Mahesh Abeynayake
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Building Information Modelling (BIM) is a solution to achieve productivity, efficiency, life cycle enhancement and sustainability in the construction industry. It also promotes the two symbiotic factors information sharing and collaborative approach among the professionals. Transference from the conventional practice to BIM will make the design liabilities change and create legal uncertainties among the professionals. This was expected to be acting as an obstacle to achieve the desires in BIM's wider adoption and a suitable legal framework was found to be necessary. The solutions for the legal uncertainties arising from the new environment needs to be formulated and on the other hand in order to adopt BIM in an effective manner it requires identifying of these legal uncertainties and provides a clear vision for the client and the design team on how they should work in the changed environment. With this prime intention, this research was conducted adopting mixture of legal and scientific research methods. Initially preliminary literature synthesis was carried out which discussed the present legal environment with the expected change through BIM. The legal analysis was carried out following the flexible iterative style where the researchers' opinion blends with the experiences from primary sources of law to build up the tentative hypothesis. Through semi structured interviews with a group of experts representing different proficiencies in the construction industry, this tentative hypothesis was tested; the collected data from construction industry experts were subjected to content analysis based on opinions and suggestions, these findings were then interpreted to identify the suitable legal framework. The legal framework which was identified includes the preventive mechanism of negligent acts, liabilities of the human factor, process and enforceability, actions, proposed provisions and suggestion. Hence, this framework is recommended to be implemented in the BIM environment.

Keywords: *Building Information Modelling (BIM); Construction Industry; Design Liability.*

1. INTRODUCTION

Building Information Modelling (BIM) is gaining its popularity in the construction industry as the latest innovation where the project team members are to work in a common platform. While working in such environment the possibility of legal uncertainties arising are high, particularly in terms of design liability. These legal concerns in fact are a reason for the reluctance of BIM adoption. The research study presented in this paper aimed to identify the legal framework for BIM's wider adoption.

2. BACKGROUND

The construction industry is being transformed by the Information and Communication Technology (ICT) which has the capability to provide better information to create cooperation between team members in a productive manner (Williams, 2007). BIM tools brought novel approaches that changed the way the Architecture Engineering Construction (AEC) industry is working and it enhances the collaboration among project team (Weygant, 2011). Different stakeholders have different uses of BIM and with it they get the capability of analyzing and predicting outcomes throughout different phases (Reddy, 2012).

BIM implementation is a social act and it is not just loading and running of a software (Deutsch, 2011), with the problems of the computer software, it will lead to unexpected results if the required information

* Corresponding Author: E-mail-thilinal,dissanayake@gmail.com

is not provided on time by all the participants (Jayasena and Weddikkara, 2013). Furthermore, Succar (2008) expressed that BIM policy is one of the interlocking BIM fields of activity which has to interact with the technological and process fields for a successful BIM framework. Even when developing a non proprietary interoperable schema like Industry Foundation Classes (IFC) will require policy field to identify "rules for decision making" while interacting with the technological Field of BIM.

When BIM level changes from team creating their own model to where all team members can access, the legal relationships will change, thus will occur legal uncertainties which needed to be answered in order achieve the original goal of BIM (Glover, 2013). Meanwhile, Wickersham (2009) explained that in addition to the legal concerns in the non BIM construction industry, other technological and policy issues inherent to BIM platform will affect the workflow once BIM is implemented and that these legal questions need to be remedied soon before it affects the future projects.

3. RESEARCH METHODOLOGY

The philosophy for the research included in this paper, was identified to be more towards the social-constructionism and the research approach was identified to be the qualitative inductive approach. Firstly the literature review was carried out using law texts and research articles to identify the legal environment which affects the delivery of construction projects. Here it was focused only on law of torts (professional negligence, contributory negligence, and vicarious liability). Thereafter, the tentative hypothesis was built based on a legal perspective where the general legal research methodology of analyzing the statutes in legislation and case laws was adopted. The research process was followed by the semi standardized open ended interviews with the experts with the priori codes developed by the tentative hypothesis. Moreover, appropriate data analysis method was found to be content analysis using Nvivo software and followed up by qualitative analysis to identify the suitable legal framework.

4. THE LEGAL ENVIRONMENT

A legal environment is established to ease the workflow and bring professionals with different mindsets to exist without affecting their counterparts in the construction project delivery. The parties to fulfilling certain obligation to another need not necessarily be agreed upon by a contract, but they hold a social responsibility to perform their duties with due care. Following is a brief of the legal environment where the design team has to work.

4.1. THE DESIGN TEAM IN THE LEGAL ENVIRONMENT

In the construction village client is expected to protect the design team values (Russell, 2006) but they are still in a quest and in expectation that design team will fulfil their non expressed feelings as well (Kamara *et al.*,2002). On the other hand Bender and Septelka (2002) was in the view that design team has to work with team qualities and with an encouragement for cooperation. The duties of the design team are defined in legislation and by case laws. Moreover they have to adhere to the expectations, otherwise as Bender and Septelka (2002) mentioned not only disputes will arise, but it will also create an unpleasant environment where the project can no longer continue.

4.2. LIABILITIES OF THE DESIGN TEAM

Designing is an iterative process with incessant refinements and this is because of the changing mind of the client and the designer(s) (Tolson, 2007). These changes do affect the construction and create conflicting situations. Therefore, it is necessary to determine the category where the problem fits in so that the legal ramifications become clearer (White, 2008).Holyoak (1992) stated that "negligence" and "carelessness" are too broad categories to form a meaningful legal discussion. It is necessary to decide whether the defendant is proved guilty on the three sub- division's duty of care, breach of duty and damages (Donoghue v Stevenson, 1932).

4.3. BIM AS AN ADVANCED OVERWRITE

In an instance where construction is the slowest to advance in technology of all other fields (Bock, 2014), BIM will act as technological catalyst which changes the construction industry with productivity and efficiency while giving recognition to the information of the facility in addition to the facility itself (Jordani, 2008). BIM is a process change rather than a technological change where the documentation is also done in a virtual format and used in the traditional construction process. Succar (2008) in his implementation framework suggested that technology, process and policy fields needs to interact and knowledge transference among these fields is essential for a conflict free delivery of a facility. His framework was also in suggestion that the liabilities of the BIM players will change and with this influence and thus necessary policies need to be developed.

4.4. IMPROVEMENT OF COOPERATION AND COLLABORATION

The increasing diversification and complexity of construction projects requires trust between different project partners and cooperation and coordination, and to achieve this optimization the information systems established has to facilitate the sharing of diverse types of information not only accurately but in a timely manner (Anumba *et al.*, 2008; Maunula, 2008). When BIM exceeds the existing practice in terms collaboration and communicating different characteristics there should be a process of documenting (Lee, 2008). According to Nemtschek Vectorworks (2014) the collaboration between parties are restricted by the lack of coordination, lost of information during data conversion, misinterpretation, limited utilization of building data created by others, other coordination issues and lack of detailed model for construction.BIM enables a situation where the workflow has to change for it to be properly implemented (Hardin, 2009). The new streamlined project delivery is an integrated system and the design liabilities will increase with the design phase extends till the construction phase (American Institute of Architects, 2007).

4.5. THE HUMAN AS A DRIVING FORCE IN BIM

With the implementation of BIM, it is necessary to manage the model and assign authority to access the model and ensure that the data entered is well structured to avoid conflicting situations. This new position is referred to as a BIM manager where he is expected to manage information process more than the design coordination. With the creation of special duties with BIM it is understood that the human factors is the most vital, when implementing BIM the people-oriented factors are the greatest challenge than solving the software, business or technical problems of BIM (Deutsch, 2011). Even then there is a high risk in sharing of the BIM model due to mistakes and misunderstandings of the collaborating design team (Autodesk, 2008). The working mindset is divided into two as lonely BIM and Social BIM (Tocci, 2008). Social BIM is the mindset to be achieved not only to provide benefit but to enhance collaboration with team members. It was clearly identified that sharing of information and collaboration of professionals are symbiotic factors in BIM which differentiates it with the conventional practice. Therefore it was concluded that change in legal position is evident with the implementation of BIM and need to be remedied.

5. THE ANALYSIS OF LAW WITH THE CHANGE IN SCENARIO

It was identified in the tentative hypothesis that original liabilities of the traditional practice exists but it may change with the BIM environment and assigning of new roles. When it comes to the professional negligence it is strict in BIM due to the virtual creation of the model depends on a collaborative workflow. Therefore, the designers are expected to have an understanding of the information behaviour in the model. In the BIM platform contractors can also be considered as liable for contributory negligence with their involvement with the project from the inception stage. Furthermore, for the legal issues at construction will be an error due to the professional negligence of the contractor, even if it would be a design error of the design team according to contributory negligence their claim will get reduced.

Since BIM manager and coordinators hold the strategic and management level of BIM they have to be aware of the fact of vicarious liability, the designer(s) fault will be BIM management team's vicarious fault as they too owe a reasonable duty of care over the design. BIM also has to answer the joint liability for the matter of fact client seeks legal service for the negligence of the design team. It becomes much complicated in a BIM environment where a faulty design can paralyze the flow of the project. The case become even worse since the level of responsibility is not clear in the BIM platform. The preventive remedy for the complication is to keep records on the level of responsibility and keep the design team informed on what is expected by them.

The tentative hypotheses derived from the legal analysis mentioned above were converted to priori codes as given in the table 1 below.

Table 1: Priori Codes from Tentative Hypothesis

Area of Law	Acts and Case Law	Priori Codes by the Tentative Hypothesis
1. Design Liability And Professional Negligence	Hedley Byrne & Co Ltd Vs. Heller & Partners Ltd (1964) Caparo Industries plc Vs. Dickman (1990) Greaves & Co (Contractors) Ltd Vs. Baynham Meikle and Partners (1975)	1-1 Negligent conduct and awareness in decision making. 1-2 Casual replies and mis interpretation. 1-3 Adhering to professional definitions of duty of care.
2. The Contributory Negligence	The Law Reform (Contributory Negligence) Act 1945 (UK) Forsikringsaktieselskapet Vesta Vs. Butcher and Others HL (1989) Barlays Bank Plc Vs. Fairclough Building Limited (1994)	2-1 Negligent act by the injured party
3. Vicarious Liability	Hewitt Vs. Bonvin (1940) Morgans Vs. Lunchbury (1973) Gomien Vs. Wear-Ever Aluminum, Inc., (1971) Morren Vs. Swinton and Pendlebury Borough Council, (1965) Lister Vs. Romford Ice and Cold storage Co. Limited (1957)	3-1 Test of right of control and delegation of authority. 3-2 Position of the employee or the design team 3-3 Selection of professionals and their conduct
4. The Joint and Several Liabilities	Civil Liability (Contribution) Act 1978 (UK,1978) Zimmer Vs. City of Milwaukee (1992)	4-1 Level of responsibility 4-2 Law of tort and breach of contract.

6. THE TESTING OF THE TENTATIVE HYPOTHESIS

The tentative hypothesis was tested with 12 experts from the construction industry. The selection of the experts was done based on the knowledge they possessed on construction law and/or arbitration and/or BIM. Approximate average experience was 25 yrs/ Expert, 4 of them had knowledge on Construction Law, 9 of them had experience as arbitrators and 7 of them had knowledge about BIM, its process as researchers and as BIM professionals.

During the analysis, it was found that experts had expressed their views as general opinions and BIM specific opinions. Similar value had to be given for both, since general opinions cannot be set aside since a new introduction always has to be compared with the existing when identifying a suitable legal framework. The main understandings of the experts were that it is necessary to facilitate the BIM environment, so that the errors are reduced rather than making a strict rule over the design team. Out of the opinions a legal position was also found to be important since the premier intentions of BIM, information sharing and collaboration cannot be achieved without a smooth work flow. Additionally, fruitful suggestions were received which were also found to be of immense importance for the identified legal framework.

7. THE IDENTIFIED LEGAL FRAMEWORK FROM THE ANALYSIS

The identified legal framework will be as in the Figure 1 below, human factor will drive this framework. As they try to work in the BIM environment issues will arise and that has to be processed and identified to which category it falls into. Accordingly, actions will be taken and the decision will be evaluated. Originally formulated suggestions and new improved areas can be fed into the BIM environment and the decision making process to achieve the intended objective.

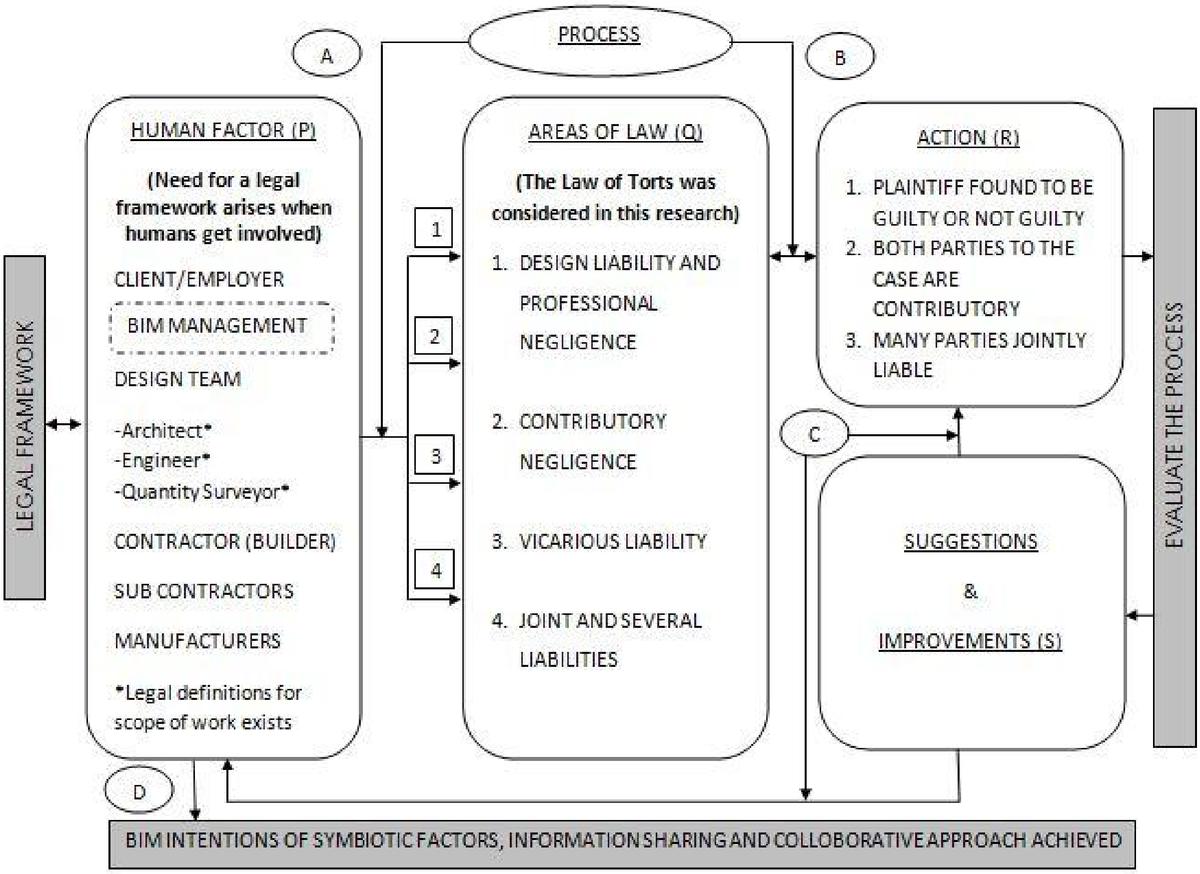


Figure 1: The Identified Legal Framework

7.1. *THE HUMAN FACTOR IN THE BIM ENVIRONMENT*

Human factor is considered as the drivers of this proposed legal framework, and following table 2 below will be the deductions in relation to the rounded rectangle names as "P".

Table 2: The Human Factor in The BIM Environment

Legal Person	Explanation
Client/ Employer	Expected to be an expert client and has to be aware of the process and his responsibility for the final output will increase.
BIM management	Has to take the overall responsibility of the model and his liability would be to facilitate the design team with the BIM environment and ensure the smooth run of the overall project.
Definitions of design team	Will not change with the original definitions, same liabilities of the traditional context will apply
Contractor	Same in the traditional context will apply, additionally contractor in the BIM environment has to provide with construction details to the design team.
Sub contractors/ sub consultants	They have to be included in the model and the same conditions to the main contractor shall apply. They will hold equal liability for the final output.
Manufacturers/Suppliers	A Construction Business Model has to be created to retrieve the best manufacturer, but it has to be done by the contractor not the design team. Manufacturers in the BIM environment will hold liability to the extent of what their warranties mentioned.

7.2. PROCESS AND ENFORCEABILITY

Process and enforceability as depicted in oval named as process, will cover how each party is made liable and process of decision making for the wrongful actions they do. Oval "A" will represent the connector between human factor and the areas of law. This connection will be further described by the squares 1-4 and will cover the different viewpoints of the analyzed four areas of law which will make the human factor in the BIM environment liable. Oval "B" will represent the two way connector indicating the decision making process, and the process of feeding to the areas of law in the form of case laws. The aforementioned squares will contain provisions to enforce the identified legal framework. Following table 3 shows the provisions developed according to priori codes in table 1. The * mark represents that fact has to be answered by a technology based legal research.

Table 3: Process Enforceable Provisions for The Researched Areas of Law

Heading	Process, Liabilities and Enforceability
1-1Negligent conduct and awareness in decision making	A professional in the BIM environment at all times shall try to solve the issues at the point of time it happened. If another professional sees that a negligent act by another professional would affect the project, he shall inform it to the legal professional indicated in the legal framework.
	The BIM manager shall not interpret information from the design team differently. Whatever happens in the BIM platform, except for the design liabilities of the design team, BIM management shall be responsible.
	Professionals have to be aware of the contractual terms with regard to the specific BIM environment addition to the implied liabilities they posses.
	Professionals shall not be liable for the faults of the software*, but they have to be aware and hold liability for the results given off by the software they use
1-2Casual replies and mis interpretation	Contracts necessarily need not be in writing, a contract can be verbal or by conduct, following are the considerations, ▪ Whether a legally recognized relationship has come into existence. If so professionals shall not be relieved. ▪ Whether it was within the professionals scope of work
	Professionals are not considered independent in the BIM environment and cannot issue any authoritative decisions over an existing decision unless the party issued

Heading	Process, Liabilities and Enforceability
	the original decision agree in writing.
1-3 Adhering to professional definitions of duty of care.	Each professional has to be responsible for their scope of work, and adhere with the legal definitions of that profession, and have a reasonable practice with care to avoid negligence.
	Professionals have to adhere to the standards of the BIM environment, Even though he adheres to the standards he will liable for the faults in the end result, if any.
	Professionals have to adhere to any liabilities imposed by the technological oriented framework* if there is any.
2-1 Negligent act by the injured party	Client is also liable under the contributory negligence since the client is expected to be an expert client, in the BIM environment. Client will be liable especially when, ▪ He was negligent in delivering information on time, ▪ He declares the responsibility of the BIM model in writing, ▪ He involve with the specific design information and the extent of control he has over the design
	Design team shall take the responsibility of the designing and preparing the estimates and he cannot be relieved from the design negligence, if the contractor acts upon it due to the time constraints.
	Involvement of contractors from an initial stage in design shall not relieve the designers from the design responsibilities. However if the contract mentions that the contractor has to verify the design he shall carry out that task.
	Contractors are responsible for the methods in construction and on the materials they choose. Additionally in the BIM environment they may advice the design team on the methods, risk and on the actual costs. If they are negligent in these expected duties then they are liable.
3-1 Test of right of control and delegation of authority	The client will be liable under the vicarious liability due to the following reasons, ▪ He has to be aware of the design, ▪ Design team acts on behalf of the client, Client is answerable to the third parties who get affected by the construction.
	Client shall then find who was actually responsible from the design team and may seek action to the extent that he did not maintain the retention of control over the design.
	Main contractors, main consultants are "vicariously liable" for the work done by the sub contractors and sub consultants.
	Since the professionals cannot be controlled by another professional a reasonable point of control has to be there, preferably client may authorize this power to the BIM management then they shall be vicariously liable.
	Client's advisory team holds vicariously liability to the extent they involve with the design.
3-2 Position of the employee or the design team	Professionals generally owe a duty of care. Therefore they are liable for their scope of work. But the instruction flow and the intention of work will be used to determine who was actually responsible.
	Professionals cannot find, Para-professionals liable for any mistake they have done.
	BIM management shall take measures to avoid conflicts in integrating the design, while the design team will have the design responsibilities.
3-3 Selection of professionals and their conduct	Client holds responsibility in selecting the professionals and he has to be knowledgeable of what they are doing, professionals shall provide timely information to the client.
4-1 Level of responsibility	The most likely responsible party has to be made liable if the evidences are clear, but if a professional continues disregarding negligence by another professional, that leads to joint and several liabilities.
	Even though professionals are working in a collaborative environment they shall not undertake another professional's responsibility.

Heading	Process, Liabilities and Enforceability
4-2 Law of tort and breach of contract.	Even though Joint and several liabilities is clearly covered in the law of torts it has to be included in the contract due to the following reasons, ▪ Appointing of sub consultants also need to be done according to the main contract ▪ The interpretation under IT environment will be different* ▪ Then it will be clear for all parties that they are covered by the Joint and several liabilities hence the negligence cases will be reduced ▪ Professionals show more concern when it is included in the contract
	If a party clearly declares that they understand the risk of BIM and still they would go with it, then to the extent that the negligence act is due to the BIM environment, will not hold any party expect the declared party liable.

7.3. AREAS OF LAW

This section is in relation with the rounded rectangle named as “Q”. The basic definitions of the legal areas are given in the Table 1. The original definitions under the legal systems in common law countries need not be changed and those original provisions apply as it is to this identified legal framework.

7.4. ACTION FOR THE NEGLIGENT ACTS

This section is in relation with the rounded rectangle named as “R”. A legal position has to be established not only to find remedy for the case at hand but to review the causes for the case and evaluate the process. Then he can feed the findings to the system and use some of them for declaring a decision when a case is brought to him. The actions have to be in accordance with the liabilities and actions as presented by the square 1-4.

7.5. SUGGESTIONS AND IMPROVEMENTS

This section is in relation with the rounded rectangle named as “S”. The framework expects this rounded rectangle to be the engine and drive the BIM environment to be a truly collaborative environment with lesser disputes among the parties. Improvements are to be the findings after evaluating the process of judgement for a particular case as mentioned in the action for the negligent acts. Oval “C” represents the connectors which will feed suggestions to the BIM environment as well as the decision making process. The proposed legal framework is to ensure the real functioning of the symbiotic factors sharing of information and collaboration. Oval “D” is considered as the output connecter of the framework and final intention of parties working in the environment should be to achieve this pre determined goal.

8. CONCLUSIONS

It was clear that there are legal uncertainties when it comes to design liability in BIM will act as obstacles for its implementation. BIM will originally reduce negligent acts in design with its features but the original liabilities on the design team from the conventional practice will prevail unchanged except for exceptions as identified in the legal framework. The current legal system for the common law countries were found to be sufficient in handling design liabilities issues in the BIM environment. Nevertheless for the achievement of primary intentions of BIM this legal system has to be practiced in the form of a legal framework. The proposed legal framework will be enforced by the proposed provisions in bringing the decision against the guilty party for four areas of law as identified. The suggestions were also revealed to minimize the negligent acts because it is better to prevent than find fault once the error occurred. The legal framework proposed the mechanism of facilitating the working BIM environment of the design team and continuous self improvement with its implementation.

9. REFERENCES

American Institute of Architects, 2007. *Integrated project delivery: A guide.* AIA California Council.

Anumba, C.J., Issa, R.R., Pan, J. and Mutis, I., 2008. Ontology-based information and knowledge management in construction.*Construction Innovation:Information, Process, Management, 8*(3). 218-240.

Autodesk., 2008. *Five fallacies surrounding BIM* [online]. Available from: http://images.autodesk.com/apac_korea_main/files/five_fallacies_of_bim_mar08.pdf [Accessed 19 May 2014].

Barlays Bank Plc v Fairclough Building Limited (1994) AC.L.R. 05/06.

Bender, W.J. and Septelka, D., 2002. *Team Building in Construction* [online]. Available from: www.cwu.edu/~benderw/Teambuildingbenderseptelka0119.doc [Accessed 24 April 2014].

Bock, T., 2014. *Future construction automation and robotic implementation* [Online], Sydney,Australia. Available from: http://www.isarc2014.org/keynotes [Accessed 20 March 2014].

Caparo Industries plc v Dickman, 1990. 2 AC 605.

Civil Liability (Contribution) Act, 1978. London:Her Majesty's Stationery Office.

Deutsch, R., 2011. *BIM and integrated design:Strategies for architectural practice.* Hoboken,New Jersey: John Wiley and Sons.

Donoghue v Stevenson, 1932. AC 562.

Forsikringsaktieselskapet Vesta v Butcher and Others HL, 1989. Lloyd's Rep 331;A.C. 852;2 WLR 290;1 All ER 402.

Glover, J., 2013. *Building information modelling and English law* [online], Available from: http://www.fenwickelliott.com/files/annual_review_2012.pdf [Accessed 20 November 2014].

Gomien v Wear-Ever Aluminum, Inc, 1971. 50 Ill. 2d 19, 21, 276 N.E.2d 336.

Greaves and Co (Contractors) Ltd v Baynham Meikle and Partners, 1975. 3 All ER 99.

Hardin, B., 2009. *BIM and construction management.* Indianapolis: Wiley publication.

Hedley Byrne and Co Ltd v Heller and Partners Ltd., 1964. AC 465.

Hewitt v Bonvin, 1940. 1 K.B. 188.

Holyoak, J., 1992. *Negligance in building law.* Victoria, Australia: Blackwell Scientific Publications.

Jayasena, H. S.and Weddikkara, C., 2013. Assessing the BIM maturity in a BIM infant industry. In: Sandanayaka Y.G. and Senatathne, S., eds. *2nd World Construction Symposium 2013: Socio- Economic Sustainability in Construction*, Colombo14-15 June 2013. CIOB, 62-69.

Jordani, D., 2008. BIM:A healthy disruption to a fragmented and broken process. *Journal of building information modelling,* 21(7), 24-26.

Kamara, J.M., Anumba, C.J. and Ovbuomwan, N.F., 2002. *Capturing clients requiements in construction projects.* London: Thomas Telford.

Lee, C., 2008. *BIM: Changing the AEC Industry.* USA: Project Management Institute.

Lister v Romford Ice and Cold Storage Co. Ltd.HL, 1957. 1 All ER 125.

Maunula., 2008. *The Implementation of Building Information Modeling – A Process Perspective.* Finland: SimLab Publications.

Morgans v Lunchbury, 1973. AC 127.

Morren v Swinton and Pendlebury Borough Council,1965. 1WLR 576.

Nemtschek Vectorworks., 2014. *Open BIM: An overview* [online]. Available from: http://www.vectorworks.net/openbim/faq.php [Accessed 20 November 2014].

Reddy, K.P., 2011. *For building owners and developers: Making a business case for using BIM on projects.* New Jersey: John Wiley and Sons.

Russel, V., 2006. *Duties and liabilities of construction professionals* [online]. Available from: http://www.fenwickelliott.com/files/Other3-DutiesandLiabilites.pdf [Accessed 24 April 2014].

Succar, B., 2008. Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, 18(3), 357-375.

The Law Reform (Contributory Negligence) Act, 1945. London:Controller of His Majesty's Stationery Office end, King's Printer of Acts of Parliament.

Tocci, J., 2008. *BIM with others. 2008 AGC BIM Forum* [online]. Available from: http://files.meetup.com/1160431/NYCRUG-2008-11.pdf [Accessed 20 November 2014].

Tolson, S.J., 2007. *Design liability, defective buildings and remedies at law* [online]. Available from: http://www.fenwickelliott.com/files/Contract16-DesignLiability,DefectiveBuildingsandRemediesatLaw.pdf [Accessed 25 April 2014].

Weygant, R.S., 2011. *BIM content development:Standards, strategies and best practices.* New Jersey: John Wiley and Sons.

White, N.J., 2008. *Construction law for managers,architects and engineers.* New York:Thomson Delmar Learning .

Wickersham, J., 2009. *Legal and business implications of building information modeling (BIM) and integrated project delivery (IPD)* [online]. Available from: http://isites.harvard.edu/fs/docs/icb.topic552698.files/Wickersham%20BIM-IPD%20legal%20and%20business%20isssues.pdf [Accessed 19 February 2014].

William, T., 2007. *Information technology for construction managers, architects and engineers.* New York: Thomson Delmar Learning.

Zimmer v. City of Milwaukee, 1992. 272 U. S. 713, 47 Sup. Ct.

TRAINING AND DEVELOPMENT FRAMEWORK TO IMPROVE EMPLOYEE JOB PERFORMANCE IN PUBLIC SECTOR BANKS IN SRI LANKA

M.L.Thilini Saubhagya Chandrasiri* and Nirodha Gayani Fernando
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Sri Lankan banking industry has grown rapidly due to the entrance of the new private banks other than the public banks. Consequently, customer attraction towards the private banks has been increased due to the customer dissatisfaction with employee job performance in public banks. This was revealed that training and development is one of human resource management strategy in enhancing the employee job performance. Therefore, the requirement of effective training and development is emerged in order to mitigate the discrepancies in employee job performance in public sector banks in Sri Lanka while overcoming the training gaps in prevailing procedure. Hence, the aim of this research is to develop an effective training and development framework to improve the employee job performance in Sri Lankan public sector banks. Accordingly, case study research was selected as the most suitable research approach for this study since in-depth investigation is required to identify the weaknesses in prevailing training and development procedure. Fourteen interviews were conducted, representing the senior managers, branch managers and banking assistants in public sector licensed commercial banks. The collected data through the interviews was analysed using content analysis. The research finding of this study revealed several weaknesses in prevailing training and development procedure such as poor design of orientation program, poor content of training program, poor choice of training, poor evaluation of training program and poor performance evaluation practice. Finally, a training and development framework was proposed in order to overcome those weaknesses in prevailing training and development procedure.

Keywords: *Employee Job Performance; Public Sector Banks; Training and Development.*

1. INTRODUCTION

The changes in the world are giving birth to the need for employees to learn continuously and to be experts on their jobs. Therefore, the ultimate objective of any organisation is to improve their business processes while enhancing the learning opportunities that stimulate better employee job performance (Latif *et al.*, 2013).Training and development is a pathway which provides learning opportunities by creating a sense of progression and purpose that leads to organisational commitment (Armstrong, 2006). Training and development are often helpful to close the gap between employee current job performances and expected future job performance (Nassazi, 2013). Consequently, Khattak *et al.*(2010) found that effective training and development is directly related with the successful employee performance and organisation.

In the banking sector, the service provided by the bank is delivered through its employee to its customer simultaneously (Awan and Saeed,2014). Hence, service errors can have an immediate impact on performance and customer satisfaction rather than manufacturing errors (Hess *et al.*, 2003). Consequently, the performance of the banking sector mainly depends upon the performance of its human resource since it is the main service delivery asset of the organisation.

Banking sector in Sri Lanka has witnessed a rapid growth in the last decade due to continuous changing competitive environment with the entrance of private banks, reflecting its importance to the country's economy (Wijetunga and Goonatillake, 2003). However, customer dissatisfaction towards the public

* Corresponding Author: E-mail - scthilini@gmail.com

sector banks is higher than the private sector banks due to lack of employee job performance (Yapa and Hasara, 2013). Hence, training and development is the best avenue to enhance the employee job performance. Moreover, Manuratne (2002) demonstrated that whether the large banks have their own training centres, lot of training gaps are occurred due to insufficient attention of Sri Lankan public sector bank managers. Therefore, there is a requirement of an effective training and development framework to fill the gaps in training while improving the employee's job performance in public sector banks in Sri Lanka. Accordingly, aim of the study was to develop a training and development framework to improve the employee job performance in Sri Lankan public sector banks. Public sector licensed commercial banks in Sri Lanka were selected as the cases and data collection was restricted to Colombo area due to time limitation. In addition, the training and development framework was mainly focused on the bank assistants in public sector banks.

2. PUBLIC SECTOR BANKS

Public sector banks are the banks that are owned by a government (Fernando and Nimal, 2014; Haq and Muhammad, 2012). The role of the public sector banks is not much varied from private sector banks. Though, ultimate objective of the public sector bank is not only to earn profit, but also to fulfil government objectives for development of nation. In case of private sector bank which operates solely to earn profit.

3. EMPLOYEE JOB PERFORMANCE

Employee job performance is a set of behaviour which employee shows when doing his/her job or amount of efficiency gained from the employee (Dizgah *et al.*, 2012). Moreover, Sultana *et al.* (2012) defined that performance is "the achievement of specific tasks measured against predetermined or identified standards of accuracy, completeness, cost and speed" (p.647). Therefore, employee job performance can be simply defined as the level of employee commitment to perform their job in order to achieve organisational goals.

3.1. IMPACT OF EMPLOYEE JOB PERFORMANCE TO PUBLIC SECTOR BANK

Human being is the main service delivery asset in the banking sector which includes providing better banking service as promise by the bank staff, willingness and readiness to help customers, effectiveness of bank staff skills and ability to cope critical incidents making customers feel safe and secure in their transactions, giving caring and individual attention to bank customers by having the customers' best interests at heart (Alamgir and Shamsuddoha, 2004). Consequently, all activities of banking industry depend on the employee-customer relationship. Hence, banking industry must strive to provide better service to the customer with a smiling face in order to cultivate and maintain long and strong relationship with their customers (Rathnaweera, 2010). As a result, employee job performance provides an opportunity to add a human tough to customer interaction (Wallace *et al.*, 2011). Therefore, better customer-employee rapport enhances customer satisfaction, loyalty and positive word of mouth (Gremler and Gwinner, 2000). Moreover, employee job performance enhances the customer trust and value (Briggs and Grisaffe, 2010).

By considering aforementioned facts, customers are the success of the organisation. Hence current regular customers can be retained and new customers can be attract towards the public sector banks in a competitive atmosphere which is created by private banks by providing high level of customer service which is a result of better employee job performance. According to Kahya (2009), employee job performance is the best predictor of an organisational effectiveness and efficiency which is capable to enhance the productivity of the organisation. Therefore, as a financial service sector which contributes to stabilization of country's economy, employee job performance is the most important factor in banking sector for the way of attainment of organisational competitive advantage.

3.2. TRAINING AND DEVELOPMENT

In the field of human resource management, training and development is one of the major areas of the HRM function which is significantly concerned with organisational activities aimed at improving the performance of individuals and groups in organisational settings (Harrison, 2000). Ghosh (2010) defined training as “the process involved in improving the attitudes, skills and abilities of the employees to perform specific jobs” (p.205). Similarly, Dessler (2004) defined training as “the methods used to give new or present employees the skills they need to perform their jobs” (p.187). According to Noe (2009), training was defined as the planned effort by an organisation to facilitate an opportunity to employee’s learning of job related competencies including knowledge, skills or behaviours that are critical for successful job performance. Though, training is in contrast with the development, if the training that provides the opportunity to enhance the employee knowledge, skills, abilities and attitudes for anticipated future jobs and roles (Noe, 2009), whilst Bernardin (2003) defined the training as any endeavour to improve employee performance on a currently held job through changing the employee specific competencies and behaviours. Similarly according to Miller (2006), training is attached with the current performance and progress of an employee whereas development is attached with the future employee performance and progress. Moreover, McNamara (2008) defined that development is a comprehensive on-going multi-faceted set of activities which is aimed at bringing employee to another threshold of performance, to perform some job or a new role in the future. Therefore, the term of development is differed with the training since the outcome of the development is long-term which helps employee to perform the future jobs, but the outcome of the training is short-term which leads employee to perform the current job.

According to Sadler-smith (2006 cited Latif, 2012), training and development is a very formal, systematic and step wise process. Furthermore, Snell *et al.* (2010) stated that a systematic approach should be used to ensure the successful training and development process. According to Snell *et al.* (2010) systematic training process consists of four phases. Initial stage is to conduct a needs assessment in order to identify the gaps between the employee’s actual performance and desired performance by analyzing the organisation, task or job and person. Second stage is to decide what sort of training is required to satisfy these needs (Armstrong, 2006). Next step is to implement the planned training program. Final phase is to evaluate the training program in order to determine its effectiveness and to determine whether the training has accomplished its objectives. According to Kirkpatrick (2006), training evaluation can be conducted into four levels as reaction, learning, behavior and result.

Every organisation invest in the training and development for its employee in order to fulfil organisational responsibilities of generating profits for its stakeholders and providing excellent service quality for its customers (Evans and Lindsay, 2011). As per Opatha (2009), training has a positive impact on employee job performance by making benefits to both the employees and the organisation. Furthermore, Opatha (2009) stated that employee’s job performance basically depends on abilities and motivation. Figure 1 shows that effect of training and development on employee’s job performance.

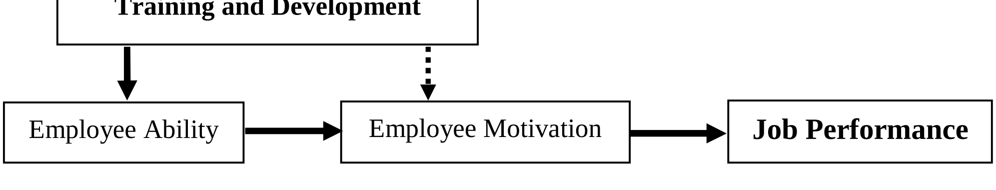


Figure 1: Effects of Training and Development on Job Performance
Source: Opatha (2009, p.450)

As shown by the above figure, training and development directly drives to increase employee ability by increasing knowledge, skills and attitudes and it indirectly affect to increase the employee motivation. When the employee ability increases, self-confidence in performing their job successfully and employee’s self-esteem will increase. Consequently, employee motivation will increase. Ultimately, employee job performance increase while increasing the organisational performance.

4. RESEARCH METHODOLOGY

This study comprised with two components as literature review and primary data collection. Initially, a comprehensive literature review was carried out in respect of understanding the general concept by means of reviewing the books, journals, articles, conference proceedings, previous dissertations, government publications and websites. Subsequently, empirical study was conducted by adopting qualitative research approach. Therefore, this research was adapted the case study research methodology in order to conduct an in-depth study about the current training and development procedure in public sector banks in Sri Lanka. Semi-structured interviews were conducted with senior managers, branch managers and banking assistants in public sector banks to identify their perceptions towards the training and development process. Collected data was analysed using a content analysis.

5. DATA COLLECTION AND ANALYSIS

Two cases were selected in order to investigate the current training and development procedure of the public sector banks in Sri Lanka. These cases comprise with the public sector licensed commercial banks in Sri Lanka. Both banks annually invest considerable amount in both local and foreign training programs and both have separate training institutes to facilitate the in-house training for their banking staff.

Data was collected by conducting fourteen semi-structured interviews covering three levels of employees in these banks. Interviewees belong to three levels as senior managers in training and development department, branch managers and banking assistants from each bank. Top level managers were interviewed for the purpose of exploring the current training and development procedure of the Sri Lanka public sector banks and to identify the strategies what they use in designing the training and development procedures. The branch managers and banking assistants were interviewed to identify their perception towards the current training and development opportunities, provided by the bank.

6. RESEARCH FINDINGS AND DISCUSSION

In here, initial attention is drawn to identify the current status of training and development in public sector banks. Hereafter, several essential themes were selected according to the systematic training and development process for the purpose of data analysis.

6.1. CURRENT STATUS OF TRAINING PROCEDURE IN PUBLIC SECTOR BANKS

Training and development procedure of both public sector banks is handled by the separate department as well as both have their own training collage in Colombo District which facilitates the residential training for its staff. In addition, both of these banks have training and development policy which is changed in time to time by ensuring the attainment of organisational goal and customer requirements. Besides, both banks annually invest the considerable amount in both local and overseas training and development programs. Other than that, orientation programs are conducted for new recruit banking assistants. Though, all respondents from banking assistants have participated for the orientation program, thus majority are pointed out that orientation program which they participated had not greatest impact to perform their job.

According to the manager's point of view, whether training programs are designed by the head office, in some circumstances that training programs are not practical in real working environment. Besides, majority of interviewees from banking assistants revealed that most of the training programs give only the theoretical knowledge and sometimes that gained knowledge was not applicable in real practice. One of banking assistant confirmed this by stating "Normally, most of the training programs are doing by the external lecturer. In such a case, there are some differences between what the trainer taught and what we have to actually do within our working culture. So that, the knowledge gained from the training would be useless when performing the job".

Currently, Sri Lankan public sector banks organize training programs to improve knowledge relating to banking activities, team work skills, communication skills, Information Technology (IT) knowledge, customer handling skills and interpersonal skills. Thus, as per the responses of the banking assistants, training programs are unable to do significant impact on improving the team work skills, improving them communication skills, improving the customer handling skills and improving the interpersonal skills. Though, these skills are very essential in competitive banking sector when attracting the customers towards the bank.

6.2. TRAINING NEEDS IDENTIFICATION

Sri Lankan public sector banks use different methods to identify the training needs of their employees such as observation of employee behaviour or performance during the working time, through the performance evaluation, request from branch managers, through the Human Resource Information System (HRIS), job test, customer complaints, feedback from retired officers, when introducing new product and services, changes in existing procedures and circulars and changes in employee job description. As per the research findings, some banks adapt more comprehensive and practical training needs identification strategies due to its importance in designing the training and development programs. Nevertheless, some banks are not currently adapted with the ways of strategically training needs identification.

6.3. SELECTION OF THE TRAINEES

Basically, main three ways are used by the Sri Lankan public sector banks in nominating the trainees for particular training. Those are that nominated trainee by the head office and nominated by the branch manager. Sometimes, trainees are participated for the training program on the personal request. When nominating the trainees by the head office, they consider annual individual performance evaluation. One senior manager stated that “When selecting the trainees, we consider every employee’s annual performances evaluation forms which are filled by their managers”. In addition, individual performance, individual learning preference, working section and job grade of the employee is considered when selecting the trainees by the branch managers. Most of the time, managers give priority to the person who has better job performance and who are willing to learn. One of branch manager said that “…. So that most of the time, I give priority for the employee who are willing to learn or have good performance. If not, we couldn’t get benefits from such training program”.

6.4. SELECTION OF THE TRAINER

For most of the training programs, experts of particular subject in their own bank were selected as the trainer since experts in banking industry are currently working for these both banks and sometimes guest lecturers who have specialized knowledge in particular subject matter are selected for some training programs.

6.5. EVALUATION OF THE TRAINING PROGRAM

According to the opinions of both senior managers and banking assistants, the effectiveness of the training program is evaluated at the end of training session by getting evaluation form. One senior manager confirmed this by saying “Training program is evaluated at the end of the training programs by getting the evaluation form from every trainee”. Though, most of the expertise in the field of Human Resource Management divulged the strategic training evaluation methods rather than getting feedback at the end of the training program.

6.6. TRAINING AND DEVELOPMENT FRAMEWORK

Figure 2 demonstrates the ideal framework for effective training and development in order to improve the employee job performance in Sri Lankan public sector banks while mitigating the weaknesses, associated in current practice. Strengths in prevailing training and development procedure overcome by the weaknesses in prevailing procedure. Figure 2 shows the strengths in current procedure as better management support, better budgetary allocation, learning based culture and better expertise knowledge within the public banks.

Meanwhile, Figure 2 illustrates several weaknesses in current training and development practice as poor design of orientation program, poor content of training programs, poor choice of trainees, poor evaluation of the training program and improper performance evaluation practice and strategies proposed to mitigate those weaknesses. Orientation program should not be limited only few hours, giving basic idea about the bank since the banking sector is wide industry which essential thorough knowledge, skills and abilities regarding the related subject matters in order to perform the job well. Many of new appointed employees for the role of banking assistant has got appointment after the completion of advance level because of this, they do not have any job experience before and relevant knowledge and skills that needs to perform the job. Therefore, it is vital to design the appropriate orientation program which gives thorough knowledge relating to banking activities as well as enhancing the customer handling skills, interpersonal skills and communication skills.

Nowadays, public sector banks give poor attention towards the improvement of soft skills, customer handling skills and communication skills. However, customer dissatisfaction has increased towards the public sector banks in Sri Lanka due to the frequent ignorance and being insensitive to customer anticipations. Therefore, managers in public sector banks in Sri Lanka must give a major concern to enhance these skills through the training and development. Further, behaviour modelling is the most suitable training method in improving those skills.

It is necessary to follow up the proper procedure to select the trainees for the training programs, so that the person who actually needs the training can be selected. Otherwise, if the previously trained and well skilful employees were selected for the same training which has no contribution to individual employee improvements as well as the organisational improvements, it will waste only money and time. This doctrine is common to the Sri Lankan public sector banks as well. Current procedure also confronts with the problem of poor selection of trainees. Therefore, when selecting the trainees, manager in public sector banks should give more attention to the person who has not trained before and less performers in particular area.

Managers in Sri Lankan public sector banks are strict in ensuring that the employees attend the training program, but evaluation of the effectiveness of training has not attracted sufficient attention. This weakness can be overcome by means of the most popular and widely used training evaluation model, introduced by Donald Kirkpatrick which consists of four levels as reaction level, learning level, behaviour level and results. In reaction level, it considers in addressing the question of how was the participants favourably to the training program. The next level of learning addresses the question of what does the trainee learn from training. In behaviour level, it is addressed the question, what are the changes in employee behaviour after training. The final level of results is measuring the final result of the training by finding the answer for how does the impact of training to the organisation. If there is the improvement organisational performance, the training is effective. Otherwise, if there is no improvement, training and development procedure needs to be revised again.

Performance evaluation is one of the best ways to measure the performance of each and every employee in the organisation. Currently, public sector banks conduct annual performance evaluation by using the specific performance evaluation form which is filling by the branch manager. Though, it is not mostly successful method. Therefore, it is better, if the banks can conduct the performance evaluation through the relevant system as well as both objective criteria and subjective criteria should be considered in performance evaluation. In addition, mini survey in rapid performance evaluation technique can be conducted by a regional managers or a senior manager who is responsible for human resource development since each banks have considerable amount of employees who are working in all around the country.

Moreover, Figure 2 illustrates the possible barriers that prevent the implementation of above proposed strategies in order to enhance effectiveness of the training and development procedure. It is difficult to realize employee for the training and development due to the tight working schedule. Implementing E-learning facility and organizing the branch wise training may be lead to mitigate this barrier. Lack of available facilities like training centers with new technologies, difficulties in use of advance technologies, generation problems like learning ability of adults, employee attitude toward the training, language problem and trade union issues are the another barriers which may obstruct the implementation of proposed strategies. Ultimately, effective training and development can be arisen by overcoming the prevailing weaknesses. Employee job performance will be increased as a result of an effective training and development process. Eventually, customer satisfaction and organisation performance will be increased as the result of better employee job performance.

7. CONCLUSIONS

When consider about the Sri Lankan banking sector, it becomes more complex with the entrance of new private banks other than the public banks. Nowadays, customers are attracting towards the private sector banks due to the dissatisfaction on service provided by the public sector banks. One of the reasons for this dissatisfaction is the lack of employee job performance. Therefore, training and development provides an avenue for the employees in public sector banks to enhance their job performance.

The managers in public sector banks in Sri Lanka have better sense towards the training and development and allowed the employees to learn from its culture, not only to face the challenges of dynamic environment, but also due to the importance that linked to learning in the Sri Lankan culture. Although, when examine the training procedure thoroughly, several weaknesses in current procedure are identified. There are some loopholes in orientation program which is designed, focusing the banking assistants as well as there are some weaknesses due to impracticability of training programs. And also, there are some mishaps in the selection of trainees and evaluation of training program.

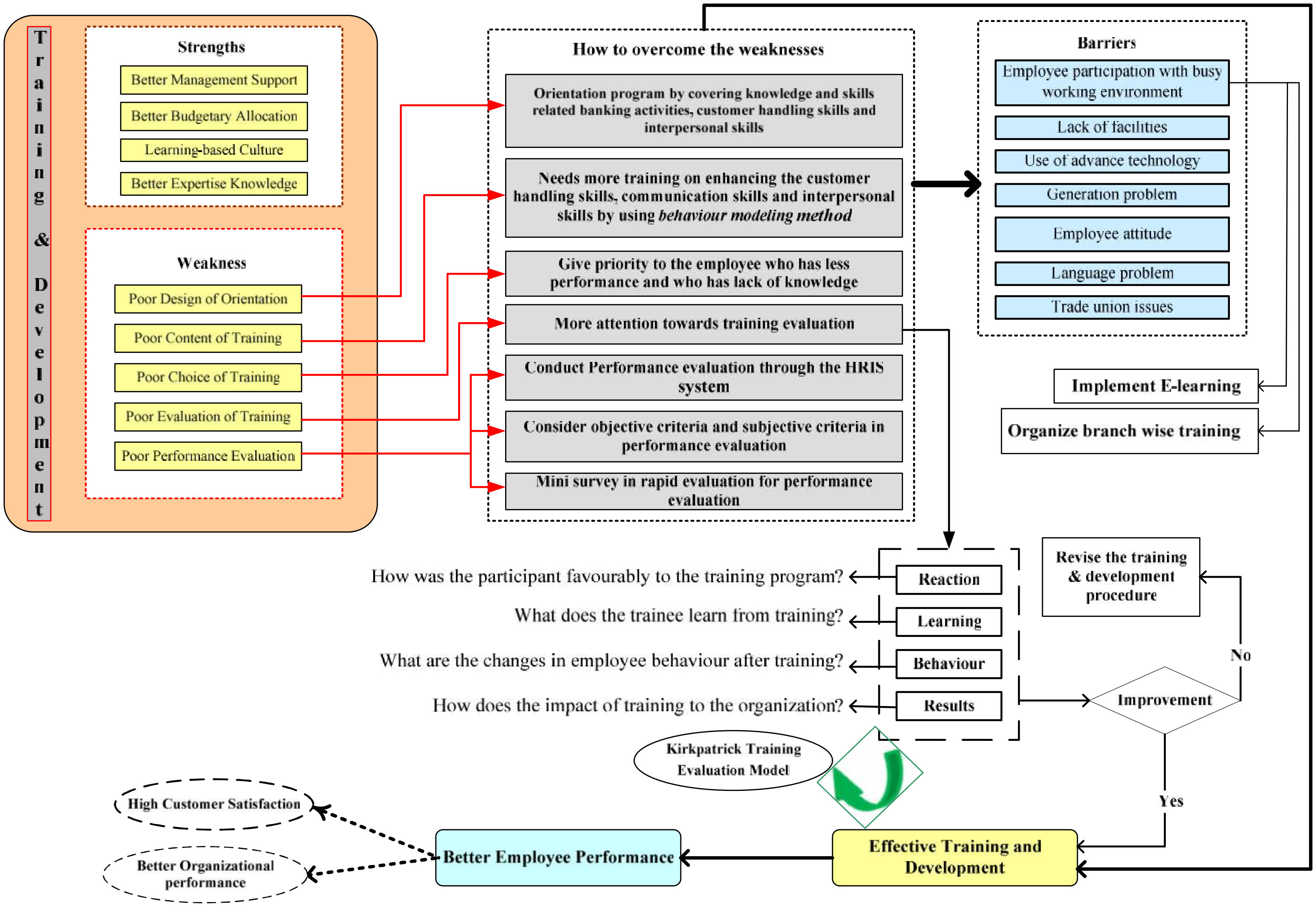


Figure 2: Training and Development Framework to Improve Employee Job Performance in Public

8. REFERENCE

Alamgir, M. and Shamsuddoha, M., 2004. Service quality dimensions: a conceptual analysis. *The Chittagong University Journal of Business Administration*, 19, 305-316.

Armstrong, M., 2006.*A handbook of human resource practice*.10th ed. London: Kogan Page Limited.

Awan, A.G. and Saeed, F., 2014. Impact of professional training on employees' performance: a case study of Pakistani banking sector. *European Journal of Accounting Auditing and Finance Research*, 2(8), 70-80.

Bernardin, H.J., 2003. *Human resource management: an experiential approach.* 3rded. New Delhi: Tata McGraw-Hill.

Briggs, E. and Grisaffe, D., 2010. Service performance-loyalty intentions link in a business-to-business context: the role of relational exchange outcomes and customer characteristics. *Journal of Service Research*, 13(1), 37-51.

Dessler, G., 2004. *Human resources management*.9thed. New Delhi, India: Prentice Hall of India Pvt Ltd.

Dizgah, M., Chegini, M. and Bisokhan, R., 2012. Relationship between job satisfaction and employee job performance in Guilan public sector.*Journal of Basic and Applied Scientific Research*, 2(2), 1735-1741.

Evans, J.andLindsay, W., 2011.*Managing for quality and performance excellence*. 8th ed. United State of America: South-Western Cengage Learning.

Fernando, J.M.R. and Nimal, P.D., 2014. Does ownership and size influence bank efficiency? evidence from Sri Lankan banking sector. *Ruhuna Journal of Management and Finance*, 1(1), 83-90.

Ghosh, B., 2010. *Human resources development and management*. New Delhi, India: Vikas Publishing House Pvt Ltd.

Gremler, D. and Gwinner, K., 2000. Customer-employee rapport in service relationships. *Journal of Service Research*, 3(1), 82-104.

Haq, W. and Muhammad, B., 2012. Customer satisfaction: a comparison of public and private banks of Pakistan. *IOSR Journal of Business and Management*, 1(5), 1-5.

Harrison, R., 2000. *Employee development*. Silver Lakes, Pretoria: Beekman Publishing.

Hess, R.L., Ganesan, S. and Klein, N.M., 2003. Service failure and recovery: the impact of relationship factors on customer satisfaction. *Journal of the Academy of Marketing Science*, 31(2), 127-145.

Kahya, E., 2009. The effects of job performance on effectiveness. *International Journal of Industrial Ergonomics*, 39(1), 96-104.

Khattak, M.A., Bashir, F. and Qureshi, T.M., 2010.Training and development paradigm, and its contribution in economic uplift of the country, a case from Pakistan. In: *12th International Business Research Conference*, Dubai 16 January 2010.

Kirkpatrick, D.L., 2006. *Improving employee performance through appraisal and coaching*. 2nd ed. New York: American Management Association.

Latif, K.F., Jan, S. and Shaheen, N., 2013. Association of training satisfaction with employee development aspect of job satisfaction. *Journal of Managerial Sciences*, 7(1), 159-178.

Latif, K.F., 2012. An integrated model of training effectiveness and satisfaction with employee development interventions. *Industrial and Commercial Training*, 44(4), 211-222.

Manuratne, M., 2002. Training gaps: Is it larger than apparent?.*Sri Lankan Journal of Management*, 7(1/2), 29-44.

McNamara, C., 2008. *Employee Training and Development: Reasons and Benefits*. New York: Authenticity Consulting, LLC.

Miller, D., 2006. Strategic human resource management in department stores: An historical perspective. *Journal of Retailing and Consumer Services*, 13(2), 99-109.

Nassazi, A., 2013. *Effects of training on employee performance*.Thesis (Master's).University of Applied Sciences.

Noe, R.A., 2009. *Employee training & development.* 5thed. New York: McGraw-Hill Companies, Inc.

Opatha, H.H.D.N.P., 2009. *Human resource management*. Sri Lanka: Author Publication.

Rathnaweera, R.R.N.T., 2010. *Do HRM practices impact employee satisfaction, commitmentor retention?: empirical studies of Sri Lankan public sector banks.* Thesis(M Sc.). University of Agder.

Snell, S.,Bohlander, G. and Vohra, V., 2010.*Human resource management: a south Asian perspective*. Delhi, India: Cengage Learning India Pvt Ltd.

Sultana, A., Irum, S., Ahmed, K. and Mehmood, N., 2012. Impact of training on employee performance: a study of telecommunication sector in Pakistan. *Interdisciplinary Journal of Contemporary Research in Business*, 4(6), 646-662.

Wallace, E., Chernatony, L. and Buil, I., 2011. Within-role, extra-role and anti-role behaviours in retail banking. *International Journal of Bank Marketing*, 29(6), 470-488.

Wijetunga, D. and Goonatillake, R., 2003. Customer satisfaction in Sri Lankan retail banking: the role of service quality. *Sri Lankan Journal of Management*, 8(3/4), 172-194.

Yapa, S.T.W.S. and Hasara, K.M., 2013. Bank service quality in Sri Lanka: A comparative study between public and private sectors. In: Bhuiyan, M.H.B., ed. *3rd Asia-Pacific Business Research Conference,* Malaysia 25 - 26 February 2013. World business Institute Australia, 1-16.

USE OF LOCALLY AVAILABLE MATERIAL TO DEVELOP A TREATMENT TECHNIQUE TO REDUCE THE WATER ABSORPTION CAPACITY OF RECYCLED AGGREGATES

W.K.A. Madawa*, R.M.S.I.B. Rathnayake, D.B. Wijethunga,T.C. Gamage and S. Karunarathne

Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka

ABSTRACT

This study was to find a treatment technique to reduce the water absorption of Recycled Aggregates (RA) which involved preparing a coating to reduce the water penetration. The materials considered for the preparation of coating was Termite Mound Soil (TMS) and ordinary Portland cement. The objective was to find their optimum proportions and the slurry thickness for a coating that gives the lowest absorption. TMS was tested for pozzolanic properties. Chemical composition was tested using Atomic Absorption Spectroscopy and other analytical techniques. Mainly water absorption, particle size distribution, AIV, LAAV of RA was tested to ensure the suitability for construction purposes. Slurry was prepared using cement replacement levels of 0, 20, 40, 60 and 80% of TMS. Three sets of coatings were prepared with water to solid ratios of 1, 1.25 and 1.5. Slurries were prepared in a concrete mixture in which the aggregates were coated for 10 minutes at a speed of 30rpm. After air drying, coated aggregates were tested for the absorption after 14 days. The absorption of treated aggregates was compared with those of natural and untreated recycled aggregates. From the successful aggregate batches three concrete test cubes were prepared from each and tested for the 28 day compressive strength after curing for 28 days. Strength values were compared with those prepared with natural aggregates. Aggregates Coated using 50% cement and 50% TMS showed a significant reduction in the water absorption up to 38.44%. The strength of concrete made from aggregates treated with 50% TMS replacement along with the water solid ratio 1 was 37.15N/mm^2 whereas the value obtained from natural aggregates was 37.3N/mm^2

Keywords: *Coating; Recycled aggregates; Termite mound soil; Water Absorption.*

1. INTRODUCTION

With the increasing growth of global construction industry, concrete has become an indispensable material which has made high rise buildings, roads, dams and many other constructions possible. Concrete is a mixture of several major constituents, namely cement, water, fine and coarse aggregates and in some cases, special additives each playing a different part in giving concrete its many desirable characteristics as a construction material. These constituents necessarily, could be manipulated to form different varieties of concretes with different performance levels.

Out of these constituents, fine and coarse aggregates play a major role in concrete by providing a comparatively less expensive filler material, by providing strength to withstand applied loads, abrasion, effect of weather etc, and by helping to reduce the volume changes happening during the concrete setting and hardening process as well as from change of moisture in the cement paste (Parek and Modhera, 2011). Natural rocks, sands or gravel are used as coarse and fine aggregates which take up about 70%-80% of concrete volume (Parek and Modhera, 2011).

However, there is a considerable environmental impact associated in the production of aggregates. Natural sands and gravel are getting scarce by the day making it harder to meet the increasing demand for the aggregates, which according to the recent studies has exceeded 26 billion tonnes by year 2011 (Otoko,

* Corresponding Author: E-mail - mayouran@bimlab.net

2014). Further, construction and demolition waste from concrete has become a major source of industrial wastes in the past years (Fucale *et al.*, 2009).

In the light of this situation, more focus is given for finding eco-friendly alternatives or substitutes for natural aggregates. One such option is the recycling of demolished concrete waste and utilizing the same for the preparation of new concrete. Many studies have proved that concrete made with this type of coarse aggregates can have mechanical properties similar to those of conventional concretes and demolition waste has been proved to be an excellent source of aggregates with some modifications (Rahal 2007; Limbachiya *et al.*, 2004; Malešev *et al.*, 2010).

However, there are several drawbacks in recycled aggregates which reduce the utilization as a substitution for natural aggregates. Higher water absorption of recycled aggregates compared to natural aggregates can be considered as the most significant drawback which can directly affect the water to solid ratio of the concrete mix which in turn may reduce the strength of concrete. (Pelufo *et al.*, 2009) This can further change the workability and uniformity of concrete mixtures (Pelufo *et al.*, 2009). Investigations have revealed such high absorption is due to excessive attached mortar and micro cracks generated in the process (Zaharieva, 2003).

To overcome these problematic characteristics of recycled aggregates, several treatment methods are implemented by several researchers. One attempt is to increase the performance of RA by heating and rubbing of aggregates, using eccentric - shaft rotor method and straight forward mechanical grinding method to remove adhered motar (Parekh and Modhera, 2011). Moreover, researchers have come up with several surface treatment techniques such as treating the aggregates with mineral oil (Tsujino and Noguchi, 2006), treating the recycled aggregates with several different types of pozzolanic materials such as sodium silicate, colloidal silica and silica fume by surface adsorption (Kim and Youn, 2005) and Treatment of recycled aggregates with Nano silica which has been comprehensively investigated (Scrivener and Crumbie, 2004).

Through this research, it was expected to find a suitable and locally available, cheap material and a technique to treat recycled aggregates. To this end, termite soil along with Standard Portland cement was used. Termite soil, a pozzolanic material, had been used in plaster and bricks by the ancient Sri Lankans to built gigantic Buddhist pagodas (Ranaweera and Abeyruwan 2004). A pozzolanic material can be defined as a siliceous or siliceous and aluminous material having very law cementation value, though finely divided and in the presence of moisture would chemically react to form compounds having cementacious properties and Termite soil is analytically proven to have pozzolanic properties (Ikponmwosa *et al.*, 2009).

Several studies have proved that addition of TMS to concrete can improve the properties of concrete (Ikponmwosa *et al.* 2009; Orie and Anyata, 2012). Cement Partially Replaced by Termite Mound Clay in the preparation of concrete beams has proven to increase the flexural strength (Ikponmwosa *et al.*, 2009). Addition of 15% mound soil by weight of cement has proven to increase the compressive strength and workability by 21.83% and 36.92% respectively. Same investigation concludes that TMS can be used as an additive in structural concrete for high compressive strength and workability (Orie and Anyata 2012).

Termite clay is obtained from termite mound, while mound is a pile of earth made by termites resembling a small hill. It is made of clay whose properties have further been improved by the excrement and saliva from the termite while being used in building the mound (Mijinyewa *et al.*, 2007). In Sri Lanka, Termite mounds are abundant in the dry zone, especially in North Western province and Eastern province of the island. Some mounds extend up to several meters in height and covers a considerable area.

This study aims on finding the optimum combination of cement and termite mound clay, and the most effective water to solid ratio for preparing a durable coating in order to reducing the water absorption of recycled aggregate by filling the micro cracks within the aggregates and reducing the porosity of attached motar.

2. MATERIALS AND METHODOLOGY

A bulk sample of Recycled concrete aggregate was collected from the COWAM centre recycling site in Galle which was started after the tsunami disaster in year 2004, and used as the materials for testing. Standard Portland cement was used and a sufficient amount of Termite mound soil was collected from a termite mound in Kottawa area, Colombo.

Methodology comprised of several steps. Initially recycled aggregates from the recycling center were tested for the physical properties to identify and analyze the major drawbacks. Physical and chemical properties of Termite Mound Soil were studied to ensure the suitability for the preparation of strong, durable, abrasive resistant coating along with cement. Then the aggregates were treated using several mix proportions under several water to cement ratios. Water absorption was tested after the surface treatment. Concrete test cubes were casted from successful batches of treated recycled aggregates and 28 day compressive strength was obtained and the values were compared with those prepared from natural aggregates under same conditions and mix design.

2.1. INITIAL PHYSICAL AND CHEMICAL TESTS

Physical and chemical properties of Termite Mound Soil were tested to ensure the desirable properties of Termite mound soil as a pozzolanic agent. Chemical analysis of TMS was conducted in accordance with BS: 4550: part 2: 1978: testing cement. Atomic Absorption Spectrophotometric method and titrametric procedures were followed. Physical properties were tested accordance with ASTM D 845.

Aggregates properties were tested in accordance with BS 812: part 2 and IS 2386. Testing was carried out for both natural and recycled coarse aggregates to identify the major drawbacks of recycle aggregates, to ensure the competency of Recycled aggregates for the utilization of construction purposes and to compare them with natural aggregates.

2.2. TESTING OF TERMITE SOIL

Following tests were carried out to test the Pozzolanic property of termite mound soil

- Total Silica analysis
- Chemical analysis for Al_2O_3, Fe_2O_3, MgO and CaO.
- Specific gravity

2.3. TESTING OF RECYCLED COARSE AGGREGATES

Followings tests were carried out to test the properties of recycled coarse aggregates and natural coarse aggregates

- Sieve Analysis test
- Water Absorption test
- AIV test
- LAAV test

2.4. PREPARATION OF MATERIALS FOR THE COATING PROCESS

Termite mound soil lumps were air dried for 7 days before they crushed into smaller particles manually using a hammer. Then the smaller soil lumps were introduced to the ball mill and milled for 20 minutes. Further crushed soil lumps were taken out of the mill and sieved manually using the 0.4mm IS sieve and the fine portion was obtained for the process.

Aggregates were air dried for 7 days and contaminants (polythene, plastic, wooden and glass pieces) were removed manually and sieved using 10mm sieve to remove smaller parti.

2.5. COATING THE AGGREGATES

Table 1: Mix Proportions for all 3 Water Solid Ratios (1, 1.25, and 1.5)

Scenario number	Cement %	Soil%	Cement (g)	Soil (g)	Water(g) (1)	Water(g) (1.25)	Water(g) (1.5)
1	20	80	160	640	800	1000	1200
2	40	60	320	480	800	1000	1200
3	50	50	400	400	800	1000	1200
4	60	40	480	320	800	1000	1200
5	80	20	640	160	800	1000	1200
6	100	0	800	0	800	1000	1200

Six scenarios were developed and all of them were prepared under water /solid ratios namely 1, 1.25 and 1.5. Table 1 summarizes the material mix proportions along with the water content for each slurry mixture. Material from each was placed in the concrete mixture with respective amount of water and was mixed well with a trowel. Then consistent slurry was formed by mixing the materials and water for 10 minutes inside the mixture. Then the Recycled Aggregates were introduced to the mixture containing the prepared slurry and the mixing was carried out for another 10 minutes for each mix proportion at a speed of 30 rotations per minute. Then the coated aggregates were removed from the mixture.

2.6. DRYING, CURING AND TESTING FOR WATER ABSORPTION

Treated aggregates were then allowed to air dry for 2 days on a steel mesh outside the laboratory and aggregates were sprinkled with water for 2 days and kept 14 days inside the laboratory for curing. After 14 days aggregates were kept in water for one day and water absorption was tested according to IS: 2386 (Part III) – 1963.

2.7. COATING THE AGGREGATES

Treated aggregate batches with lowest water absorption were used to cast concrete cubes. A standard mix design for grade 30 concrete was used to cast cubes of size 150mm x 150mm x150mm. Batching was carried out by weight and the cubes were removed from the moulds after 24 hours. The samples were then transferred into the curing tank which was maintained at room temperature. The cubes were tested for compressive strength on removal from the curing tank at the age of 28 days, using compression machine to the requirements of BS 1881: Part 116. Concrete cubes from natural aggregates were prepared and tested under same conditions to compare the results.

3. RESULTS AND DISCUSSION

3.1. CHEMICAL COMPOSITION OF TERMITE MOUND SOIL

Table 2: Major Chemical Constituents in TMS

Constituent	Percentage (%)
CaO	0.283
SiO_2	49.6
Al_2O_3	25.2
Fe_2O_3	2.76
MgO	1.82

Table 2 summarizes the percentage of major chemical constituents of TMS. The percentage of SiO_2 AL_2O_3 and Fe_2O_3 in Teremite mound soil was 49.6%, 25.2% and 2.76% respectively. The combined percentage of above three components is 77.50%, which satisfies the ASTM requirement for pozzolanic materials of minimum of 70%. MgO composition was found to be 1.82% which is less than 4% maximum limit, while CaO composition is 0.283% within the recommended range of ASTM C6I8-78. Similar results have obtained by several other researchers (Ikponmwosa *et al.*, 2009).

3.2. PHYSICAL PROPERTIES OF TERMITE MOUND SOIL

Specific gravity of TMS was found to be 2.4073 ± 0.01644. It is a significantly low specific gravity compared to that of Cement which is 3.15. From the chemical tests it is proven that Termite mound soil have pozzolanic properties. Low specific gravity is a great advantage for a cementacious material. Thus termite mound soil can be utilized or can be used as an additive in high strength light weight concrete constructions.

3.3. COMPARISON OF PHYSICAL PROPERTIES OF RECYCLED AGGREGATES AND NATURAL AGGREGATES

Table 3: Physical Properties of NA vs RA

Test	Natural aggregate value (%)	Recycled aggregate value (%)
LAAV	27	43.3
AIV	13	27.58
Water absorption	2.5	5.67

According to BS 882:1992, specifications of coarse aggregates for concrete, standard value for abrasion should not exceed 40%. The average value obtained for untreated recycled aggregates was 43.3% and that is slightly more than the limiting value while deviating highly from the value of natural aggregates which is around 27%.

AIV value for aggregates is not expected more than 30% in the standards and the value obtained for natural aggregates was 13% and the value for untreated recycled aggregates was 27%. It is evident that the AIV value lies within the desirable region and can be utilized for construction purposes.

The average water absorption of natural aggregates lies in the range of 2% to 2.5% but for untreated recycled aggregates the value was close to 6%. It is quite oblivious that recycled aggregates have higher water absorption capacity compared to natural aggregates. Approximately recycled aggregates have 55% higher absorption than the natural aggregates which are a quite high value compared to the specified value, 2%. This can be due to the amount of cement motor attached with aggregates and cracks within the aggregates.

According to the requirements of B.S. 882 aggregate grading was within the expected region. The passing percentage from the 20mm sieve was 89.93 which comply with the given range (85-100), passing percentage from 10mm sieve was 18.81 which also lies in the required range. Also the passing percentage from 5mm sieve was 2.78 which are expected to be between 0 and 5. Thus the recycled concrete aggregates from the Cowam recycling center have many desirable characteristics.

3.4. WATER ABSORPTION OF TREATED RECYCLED AGGREGATES

Table 4: Water Solid Ratio 1.0

Cement (%)	Soil (%)	Average Absorption (%)
20	80	4.13
40	60	4.41
50	50	3.49
60	40	4.81
80	20	4.76
100	0	4.49

In the real case the coating was thicker than both 1.25 and 1.5, and a neat finish could be obtained. It can be observed that all the aggregates treated with the water to solid ratio of 1 have water absorption values lower than before treating. The highest absorption was 4.81 which comprises from 40% soil and 60% cement and the lowest was 3.49 which comprises with similar soil and cement amounts. That can be noted as a significant reduction in absorption as this is very low absorption compared to the absorption value of recycled aggregates before treating. A standard T test was carried out for the results and the mean was 4.34833 with a standard deviation of 0.48803 having a calculated T value of -6.63364 which is less than -3.365, the standard T value for 99% confidence.

Table 5: Water Solid Ratio 1.25

Cement (%)	**Soil (%)**	**Average absorption (%)**
20	80	4.54
40	60	4.09
50	50	4.08
60	40	4.24
80	20	4.07
100	0	4.50

In this case the absorption values seem bit random with the varying soil amount. Still the absorption tends to become lower in the region where soil and cement present in similar quantities. It can be noted that all the absorption values are below than the absorption values of untreated recycle aggregates being 4.54 the maximum and the 4.07 the minimum. A standard T test was carried out for the results and the mean was 4.25333 with a standard deviation of 0.21612 having a calculated T value of -16.0564 which is less than -3.365, the standard T value for 99% confidence.

Table 6: Water Solid Ratio 1.5

Cement(%)	**Soil(%)**	**Absorption average (%)**
20	80	4.42
40	60	4.25
50	50	3.83
60	40	4.59
80	20	4.71
100	0	5.40

In this water solid ratio it is quite evident that the lowest absorption can be obtained when cement and soil present in similar amounts. The lowest absorption 3.83 is observed in the 50% soil and 50% cement stage while the highest absorption is reported when the cement percentage is 100% and without soil. So it proves that the soil has a considerable role in reducing the water absorption. It also evident that 80% soil is always got a higher absorption proving that too much of soil or soil alone cannot reduce the absorption in a significant level. A standard T test was carried out for the results and the mean was 4.5333 with a standard deviation of 0.52409 having a calculated T value of -5.3127 which is less than -3.365, the standard T value for 99% confidence.

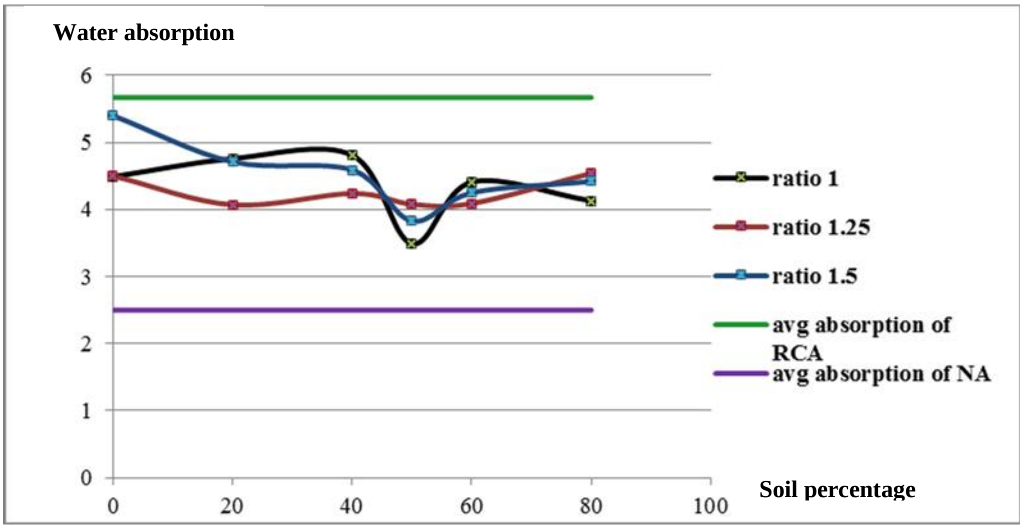


Figure 1: Variation of Water Absorption with the Soil Amount and Water Content

Based on the standard t test results all 3 sets of coatings have reduced the water absorption of recycled aggregates with a 99% level of significance compared to the water absorption value of recycled aggregates before treating. Further a significant reduction in absorption could be noticed in the 50% cement and 50% TMS stage in all 3 water solid ratios compared to other mix proportions and the least absorption was achieved in water solid ratio 1 as reflected in Figure 1.

3.5. *Comparison of Physical Properties of Recycled Aggregates and Natural Aggregates*

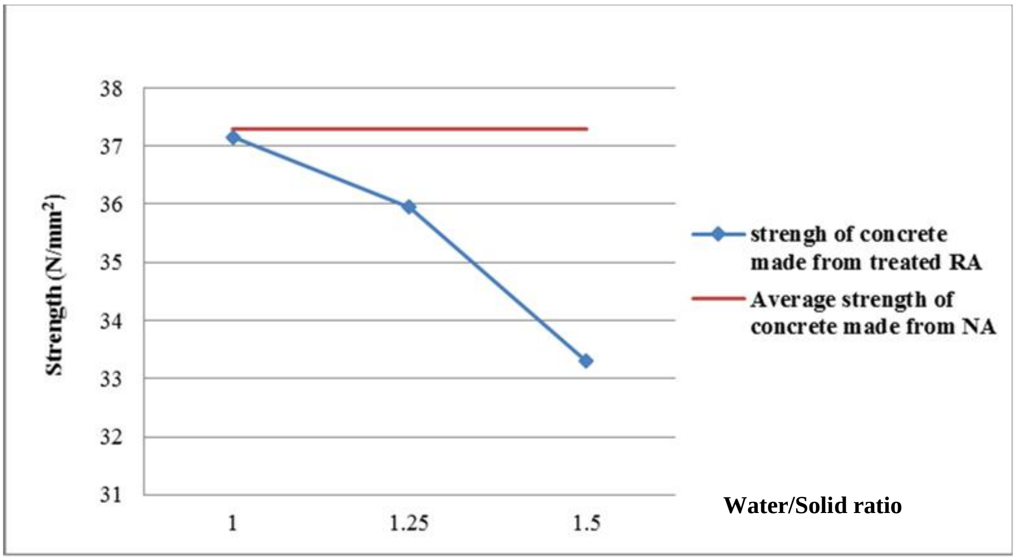


Figure 2: Variation of 28 Day Strength of Concrete with Water Solid Ratio of The Coating

The concrete was made under grade 30 mix design using 50% soil and 50% cement coating from all three water to solid ratios. The 28 day strength values are summarized in figure 2. The average strength value for concrete made from natural aggregates was 37.3N/mm^2 and the average strength values obtained for water solid ratios 1, 1.25 and 1.5 were 37.15 N/mm^2, 35.95 N/mm^2 and 33.3 N/mm^2 successively. It is evident that higher the slurry thickness higher the strength achieved.

4. CONCLUSIONS

From the results analysis and discussion it is evident that coatings made using mixtures of 50% cement with 50% Termite mound soil, at water/cement ratios of 1 and 1.5 can be used as a treatment method to reduce the water absorption of recycled aggregates up to 38.44%. Considering the 28 day strength of concrete made from successful aggregate batches it can be concluded that the aggregates treated with 50% and 50% soil under the water to solid ratio 1 is the optimum coating to reduce the water absorption while maintaining the design strength similar to those concrete made from natural aggregates.

From the research findings it is quite oblivious that termite mound clay can be used along with cement for treating recycled aggregates to reduce the water absorption of recycled aggregates. Termites are considered as pests and due to their activities wooden structures are degraded quickly. These mounds make no any economical value and are destroyed to control Termites. Thus Termite soil can be obtained freely or at a very low cost. Compared to the cost of natural aggregates this method is economical and can save the environment while at the same time giving a solution for managing construction waste.

5. RECOMMENDATIONS

1. Recycled aggregates have competitive properties similar to natural aggregates except water absorption and can be utilized for construction after treating.
2. Construction wastes must be properly sorted before processing as it could be noticed that in the recycled aggregates we used we could find lot of impurities such as tile pieces, Calicut tile pieces, glass and wooden pieces. It is recommended that a proper selection is required before crushing the demolished wastes to manufacture high quality recycled aggregates to meet the technical specifications.
3. From the research findings it can be recommended that termite mound clay can be used along with cement for treating recycled aggregates to reduce the water absorption of recycled aggregates.
4. Further researches are recommended to identify the variation of concrete strength with the addition of TMS. Also we could notice that higher the slurry thickness higher the strength leading to a question that addition of termite mound soil can increase the strength of concrete. Several studies have done on this matter and this makes it interesting for further investigation and research as the carbon foot print for cement production is very high.

6. REFERENCES

Ikponmwosa, E., Salau, M. and Mustapha, S., 2009. *Strength Characteristics of Concrete Beams with Cement Partially Replaced by Uncalcined Soldier-Ant Mound Clay.* In: Second International Conference on Advances in Engineering and Technology.

Otoko, G.R., 2014. A Solution to the Problem of Recycled Concrete Aggregates [online]. *International Journal of Engineering and Technology Research*, 2(4). Available from: http://www.ijeatr.org/IJEATR.org/IJEATR_Vol.%202,%20No.%204,%20April%202014/A%20SOLUTION.pdf [Accessed 10 May 2014].

Rahal, K., 2007. Mechanical Properties of Concrete with Recycled Coarse Aggregate [online]. *Building and Environment*, 42(2007), 407–415.

Kim, J.J., Youn S.H., Cho M.J., Shin H.T., Yoon J.B., Hwang K.H. and Lee D.S., 2005. *The Recycled Aggregates with Surface Treatment by Pozzolanics*. Nat'l: University,Korea.

Limbachiya, M.C., Koulouris, A., Roberts, J.J. and Fried, A.N., 2004. Performance of Recycled Aggregate Concrete. In: *RILEM International Symposium on Environment-Conscious Materials and Systems for Sustainable Developments*, RILEM Publications SARL.

Pelufo, M. J., Domingo, A., Ulloa, V. A. and Vergara, N. N., 2009. Analysis of Moisture State of Recycled Coarse Aggregate and its Influence on Compression Strength of the Concrete, In: *International Association for Shell* *and Spatial Structures (IASS) Symposium 2009*, Valencia Evolution and Trends in Design, Analysis and Construction of Shell and Spatial Structures.

Mijinyawa, Y., 2007. Termite Mound Clay as Material for Grain Silo Construction, *BC 07002*, 9(July 2007), 1-21. Agricultural Engineering International: the CIGR E journal Manuscript.

Malešev, M., Radonjanin, V. and Marinković, S., 2010. Recycled Concrete as Aggregate for Structural Concrete Production [online]. *Sustainability*, 2, 1204-1225. Available from: doi:10.3390/su2051204 [Accessed 10 May 2014].

Ranaweera, M. and Abeyruwan, H., 2007. *Materials Used in the Construction, Conservation, and Restoration of Ancient Stupas in Sri Lanka.*

Orie, O.U. and Anyata, B.U., 2012. Effect of the Use of Mound Soil as an Admixture on the Compressive Strength of Concrete. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS),*

Parekh, D.N. and Modhera, C.D., 2011. Assessment of Recycled Aggregate Concrete. *Journal of Engineering Research and Studies*, 2(1), 1-9.

De Medeiros (Jr), R. A., Fucale, S. P., Póvoas, Y. V. and Gusmão, A. D., 2009. Research Charactorizing the Physical Properties of Recycled Aggregate of Civil Construction Wastes. In: *11th International Conference on Non-conventional Materials and Technologies (NOCMAT 2009).*

Zaharieva, R., Buyle-Bodin, F., Skoczylas, F. and Wirquin. E., 2003. Assessment of the Surface Permeation Properties of Recycled Aggregate Concrete. *Cement and Concrete Composites*, 25, 223-232.

Scrivener, K.L., Crumbie, A.K. and Laugesen, P., 2004.*The interfacial transition zone (itz) Between cement paste and aggregate in concrete*. Switzerland: Polytechnique Lausane.

Tsujino, M. and Noguchi, T., 2006. *Study on the Application of Low-quality Recycled Coarse Aggregate to Concrete Structure by Surface Modification Treatment*. University of Tokyo

VACANT BUILDINGS IN INFRASTRUCTURE PROJECTS: STRATEGIES FOR REUSE

Vaishali Anagal*, Dharati Sote and Shamishtha Ruikar
Dr. B. N. College of Architecture, Pune, India

ABSTRACT

Vacant Buildings in infrastructure projects has become a serious environmental and economic issue in Indian planning scenario. Several instances of newly constructed unoccupied buildings indicate wastage of financial and environmental resources such as virgin building materials and most importantly land resource. Vacant vegetable markets constructed as a part of public infrastructure projects by municipal authorities in many cities particularly in the city of Nasik is a glaring example of such redundant investments in Maharashtra state of India. Large scale presence of abandoned, vacant and unoccupied buildings is resulting into an ineffective use of resources and increasing risk to first responders and the community. Vacant and abandoned properties, whether residential or commercial, are a drain on city budgets in addition to detracting from the quality of life, as well as the economic opportunities, of those living around them. They are an impediment to individual neighbourhood redevelopment and, ultimately, to achievement of city wide economic development goals. Minimizing the harm done by vacant and abandoned properties and restoring these properties to productive use are priorities for city planners across the globe.

This research attempts to quantify the amount of resources in terms of embodied energy invested into such projects using a case study method. It further evaluates the reuse potential of such built spaces to prompt the meaningful use of resources by investigating its structural capacity and architectural configuration. A spatial analysis with respect to adjacent land uses will also be done to identify the best suitable reuse of the case-study building. Finally, this research draws conclusions to suggest planning strategies to prevent building vacancy in public sector buildings and also reuse strategies for existing unoccupied buildings to evade wastage of environmental resources.

Keywords: *Building Reuse; Infrastructure Projects; Reuse strategies; Vacant Buildings.*

1. INTRODUCTION: VACANT BUILDINGS AND ASSOCIATED RISKS

Worldwide, building vacancy has been considered as a major socio-economic issue for local governments to tackle with. A vacant building poses a financial burden on local government in terms of its maintenance, fire safety and well-being of the neighbourhood in general. It is thus reflected in the definition of vacant building derived by various agencies.

The National Vacant Properties Campaign in Washington (NVPC, 2005) defines vacant properties as residential, commercial, and industrial buildings where a site poses a threat to public safety (meeting the definition of a public nuisance), or the owners or managers neglect the fundamental duties of property ownership (e.g., they fail to pay taxes or utility bills, default on mortgages, or carry liens against the property.) Here, vacant properties can include abandoned, boarded-up buildings; unused lots that attract trash and debris; vacant or under-performing commercial properties known as grey fields. On the other hand, some of the authorities and insurance companies define the vacant building based on the occupancy percentage and period of vacancy. For instance, in Building and Personal Property Form CP 00 10, the Insurance Services Office (ISO), 2009, Zurich, North America, a building is considered vacant unless at least 31% of its total square footage is rented to a lessee or sub-lessee to conduct its customary operations and/or used by the property owner to conduct customary operations. A report on Vacant & Abandoned

* Corresponding Author: E-mail - vmanagal@rediffmail.com

buildings in Oklahoma City views a building vacant if has had 30 percent or greater vacancy as identified in the U.S. Postal Service database or had its water, gas or electricity shut off for six months or more. Similarly, an ordinance issued by the city of Evanston on vacant buildings defines vacant buildings, especially those which remain boarded for more than six (6) months, are unsightly and diminish neighbouring property values and neighbours' sense of well-being, and are a public nuisance.

It is important to note that the term 'abandoned' and 'vacant' are interchangeably used, however, there is elusive difference between these terms (Abandoned Building Project, 2006; Botts, 2010). The dictionary meaning of 'vacant' is empty or unoccupied, whereas the dictionary meaning of 'abandoned' is surrendered or deserted. This difference is sometimes denoted with the status of ownership and sometimes with the status of the building. For example, a building that is unoccupied and has a viable owner who is interested in the property and can be easily contacted is considered vacant. On the other hand, a building that does not have a viable owner is generally considered abandoned (Abandoned Building Project, 2006). Coleman (2004), defines unoccupied building that is one with contents, but no humans inside at the time of fire, whereas, vacant building is one that is with no (or only a few worthless) contents inside. These definitions are developed to understand the life risks and conservation potential in the building for fire department in the Toledo, Ohio State, U.S. Abandoned buildings are considered to be in the state of grave disrepair, perhaps boarded up, strewn with trash, and scrawled with graffiti (Shane, 2011).

Vacant buildings are considered as shelters of criminal activities, hazard for public safety and often victims of vandalism, theft and fire casualties. They create nuisance in surrounding neighbourhood through their unsightly appearance. (An Ordinance, the city of Evanston; A report on vacant Properties, US, 2011; Halvey, 2009). Vacant buildings are a huge burden on local authorities for maintenance, fire brigades and police departments to encounter the theft and other illegal acts. (An Ordinance, the city of Evanston; Vacant Properties-The True Costs to Communities, 2005) A vacant building does not only depreciate its own value, but also devaluates the properties and lead to blight in the surrounding neighbourhood. (How Can Municipalities Confront the Vacant Property Challenge? ,2010)
The vegetable markets that are studied in this research are 'unoccupied' since its inception, have a viable owner (Local Municipal Authority), are structurally in sound condition and therefore are considered as 'vacant buildings'.

2. ENVIRONMENTAL IMPACT OF VACANT BUILDINGS

Researchers in construction industry have always been inquisitive about assessing the environmental impact of built forms. Life Cycle Analysis has been regarded as a tool to evaluate the environmental impact of buildings over its life cycle i.e. from raw materials to final disposal of the product. The environmental impact of a product is assessed in terms of atmospheric emissions, waterborne waste and solid waste (Williams, 2009). In case of vacant buildings, since its full life cycle is not being realized, it is difficult to carry out its life cycle analysis. In addition, it is highly challenging to calculate the atmospheric emissions that a building releases during its vacancy. However, there is a common agreement on the building's negative impact on the environment throughout its life cycle.

In designing a life cycle analysis, the inputs and outputs of a process or product are clearly defined where inputs include energy and raw materials and outputs include various types of products and wastes. (See figure no.1).The concern with regards to vacant buildings is resource investments in terms of energy and materials till the construction completion stage. Since the building is not in operation, operational energy is almost negligible for these vacant buildings. However, there are investments incurred in terms of energy and finance for maintenance purpose. In this research, embodied energy in the building till construction completion stage is considered as one of the parameters of this resource consumption. The energy calculations for case-study building indicated that 26251445 MJ i.e. 7010 MJ/Sq. M. embodied energy is consumed by the case-study building (See Annexure). Looking at the average 20% rate of vacancy in vegetable markets in urban area of Maharashtra State, the overall resource wastage that occurs due to the building vacancy of these markets can be anticipated.

It should be noted that the land as an important resource has not been discussed yet. In urban areas, where land scarcity is a roaring issue, wastage of land through vacancy cannot be tolerated. If vacancy of existing built stock continues, there would be additional resource consumption in the construction of buildings for same purposes which will have its own economic and environmental repercussions. This research emphasizes on meaningful utilization of these resources.

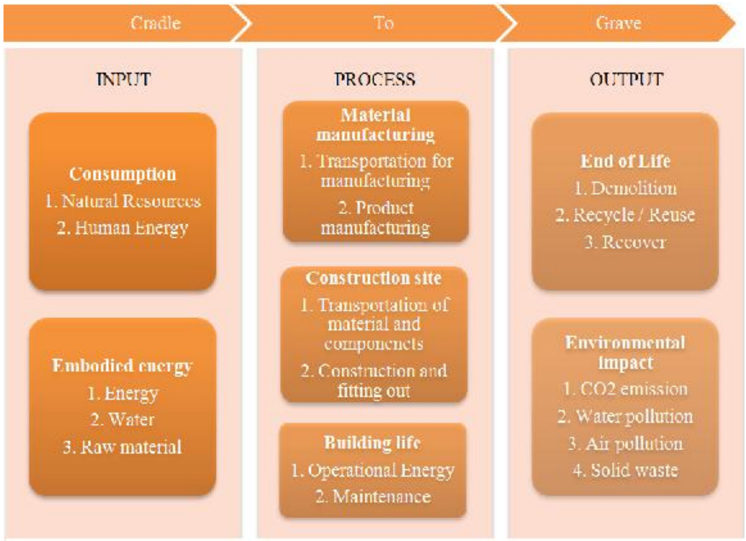


Figure 1: Life Cycle Analysis of Building Block
Source: Adapted from Williams (2009)

3. VACANCY IN INFRASTRUCTURE PROJECT IN MAHARASHTRA

In Maharashtra state of India, 20% of existing markets built by local municipal authorities are laying vacant waiting for vendors to occupy their stalls (See figure no.2). Municipal corporations have already invested land as the most precious resource and also the administrative and financial resources in these properties. In addition, their administrative and financial resources are being further exhausted by legal battles with vendors who have simply denied occupying these buildings. In the absence of any regulations to address the issue of safety, maintenance and reuse of vacant buildings, managing these buildings has become financially a daunting task for municipal corporations. Thus, these public buildings have turned out to be ‘No man’s Land’ and havens of illegal activities at the same time.

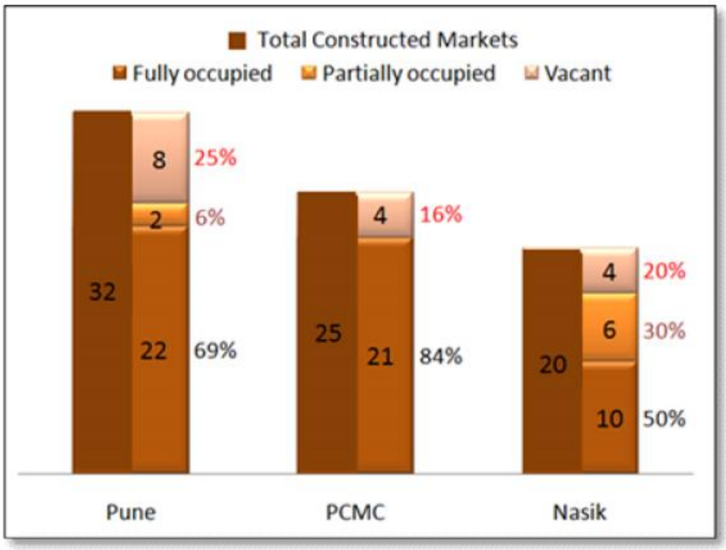


Figure 2: Vacancy in Vegetable Market in 3 Major Cities in Maharashtra
Source: Adapted from Mandai Market Department, PMC, PCMC,NMC (Dept- of Taxes,), and Site survey.

This research aims on identifying the reuse potential of these markets to bring life to the redundant building and to negate its socio-economic and environmental impact. It also interrogates the deficient planning process that is devoid of participatory approach and long term sustainability goals.

4. METHODOLOGY

This research adopts a case study method to study the factors responsible for vacant vegetable markets. Case study is selected from the city of Nasik where financial and resource investments were quite high. Structured interviews were conducted with vendors, customers and officials in Nasik Municipal Corporation to study the reasons of unoccupied vegetable markets. The intentions of these interviews included to gauge the possibility of continuing the use of the building for intended purpose and also to obtain the insight into guidelines for future planning that focuses on preventing building redundancy. Further, socio-economic and environmental impact of vacant buildings is studied with respect to case-study building. To analyse the environmental impact of vacancy in a typical vegetable market, embodied energy of the building has been considered as an indicator. It is highly essential to evaluate reuse potential of these vacant markets so that resources invested in these built structures can be efficiently recovered. To identify the reuse potential of the case study building certain filters are being used. Initially, a spatial analysis was done to understand the existing land-use. A spatial analysis was complimented with a study of development plan (1996-2016) provisions and population studies. This triggered various options of building uses that can be employed based on the needs of the population. However, building cannot sustain all of these uses structurally for which it is not designed. Therefore, it was essential to carry out a structural analysis of the building to examine what type of function will be supported by the existing building. This process facilitated further filtration of proposed reuses and finally, architectural configuration was studied to assess what type of reuses are most suitable so that building can be well adapted to new uses with minimum destruction and additions to conform Development Control Rules. Thus, the methodology adopted in this research for the assessment of reuse potential of existing vegetable market offered insight into defining strategies for adaptive reuse of existing vacant markets and can be widely applied to public infrastructure projects. The higher rate of vacancy in these types of public projects poses a question on the existing planning process. Therefore, at the end, this research also suggests recommendations on shifting the planning approach in infrastructure projects.

5. CASE STUDY

5.1. INTRODUCTION

Nasik, a third largest city after Mumbai and Pune is important city in Maharashtra State with its socio-cultural and economic context. A city with more than 1.4 million populations has been earmarked as a part of The Delhi Mumbai Industrial Corridor (DMIC) project. Nasik, also recognized as Vine Capital of India plays a significant role as an exporter of vegetable produce.

Nasik Municipal Corporation (NMC) is a local governing body in the city which is responsible for planning, development and maintenance of public infrastructure as per Maharashtra Regional and Town Planning Act (1966). Out of 26 existing markets, the city corporation has developed 20 built vegetable markets in the city as a part of public infrastructure projects. Out of these built markets only 50% markets are successfully operating with its full occupancy. (See figure 3). In 30% of the markets, only few of the vendors have occupied their stalls and these markets are partly used. Some of the markets are provided with platforms for vendors with storage space underneath and roof (steel truss with sheet roofing) above, whereas some of the markets are enclosures with Reinforced Concrete framed structures with staircase and toilets. A selected case-study of Ganghat market falls under later category with a footprint of 3745.06 Sq.M.

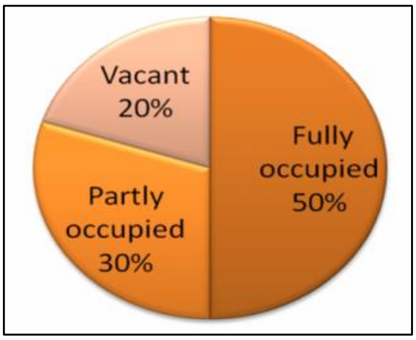


Figure 3: Vegetable Markets in Nasik
Source: Adopted from NMC (Dept- of.Taxes,), Site survey

5.2. BACKGROUND

The traditional vegetable market is located on the bank of river Godavari which was established during Peshwa regime in 1818. The existence of this market can be revealed in the gazette of the British Government. Since the vegetable market has its existence for more than 200 years, it is ancestral occupation of many of the vendors. It was the only vegetable market in the city until last 25 years and used to serve the entire city. Although, there are number of markets developed by Nasik Municipal Corporation in various parts of the city, few customers from distant locations regularly visit this market. Almost 600 vendors run their business at this location under temporary shelter and cater mainly to the population in down town area. (Old Nasik) (See Figures 4 and 5).

A new vegetable market was constructed since there is a dearth of infrastructure including potable water, toilets, solid waste disposal at the existing market. In addition, the existing market adds to the pollution of the river due to waste water and solid waste disposal (See Figure 6). The paucity of parking space for vendors and customers lead to traffic problems and air pollution.

Figure 4: Aerial Vew Figure 5: Temporary Shade Devoid of Infrastructure
Photo Courtesy: Ruikar Sharmishtha

In 2009, a new market was built at 200m distance on south-eastern side of existing market with an aim to reduce the nuisances of existing market and to provide better infrastructure to both the vendors and customers, to shift the vegetable market permanently from the river bank (See Figure 7)

Figure 6: Pollution in River :
Water Waste and Solid Waste Disposal

Figure 7: Location of Two Markets

Photo Courtesy: Ruikar Sharmishtha

Located on 12 meter wide Mahatma Phule road and accessible from all three sides of city namely, Ganeshwadi (Panchavati area), Gadgemaharaj Bridge (New city area) and Gangaghat (Malegaon stand), Gagaghat vegetable market is RCC framed single story structure with provision of vertical expansion of additional 3 floors. The market facilitates built platforms with storage facility for vendors, separate washing areas for vegetables, finished flooring with floor drains for maintaining hygiene and a toilet block separated from the main structure and parking facility for vendors and customers (See Figures 8 and 9). The architectural planning offers the view of all the vendors at a glance from the entry point. Despite the fact that a new facility provides much better infrastructure as compared to the existing one, vendors were highly rigid to shift. They moved the court against the NMC and the court had given its verdict in favor of vendors in 2012.

Figure 8: Platforms for Vendors in New Market

Figure 9: Toilet Block in New Market

Photo Courtesy: Ruikar Sharmishtha

5.3. FACTORS THAT ARE RESPONSIBLE FOR BUILDING VACANCY

The structured interviews with vendors revealed that there was a lack of participatory approach in planning. The vendors were not taken into confidence by local municipal authority in planning and designing stage of new vegetable market. There was neither any participation in terms of deliberations nor in terms of any financial involvement of the vendors in the entire process. Vendors also raised an issue of inaccessibility of new market for aged and differently able customers since the new market has a high plinth (40 steps) from temple side without any provision of ramps. (See figure 10). The new location is being perceived as a high risk of losing business by the vendors, as against the existing market which is located next to the temple where people buy vegetables on their way to home. The proposed use of the land where existing market is located is not revealed by the municipal authority and hence, there is apparent risk in the minds of vendors that this land will be encroached by new vegetable vendors and the business in the new market will be at loss. This uncertainty of business is leading to the apprehension regarding the new market for the vendors.

Figure 10: New Market with Entrance Steps
Photo Courtesy: Ruikar Sharmishtha

In the planning process when the reservations for public amenities are proposed, the vacant lands under the ownership of municipal authorities are given priorities for new proposals in the development plans to avoid the heavy compensation liabilities and also the lengthy bureaucratic and legal processes against the land acquisitions of private lands. In urban areas where the paucity of land is a major issue, available lands in the hands of public sector are reserved for public amenities. In such a constrained situation, other factors of planning such as convenience of people are overlooked which results into vacancy in infrastructure projects.

Vegetable market has been viewed as a convenient shopping in Indian scenario. Therefore, 'Convenience' of customers is the 'key word' and plays a significant role in planning and design of vegetable markets. Historical evidences reveal that vegetable markets have always been an open air and road side activity where senior citizens, housewives and working people buy the vegetables on the way to their home after finishing their routine works. The study of vacant markets in 3 major cities in Maharashtra state demonstrates that the justification of vacancy is associated with the inconvenience of customers which affect the business of vendors on account of flawed planning processes.

5.4. SOCIO-ECONOMIC IMPACT

As discussed in the literature review, vandalism, fire and thefts are common issues in vacant sites. The vegetable markets constructed by corporations are public buildings and semi-open structures that cannot be locked and hence, are accessible to everyone. Thus, these buildings become 'home' of 'homeless' people. Easy access for the vandals in vacant buildings leads to annoyance of litter, damage, illegal and criminal activities and threat to the public safety. (See Figures 11 and 12).

Figure 11: 'Home' of 'Homeles' Figure 12: Deterioration of Paving and Compound Wall
Photo courtesy: Ruikar Sharmishtha

5.5. IDENTIFYING REUSE POTENTIAL OF NEW MARKET

With a view to reduce the socio-economic and environmental burden of vacant buildings, it is imperative to evaluate existing built stock for its reuse potential and reclaim these buildings for new purpose. In some instances, a partial reuse of vacant markets has been observed in Maharashtra state. Ganeshwadi vegetable market is being partially used as a local library (See Figure 13) However, a scientific approach in identifying a new function is lacking since the reuse is focused more on economic considerations that is the financial returns from the reallocated function.

Figure 13: Ganeshwadi Market.
Photo courtesy: Ruikar Sharmishtha

5.6. SPATIAL ANALYSIS

A scientific approach to recoup these redundant markets necessitates a comprehensive study of its spatial setting to understand its accessibility and proximity, existing land use zoning to recognize compatibility of proposed functions, population studies to identify their needs, and provisions in developments plans that have not yet been realized and development control regulations so that additional requirements of proposed uses to adhere to these rules can be identified.

The reuse of vacant lots and abandoned buildings could provide cities with excellent opportunities of mixed-use neighbourhoods that are walk-able and pedestrian friendly (Schilling J.M.). City and neighbourhood plans can provide a framework through which to evaluate commercial property reuse alternatives. While determining property reuse alternatives, the long-term vision and policy goals for the area and the preferences of neighbourhood population, present and future market demand for various uses, public sector costs for uses and availability of resources, and developer interest in specific uses for the property needs to be considered (Eppig *et.al.,* 2014).

The interviews with customers of existing market indicated that this market serves the population of around 100 thousands which is located in the radius of around 1.5 km. Existing public amenities in this radius were also located by studying existing land use to identify the gaps. Majority of land-use is dominated by residential zone with amenities such as schools, public library, theatre, cinema hall, community halls, grocery shops (wholesalers), Health Care facilities, post office and banks etc. (See Figure 14).

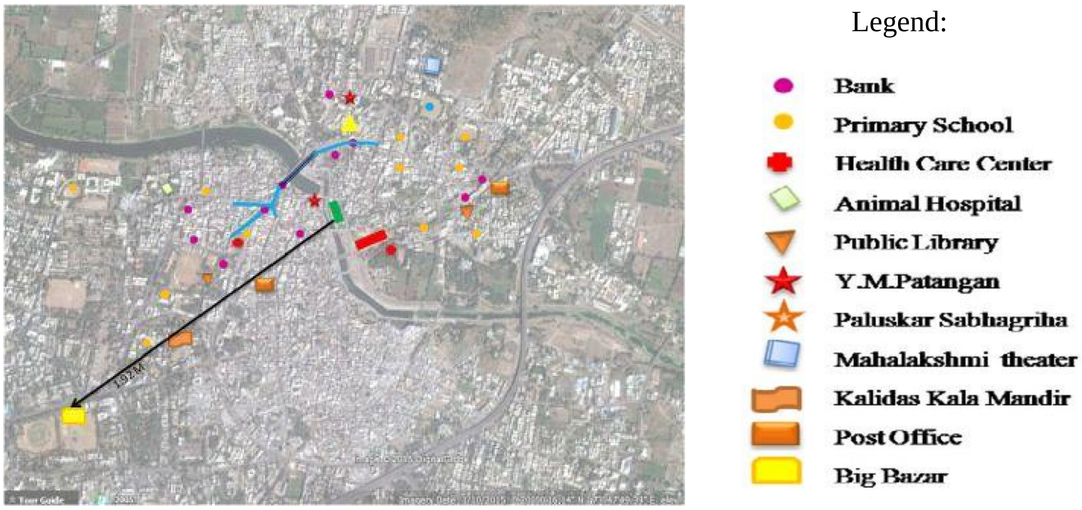


Figure 14: Spatial Analysis in the Surrounding Neighbourhood

This prompted few reuse alternatives that can be assigned to the vacant buildings:

Table 1: Proposed Uses and Their Rationale

Sr. No.	Proposed Reuse	Rationale	Social Benefits
1	Small Scale Industry for Women	The site has a slum in the proximity. A small scale industry will provide employment opportunity for women from economically weaker section of the society.	Social upliftment and Women Empowerment
2	Vedic School (School of Traditional Hindu Rituals Learning)	Nasik has its great historical and cultural values. Located on the bank of river Godavari, site has advantage of natural setting and is best suitable location for Vedic School.	Historical and cultural context of Nasik sets a great advantage for running Vedic School to boost his traditional culture.
3	Yoga Center	This facilitates a complimentary role to Vedic School that Boosts Indian Traditional Physical Education.	Fitness and good Health for all age groups
4	Gymnasium	A well-equipped Gymnasium is not available for sportsmen and young generation in the vicinity	Fitness and good Health for all age groups
5	Music School	In the radius of 1.5km there is no Music school where Indian Traditional or other forms of Music are taught.	Propagating Indian Music and other forms of music to new generation.
6	Agriculture Information Center and Sales	Nasik is one of major exporters of agricultural produce.	Agricultural Information Center and Sales will cater to the farmers in Nasik Region.
7	Retail Shopping Centre	The area is served by wholesalers' shops. Retail Shopping facility under one roof is not available.	Population can get better shopping experience along with eatery places.
8	Industrial Training Institute	Residential area is by middle and low income group. This facility can serve to the population in Nasik Region.	It can provide skill set to the young generation for job opportunities and self-employment.
9	Banks	Although there are few banks in this area, co-operative/ nationalized banks have opportunity to establish their extension counters.	Financial empowerment of local residents.
10	Offices	The surrounding area does not have buildings exclusively designed as office buildings. Growing city like Nasik requires commercial buildings.	Support to the local businesses.

5.7. STRUCTURAL ANALYSIS

The alternative reuses that is outcome of above-mentioned study needs to be supplemented by the structural analysis of the said building to examine whether it supports a particular function. To assess the structural potential of the case study building interviews with practicing structural engineers were conducted. Experts were provided with architectural and structural drawings of the building. Experts suggested that structure can be reclaimed by any commercial activity where loading conditions are upto 400kg/Sq. M. Industrial Training Institute requires heavy machineries in the training workshops, hence cannot be supported at upper floors. Also, if this use is considered at ground floor, it will require machine foundations at ground level and thus, requires significant intervention. The bank can be allotted without a vault at any floor. Gymnasium which necessitates accommodating heavy equipment can be accommodated at ground floor. Structural analysis ameliorated the filtration process of the proposed reuses.

5.8. ARCHITECTURAL CONFIGURATION

A vegetable market with RCC Framed structure having 10 bays with column grid of 5.7 X 5.7m and 7.6m centre to centre distance between columns of adjacent bays (See figure no. 15)and a clear floor height of 4.3m can complement above mentioned proposed reuses. 7 numbers of staircases planned on the periphery of the structures provides a separate access for each bays on upper floors. This can easily facilitate mixed use development within a same structure. Although a structure lacks provision of toilet blocks to conform to Development Control (DC) rules for the proposed reuses, the side margins in the site offers opportunity of addition of toilet blocks as per DC Rules. The existing building is semi-open building which does not have façade on any of its sides. Any commercial reuse would require a well-designed façade that can attract businesses. Thus, a building entails few additions such as services in terms of elevators, sanitary facilities, electric services and data cabling to support offices and a façade. It also necessitates removal of existing platforms designed for vegetable sales.

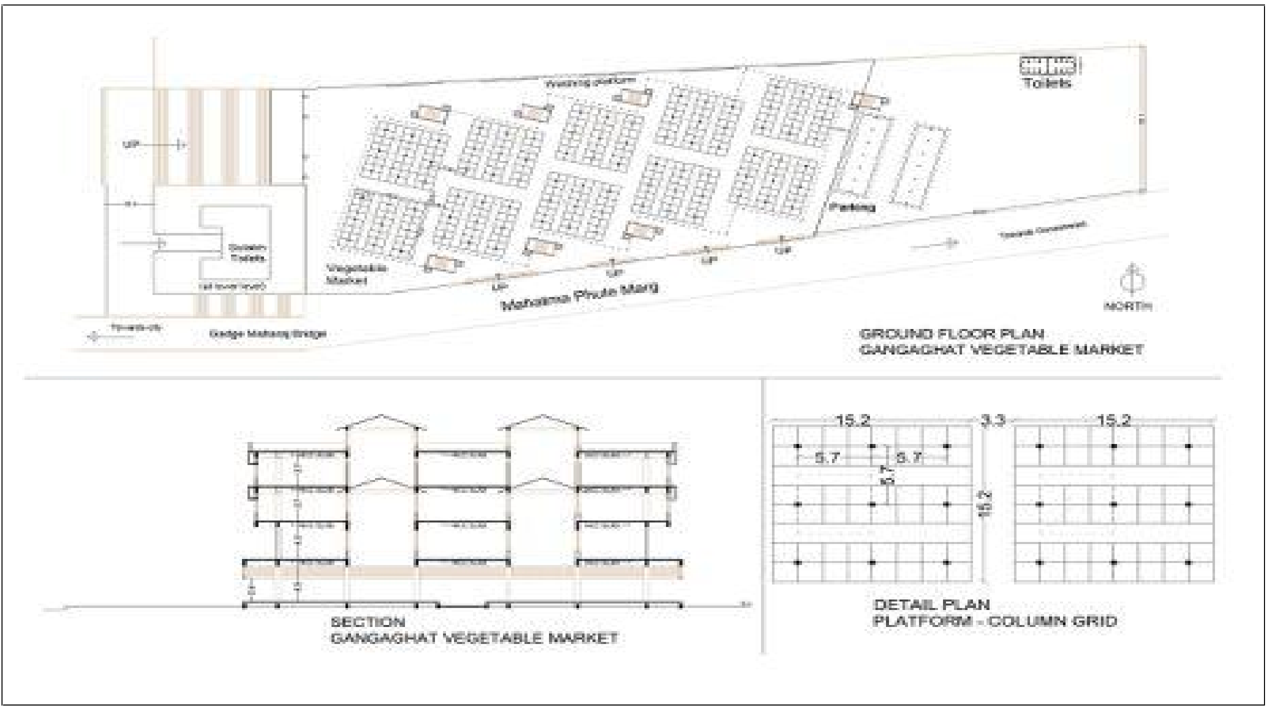


Figure 15: Plan and section of vegetable market.
Source: Architects Sanjay Dhumne Associates, Nasik, Maharashtra

5.9. COMPATIBILITY STUDY AND RESULTS

A simple grid planning offers an opportunity to reconfigure the existing market to adapt to the proposed reuses. From the structural analysis and study of architectural configuration, it can be deducted that Industrial Training Centre cannot be provided in this building, whereas Gymnasium can be provided at ground floor level. The proposed reuses suggested in Table 1 are not exclusive. The larger floor plate allows mixed use development depending on their compatibility. This further prompts to a compatibility study of different functions which can be conceded together on one floor as follows:

Table 2: Floor wise Proposed Uses

Sr. No.	Floor	Proposed Reuses	Alternative Reuse
1	Ground Floor	Retail Shopping centre, Small scale industry for women and their sales counter	Vedic School, Yoga Centre, Gymnasium, Music School
2	First Floor	Offices, Extension counters of Bank, Post Office	
3	Second Floor	Agriculture Information Centre and sales	
4	Third Floor	Few Departments of Nasik Municipal Corporation, Post office	

With the involvement of prospective users, these reuses can be finalised based on common consensus and financial benefits to the municipal corporation. With the aim to reduce the financial burden on Municipal Corporation to develop and maintain these properties and to reduce risks of building obsolescence, appropriate decisions on reuse of existing vacant buildings can be taken.

6. DISCUSSION

Although a simple grid planning can support above mentioned reuses; certain additions and demolitions that are essential for future reuses demands investments in terms of new material and financial resources. In Indian Scenario, local governments are always in the deficit of financial resources. These new requirements will certainly pose additional burden on their machineries. Therefore, there is great requirement of mechanisms that can augment financial resources on one hand and revitalize cities by creating vibrant commercial spaces through reclamation of vacant buildings on the other hand.

There is every possibility these proposed reuses may fail in the absence of participatory processes. Public- Private Partnerships and community organizations can play a significant role in these rejuvenation projects if involved throughout the stages of initial planning, funding and execution. Private partners who could be potential users of the proposed mixed use developments can be involved while conceiving the ideas of new proposals to understand their preferences, concerns and ensure the occupancy for the new functions. Public participation through community organizations is also equally important to give them a sense of inclusion and understand their felt needs and aspirations. It has been observed through a case study that although, MRTP act envisage public participation in planning process, participatory process of all stakeholders is lacking due to negligence of both the parties - government and stakeholders resulting into redundancy of infrastructure projects. The case studies of vacant markets in these 3 cities also indicated that since there was no financial involvement of vendors in the project, there was no consciousness about the utilization of the infrastructure. Participation of potential users (Entrepreneurs, Vendors) in planning limited to conceptualization of project will give them a sense of inclusion, whereas monetary contribution in the project will give them a sense of belonging and accountability.

7. REDEFINING PLANNING APPROACH TO PREVENT BUILDING VACANCY

The significant percentage of building vacancy in vegetable markets in Maharashtra State and case-studies suggest that there is need to redefine planning approach towards infrastructure projects. The planning clues conceived from historical and cultural context are essential in any planning projects. Public infrastructure is intended for public use and therefore, stakeholders' involvement in planning process would ensure the success of such projects. Stakeholders' contribution should not be confined to idea board; rather it should be extended to financial involvement. In other words, there should be shift in governments' role from provider to catalyst. Public infrastructure is developed through public funds and resources, therefore it is crucial to design it with the perspective of long term use and hence, mixed use developments and adaptive reuse should form design priorities so that optimum utilization of resources can be realized throughout its life cycle.

8. REUSE STRATEGIES FOR EXISTING VACANT BUILDINGS

With the prospect to retrieve the resources consumed in existing vacant building following strategies are recommended for their reuse as an outcome of this research based on case-studies and literature:

1. Formulation of regulation for vacant buildings to address the issues of security, fire safety, maintenance and possession of vacant properties
2. Development of inventory of existing vacant built stock with their documentation of physical status though photographs, architectural and structural drawings, age, building footprint, access to the building, availability and status of provision of parking, vertical access and services such as water supply, electrification, drainage and sanitation, etc.
3. Preparation of a report of each of the building including land use zoning in surrounding areas, amenities in proximity of the building and population studies etc.
4. Evaluating vacant buildings for its reuse potential using spatial analysis to study market demands, structural analysis to study its technical potential to sustain a particular function and studying architectural configuration to assess spatial flexibility for intended reuse.
5. Defining best suitable reuse of the building based on socio-economic and environmental considerations.
6. Encouraging receivership to allow private sector participation and other stakeholders involvement in reuse project to lessen the financial liabilities of local government.
7. Sharing economic benefits of reclaimed projects through public private partnerships.

9. CONCLUSION

The shift in planning approach recommended in this research will certainly reduce the rate of building vacancy. There is also a need to change the design approach from designing buildings for too specific purpose to designing building for generic purpose in the public sector by adopting design strategies for adaptive reuse. A vacant properties bank can be developed using above mentioned strategies which can aid in combating land scarcity in urban areas and serve as a land management tool. Vacant properties also offer an opportunity for local government to employ these building to Development Plan provisions which have not yet been realized and thus, reduce the financial burden of acquisition of land and construction of other public amenities. Commercial properties can be effectively rejuvenated and brought back to vibrant social life through private and community participation. The financial benefits can be pocketed by all the stakeholders and thus, can create a win-win situation for all. Strategic reuse of buildings can convert unsightly and hazardous vacant buildings which are considered to be financial, administrative and social nuisance into fostering economic opportunities for both the society and local government.

It should be noted that, there is a scope for further research on a development of tool that can assist in weighing proposed reuses based on socio-economic and environmental considerations.

10. REFERENCES

An Ordinance, Adding a New Chapter 20 to Title 4 of the City Code, "Vacant Buildings" [online], 2004. Available from: http://www.cityofevanston.org/pdf/vacant_buildings_ordinance.pdf [Accessed 29 March 2015].

Atlanta Regional Commission Staff, 2011. City of Alpharetta Strategies for Vacant Commercial Property Re-Use [online], Available from: http://www.google.co.in/atlantaregional.com/Library/Services/community/choices/alpharetta.pdf/ [Accessed 1 April 2015].

BJA, n.d. *Addressing Foreclosed and Abandoned Properties* [online]. Available from: www.courtinnovation.org [Accessed 4 April 2015].

Botts S. M., 2010. *Analyzing the Problem of Abandoned, Vacant and Unoccupied Buildings in Middletown, Ohio* [online]. Available from: https://www.usfa.fema.gov/pdf /efop /efo44528.pdf [Accessed 12 April 2015].

Cleveland City Planning Commission, n.d. *Ideas for Vacant Land Re-Use in Cleveland* [online]. Available from: http://www.google.co.in/ Ideas for vacant land re-use in Cleveland.pdf [Accessed 25 March 2015].

Coleman, J., 2004. *Fighting Fires in Vacant Occupancies* [online]. Available from: http://www.fireengineering.com /articles/print/volume-157/issue-4/departments/roundtable/fighting-fires-in-vacant-occupancies.html [Accessed 12 April 2015].

Communities and Local Government, 2012. *New Opportunities for Sustainable Development and Growth through the Reuse of Existing Buildings, Consultation* [online]. Available from: https://www.gov.uk/government/uploads/system/ uploads/attachment_data/file/8351/2171937.pdf [Accessed 2 April 2015].

Community Safety Initiative_LISC_CSI, n.d. Combating Crime Problems Stemming from Foreclosed and Vacant Properties [online]. Available from: http://www.google.co.in/ _safety_topics_asset_upload_file.pdf [Accessed 28 March 2015].

Enconsult Corporation, Penn institute for urban research, 2010. *Vacant Land Management in Philadelphia, Final Report, The Cost of the Current System and the Benefits of Reform, Prepared for Redevelopment Association of Community Development Corporations* [online]. Available from: http://planphilly.com/uploads/media_items/http-planphilly-com-sites-planphilly-com-files-econsult_vacant_land_ full_report-pdf.original.pdf [Accessed 20 March 2015].

Energy Analysis and Saving Technologies: Life Cycle Energy Analysis (LCEA) of Building Construction [online], n.d. Available from: http://www.emsd.gov.hk/emsd/eng/pee/lceabc.shtml [Accessed 7th April 2015].

Marianne, E. and Brachman, L., 2014, *Redeveloping Commercial Vacant Properties in Legacy Cities, A Guidebook to Linking Property Reuse and Economic Revitalization* [online]. The German Marshall Fund of the United States and Greater Ohio Policy Center. Available from: https://www.mml.org/resources/sample_docs/ordinances/blight/toolkits-and-reports/redeveloping%20commercial%20vacant%20prop-may14.pdf [Accessed 28 March 2015].

GSBS Richman Consulting, 2013. *Final Draft, Addressing Vacant and Abandoned Buildings in Oklahoma City, Prevalence, Costs + Program Proposal* [online]. Available from: http://www.okc.gov/documents/ vacant%20and%20abandoned%20home%20study.pdf [Accessed 29 March 2015].

Mike, H., 2009. *Protecting your Vacant Building: How to Reduce the Risks and Become More Aware of Coverage Pitfalls* [online]. 2009 Zurich Services Corporation, Real Estate Practice Leader, Zurich in North America. Available from: http://www.zurichna.com/internet/zna/SiteCollectionDocuments/en/media/whitepapers/RECold2AvacantpropertyWhitepaper.pdf [Accessed 26 March 2015].

How Can Municipalities Confront the Vacant Property Challenge?, 2010. *Report by Business and Professional People for the Public Interest, Chicago Metropolitan Agency for Planning, Metropolitan Mayors Caucus* [online]. Available from: https://www.google.co.in/How+Can+Municipalities+Confront+the+Vacant+Property+Challenge.pdf [Accessed 6 April 2015].

IAAI/USFA Abandoned Building Project, 2006. *Managing Vacant and Abandoned Properties in Your Community* [online]. Available from: https://www.firearson.com/uploads/Background-Paper.pdf [Accessed 3 April 2015].

National Vacant Properties Campaign, Creating Opportunity from Abandonment, 2015. *Vacant properties, the True Costs to Communities* [online]. Available from: http://www.smartgrowthamerica.org/documents/true-costs.pdf [Accessed 25 March 2015].

Orange County Planning, n.d. *Adaptive Reuse of Vacant Properties, Smart Growth Principles at Work* [online]. Available from: http://www.cityofnewburgh-ny.gov/sites/newburghny/files/u98/orange_county_planning_department.pdf [Accessed 1 April 2015].

Planning Property and Development Department, n.d. *Vacant Buildings* [online]. Bylaw No. 79/2010. Available from: http://www.winnipeg.ca/ppd/pdf_files/bylaw79-2010.pdf [Accessed 3 April 2015].

Preservation Green Lab and Urban Land Institute, Philadelphia, 2014. *Retrofitting Philadelphia*: *The Partnership for Building Reuse* [online]. Available from: http://www.preservationnation.org/information-center/sustainable-communities/green-lab/partnership-building-reuse/04614-NTHP-Philadelphia-WEB-FINAL.pdf [Accessed 3April 2015].

Schilling, J. M., n.d. *The Revitalization of Vacant Properties - Where Broken Windows Meet Smart Growth* [online]. International City/Country, ICMA Management Association. Available from: http://www.usmayors.org/brownfields/ library/Revitalization_of_Vacant_Properties.pdf [Accessed 30 March 2015].

Shane, J.M.,n.d. Abandoned Buildings and Lots, Guide No. 64, The Problem of Abandoned Buildings and Lots, Available from: http://www.popcenter.org/problems/abandoned_buildings_and_lots/http://www.popcenter.org/ problems/abandoned_buildings_and_lots/ [Accessed 12 April 2015].

Shane J.M., 2011. Abandoned Buildings and Lots. *22nd Annual Problem-Oriented Policing Conference Miami*, Florida October 10-11, 2011.

The United States Conference of Mayors, 2006. *Combating Problems of Vacant and Abandoned Properties Best Practices in 27 Cities*.

The United States Conference of Mayors, 2008. *Vacant and Abandoned Properties, Survey and Best Practices* [online]. Available from: www.usmayors.org [Accessed 12 April 2015].

United States Government Accountability Office, GAO, 2011. *Vacant Properties, Growing Number Increases Communities' Costs and Challenges, Report to the Ranking Member, Subcommittee on Regulatory Affairs, Stimulus Oversight, and Government Spending, Committee on Oversight and Government Reform, House of Representatives* [online]. Available from: http://www.gao.gov/assets/590/586089.pdf [Accessed 4 April 2015].

Way, K., McCarthy, M. and Scott, J., 2007. *Building Hope: Tools for Transforming Abandoned and Blighted Properties into Community Assets, a Report on Dallas, Texas*. Prepared for: Builders of Hope

Luke, W., 2011. Vacant Property: Strategies for Redevelopment in the Contemporary City, Georgia Institute of Technology, MCRP.

Williams, A, 2009. *Life Cycle Analysis: A Step by Step Approach* [online]. University of Illinois at Urbana Champaign. Available from: http://www.istc.illinois.edu/info/library_docs/TR/TR040.pdf [Accessed 24 March 2015].

Willis, 2010. *Strategic Outcomes Practice, Technical Advisory Bulletin* [online]. Available from: www.willis.com [Accessed 6 April 2015].

ANNEXURE 1: EMBODIED ENERGY CALCULATION

		Material	Location	Specification	Unit	Quantity	Embodied Energy of material		Total Embodied energy	
1		Steel		Recycled						
	a		Reinforcement in structural members in Ground Floor and First Floor	Galvanised from ore	MT	398.80	MJ/Kg	25	MJ	997000.00
	b		Entrance gate, Skylights	Galvanised from ore	MT	28.00	MJ/Kg	25	MJ	70000.00
	c		Shutters, Grill, Railing	Galvanised from ore	MT	420.00	MJ/Kg	25	MJ	1050000.00
2	a	Concrete with Portland cement	Pile and Pile cap	Structure, reinforced	CuM	421.94	MJ/Kg	1.5	MJ	1518984.00
	b		Upto Plinth	Structure, reinforced	CuM	1363.35	MJ/Kg	1.5	MJ	4908060.00

	c		Upto First Slab	Structure, reinforced	CuM	1213.72	MJ/Kg	1.5	MJ	4369392.00
	d		Upto Second Slab (Toilet block)	Structure, reinforced	CuM	6.54	MJ/Kg	1.5	MJ	23544.00
	e		Parking floor	Structure, reinforced	SqM	2663.00	MJ/Kg	1.5	MJ	1438020.00
	f		Percast chamber covers	Structure, reinforced	CuM	62.10	MJ/Kg	1.5	MJ	223560.00
3	a	Mortar and plaster	Plaster Internal and External		SqM	15543.20	MJ/Kg	1.0	MJ	442981.20
	b		Terrace Waterproofing		SqM	3807.98	MJ/Kg	1.0	MJ	578812.96
	c		Toilet waterproofing		SqM	51.98	MJ/Kg	1.0	MJ	9876.20
	d		Dry mortar below Kota flooring for platforms		SqM	350.00	MJ/Kg	1.0	MJ	16625.00
	e		Dry mortar below flooring in toilet block		SqM	75.35	MJ/Kg	1.0	MJ	9305.73
	f		Mortar in Brick work		Cu m	24.57	MJ/Kg	1.0	MJ	46683.00
4	a	Masonry	Masonry for Platforms and toilet	Fired clay (well fired bricks massive) 150 x 150 x 76	CuM	351.04	MJ/Kg	3.0	MJ	2000928.00
	b		Koba filling for waterproofing on terrace	Fired clay (well fired bricks massive) 150 x 150 x 77	SqM	3756.00	MJ/Kg	3.0	MJ	1605690.00
	c		Koba filling for waterproofing in toilet	Fired clay (well fired bricks massive) 150 x 150 x 78	SqM	51.98	MJ/Kg	3.0	MJ	29628.60
5	a	Flooring	Kota for Platform flooring		SqM	350.00	MJ/Kg	0.5	MJ	15120.00
	b		Kota for Washing areas		SqM	90.00	MJ/Kg	0.5	MJ	3037.50
	c		Tiles in Toilet block	Ceramic tiles 300x300	SqM	75.35	MJ/Kg	8	MJ	6028.00
	d		Wall tiles in Toilet (Inside & outside)	Ceramic tiles 300x150	SqM	305.16	MJ/Kg	8	MJ	14647.68
6		Electrical conduit		Polyvinyl Chloride Pipe (dia 40 to 63 mm, wt 0.33 to 0.56 kg/m)	RM	487.40	MJ/Kg	85	MJ	17400.18
7	a	Plumbing	PVC - Drainage	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	RM	132.30	MJ/Kg	85	MJ	8771.49
	b		From septic tank to Main	Soil pipe (Cast Iron) dia	RM	35.00	MJ/Kg	13	MJ	3822.00

			drainage line	110mm, wt 8.40 kg/m						
	c		PVC - Water supply	Polyvinyl Chloride Pipe (dia 40 to 110 mm, wt 0.33 to 1.64 kg/m)	RM	180.20	MJ/Kg	85	MJ	6433.14
8		Glass in skylights		Wired glass 12 mm thk	SqM	706.48	MJ/Kg	12	MJ	244159.49
9		Paint		cement paint (Double coat)	SqM	15543.20	MJ/Kg	59	MJ	22926.22
10	a	Plinth filling	Substrate made of gravel and crushed rocks of thickness = 1000 mm	Stone structural	Cu M	4188.86	MJ/Kg	0.5	MJ	5654961.00
	b		Blinding course muroom of thickness 150 mm	Earth compressed structural	Cu m	907.01	MJ/Kg	0.5	MJ	907010.00
11		Doors	Concrete frame		R m	74.4	MJ/Kg	1.5	MJ	1607.04
			PVC Panel		No	14	MJ/Kg	85	MJ	5950.00
12		Toilet	Cement jali in toilet window		Sq M	5.04	MJ/Kg	1.0	MJ	478.80
Total									**MJ**	**26251445**
Building footprint									**Sq. M.**	**3745.06**
Embodied energy per Sq. M.									**MJ/ Sq. M.**	**7010**

VALUE ENGINEERING PRACTICES AND ITS IMPACT TO CONSTRUCTION INDUSTRY

R.G. Kosala* and Gayani Karunasena
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Value engineering (VE) is a systematic method to elevate the value of goods, products and services. Purpose of this paper is to investigate the current situation and real practice of VE technique in Sri Lankan construction sector and to give recommendations to construction organisations and national level construction regulatory bodies to standardize, VE practices toward achieving value for money for all stakeholders. A broad literature survey was carried out and seven case studies, thirty nine interviews and six expert interviews were conducted among construction professionals, who are having extensive knowledge on VE technique in Sri Lankan construction industry to gather facts. Content analysis and cognitive mapping were used in this research to analyze data and to identify the patterns of cases.

Findings of the research revealed that the application, knowledge and experience of construction professionals are not satisfactory in VE technique. Some recommendations can be mentioned as reduce contractor's design responsibility, introduce a proper VE guideline and regulate VE technique by law. This research is an ongoing research and a framework is going to build up which will help authorities to improve the applicability of VE technique. A formula is also going to form to determine a margin between contractor's portion due to VE technique and original profit of the contractor.

Keywords: *Construction Industry; Stakeholder; Value; Value Engineering.*

1. INTRODUCTION

"The construction industry can be differentiated from other industries by its organisation and products, its stakeholders, its projects, its processes, and its operating environment" (National Research Council, 2009, p.10). The development of construction industry is based on government decisions, procedures and regulations which have an obvious relationship between construction value for money (Wijewardana *et al.*, 2013).

By enhancing the value of a project can originate an affirmative collision on the economy of the country (Rameezdeen and De Silva, 2002). Zhang *et al.* (2009) reported that, Value Engineering (VE) is the most appropriate technique to regulate value in construction projects. It further described that, other techniques moreover focus on time and quality other than value. Altogether Miles (1972), Parker (2001) and Zar *et al.* (2011) contended that, VE is a systematic method to elevate the value of goods, products and services by undertaking an investigation of intention. Gudem *et al.* (2013) stated that, the project cost will be reduced up to 26%, enhance operational performance 40-50% and upgrade product quality 30-50% by implementing VE in projects.

In this context, this paper intends to examine prevailing VE practices in order to identify prevailing situation with intention of enhancing the standard value application in construction industry. Mainly scope of this paper is confined to major building and road construction projects, which practices VE techniques.

* Corresponding Author: E-mail - kosala.gamage.1989r@gmail.com

2. LITERATURE SYNTHESIS

2.1. VALUE AND ITS IMPORTANT IN CONSTRUCTION INDUSTRY

Value is a subjective term and is conspicuous in various ways such as desire, attitude, preference need, criteria and belief (Leung and Liu, 2003). Thiry (1997) stated that, value is a very subjective concept which has several definitions for various people, “best buy” for a customer, “the lowest cost” for a manufacturer and “highest functionality” for a designer.

A fundamental issue for construction firms is to guarantee value creation within and across projects (Lozon and Jergeas, 2008). Kliniotou (2004) stated that, various value measuring techniques can be found in plenty of industrial sectors such as value management (VM), bench marking, total quality management (TQM), financial management techniques (FMT), cost benefit analysis (CBA), supply chain management, project management, whole life cycle costing (WLCC) and earned value management (EVM).

Among these techniques VM is the unique application which assign throughout the stages of Royal Institute of British Architects (RIBA) plan and it is the most preferred value measuring technique among other value measuring techniques (Stenstrom *et al.*, 2013). VM has great accuracy over other techniques because all the factors which affect to the value of the product are considered in VM (Kelly *et al.*, 2004).

According to Potts (2008) and Male *et al.* (1998), the systematic operation of VM can be simply separated into three prime techniques, specifically Value Planning (VP), Value Engineering (VE) and Value Analysis (VA) to certify that the value is conveyed to the project in the most adequate manner.

VE is a disciplined and creative method which examines to submit the client a trustworthy opportunity for cost savings without detriment to quality or performance (Miles, 1972). According to Othman (2008) and Fan and Shen (2011), VE investigates, analyses, compares and selects amidst the various alternatives to generate the desired function and encounter or surpasses the customer goals and expectations. Each and every job plan phases, procedures and activities under the phases are clearly explained by Norton and McElligot (1995), Thiry (1997), Leung *et al.* (2002) and Othman (2008) as pre-study phase, information phase, objectives phase, functional analysis phase, consensus phase, development phase, evaluation phase and creativity phase.

2.2. VALUE ENGINEERING (VE) AND ITS IMPACT TO CONSTRUCTION

Value impulse clauses have been compounded into building contracts and statutory legislation could be institute to encourage the use of VE (Fong and Shen, 2000). Abidin and Pasquire (2007) reported that, VE had extensively acknowledged as a paramount contrivance in the management of construction projects in all over the world.

Dell’Isola (1997) advances typical VE savings as follows:

- In construction programmes to a value of €10 million, savings typically range from 3 to 10 times the value engineering effort.
- In programmes from €10-75 million, savings range from 5 to 15 times the effort.
- In programmes over €75 million, savings range from 10 to 20 times the effort.

According to Luu *et al.* (2003) and Ashworth (2002), factors affecting the VE selection can be categorized under following four main categories.

- Client Requirements
- Client Characteristics
- Project Characteristics
- External Environmental Factors

According to the Society of American Value Engineers (SAVE) (2006), as every technique, VE also have lot of benefits and some drawbacks, which limit the performance of the technique. Bowman and

Ambrosini (2010) have introduced several benefits of VE for construction projects such as, elevated competitiveness and profitability, can get a full authorized review of the total project, can generate a continuous improvements in quality and performance and quantum increases in productivity of the project. According to Hamilton (2002), improved identification of merits of VE has caused for the affluence of market level in worldwide. Lack of flexibility, lack of support and lack of knowledge and awareness of VE in some regions are basis for its minimal implementation (Cheah and Ting, 2005).

3. RESEARCH METHODOLOGY

This study is adopted qualitative research approach because, qualitative research describes a situation as it exists, without involving formal hypotheses, however focusing on explaining social processes intensely. Therefore, among various approaches available in the qualitative approach, case study is selected. The unit of analysis or the case in this paper is construction projects which applied VE in Sri Lanka. Number of cases increased up to seven and they are further divided to seventeen items to get a broad picture about VE applications which were done in those selected cases.

The cases were selected from building projects and road projects due to the abundance of such projects and also to avoid complexities which may occur when evaluating building and civil projects simultaneously. Cases are vary from super luxury residents to low cost housing projects and used different procurement methods as design and build, lump sum and measure and pay. Since this study is based on importance of VE technique in construction, had to select projects which use VE for their project. These projects are well known in construction industry due to the applicability of VE technique. For more details refer Table 1.

Table 1: Case Study Description

Project	Type	Contract Sum (Rs. million)	Duration	Procurement Method
Project A	Super luxury residential building	4,455	26 months	Lump sum
Project B	Low cost housing residential building	1) 915 2) 2,890 3) 2,180 4) 1,360	24 months	Design and build lump sum
Project C	Super luxury office complex	90,000	48 months	Design and build lump sum
Project D	Low cost housing residential building	1,070	24 months	Design and build lump sum
Project E	Super luxury office complex	7,550	36 months	Design and build lump sum
Project F	Expressway project	18,700	24 months	Measure and pay
Project G	Hostel building	196	12 months	Design and build lump sum

The interviews were carried out face-to-face in semi structured manner. Thirty nine case study interviews were carried out to collect data. Six expert interviews were conducted to clarify and validate research outcomes gathered through case studies. The interviews were carried out with three significant participants of the construction project team: client’s representative, consultant’s representative and contractor’s representative. Content analysis and cognitive mapping were used in this paper to analyse data.

4. RESEARCH FINDINGS

4.1. IMPORTANCE OF VE TO CONSTRUCTION INDUSTRY

Respondents stated that every project is unique to one another and one factor will not affect to another in a same way. Thus according to respondents' view, VE proposals must be carried out with broader understanding about project requirement and outcome from VE technique. That includes type of the project, government rules and regulations, perspectives of client, consultant and contractor. Selected case studies revealed that some projects were used VE technique to reduce cost and another set of projects used VE technique to reduce time for completion. In construction projects almost all clients are looking for cost reduction of the project due to budget constraints in the project.

4.2. REAL VE PRACTICE IN THE CONSTRUCTION INDUSTRY

In the process of application, there are some limitations in projects and according to respondents, those limitations need to be identified prior to think about VE application. Otherwise there would be errors in the final output or in the process of application. Respondents stated that, contractors suggest VE proposals after considering these limitations and after giving the proposal, consultants also evaluate that proposal considering limitations in the process of application.

Basically a project is a requirement of the client and client is the person who is investing the project. Client's requirements play a significant role in construction industry. There are factors which need to be accepted, such as political factors, government rules and regulations, economical and environmental factors. Stakeholders need to take necessary precautions to reduce the impact of these factors. According to empirical findings almost all the respondents mentioned that there is no any predefined way to apply VE technique in construction industry. When they are applying VE technique, it is revealed that, in most of the time stakeholders do not consider about the life cycle cost of the project before application of VE technique.

According to respondents, stakeholders are required to accept, avoid, share or transfer those considered factors to have better outputs through projects. Stakeholders are always trying to balance market requirements and demand. To fulfil the demand, there are other factors which need to satisfy. Some of them are availability of material, labour, plant and equipment. Figure 1 will give a brief amplification about impact to cost and time due to VE application of the projects.

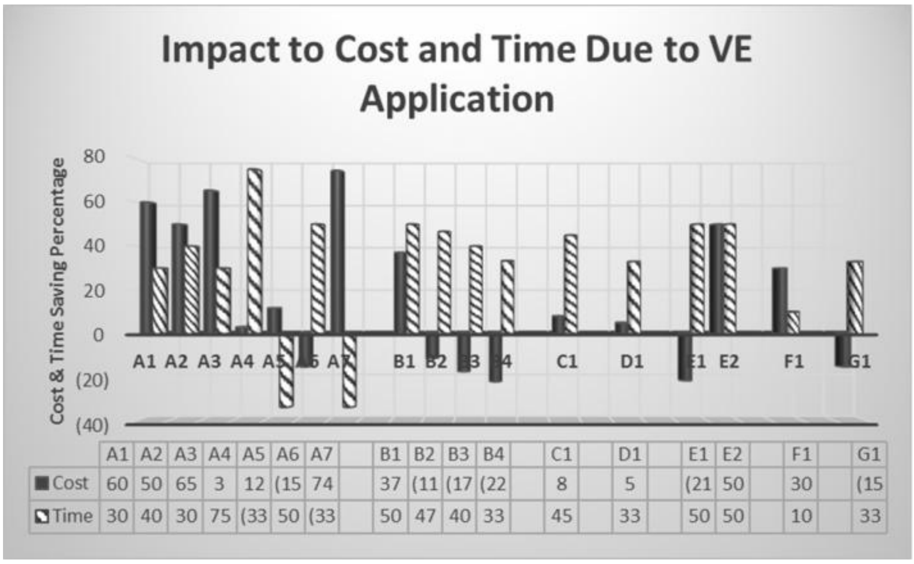


Figure 1: Impact to Cost and Time due to VE Application

Figure 1 is created from empirical data collected from case studies and VE applied items. Altogether 17 items were considered in 7 projects. Plain colour and downward diagonal pattern columns indicate cost and time reduction while columns below “0” percentage level indicate cost and time addition due to VE applications in the projects. According to objectives of the construction projects, time saving to the project was considered mainly in Projects C, D, E, G and both cost and time saving to the project was considered in Projects A and F.

In Project B there were four contractors in different construction sites constructing low cost houses for low income people. Construction methods, experience, labour force, plant and equipment, construction cost and time got varied among contractors.

There is a huge cost and time saving due to usage of Aluminium system formworks. Among selected cases Project A, item A2, Project B, Project C and Project E, item E1 indicated cost and time saving in Figure 1. According to findings, all Aluminium system formwork projects other than Projects B and E achieved both cost and time saving. In Project C, the contractor imported new set of Aluminium system formworks for the project. Not like Project B, Project C was a large scale project and the contractor used system formworks for all typical buildings. Project A reduced its cost by reusing previously used Aluminium system formworks. In Project E, item E1 the contractor BB used newly imported set of Aluminium system formwork and due to that cost was increased and subsequently time for completion was reduced.

In Project G, cost was increased due to the usage of precast concrete sections instead of in-situ concrete. Contractor got more advantages like reduction of construction time, less impact from weather, less labour force and plant requirements and got the chance to use products from their subsidiaries.

Most of respondents declared that, intangible benefits which are hard to achieve in normal construction process can be achieved by VE technique which leads the end product more compatible with surroundings and also with occupants. Then client can get higher value for money. When there are need of VE proposals in the project, contractors use his experience and latest technology available with him to suggest better VE proposals which will compatible with project requirements. From this VE proposals, client will get a project with latest technology while contractor will try to achieve cost and time benefits. Contractors can also use his subsidiary products in the project with prior approval of the consultant.

According to empirical findings, every technique has drawbacks and necessary actions need to be taken to mitigate those drawbacks. Respondents stated that VE is a technique which has less number of drawbacks compared to benefits which can be achieved. Main reason for these drawbacks is less awareness of the VE technique and its applicability. Experts review this problem and stated that after giving good knowledge to construction stakeholders, this problem can be mitigated. Then government clients will also encourage contractors to give VE proposals prior to construction stage and in the construction stage.

4.3. IMPACT TO CONSTRUCTION STAKEHOLDERS DUE TO VE TECHNIQUE

Construction stakeholders understand and apply VE technique in projects as their knowledge and experience. In Sri Lankan construction industry, professionals use VE technique as their own way which is compatible with Sri Lankan context. According to respondents VE application stage govern project aims and objectives. Stakeholders in the construction industry prefer different stages of VE application. Project managers (client, consultant mix) and consultants prefer pre contract stage for VE application and contractors prefer post contract stage. Most of stakeholders prefer VE technique in pre contract stage due to high amount of benefits. But, contractors prefer VE in post contract stage, because it is the stage which contractor can directly involve in the design and get a fee for VE work.

Case study findings revealed that most stakeholders prefer cost reduction VE proposals than time reduction VE proposals. Figure 2 indicate those findings according to relative importance index (RII).

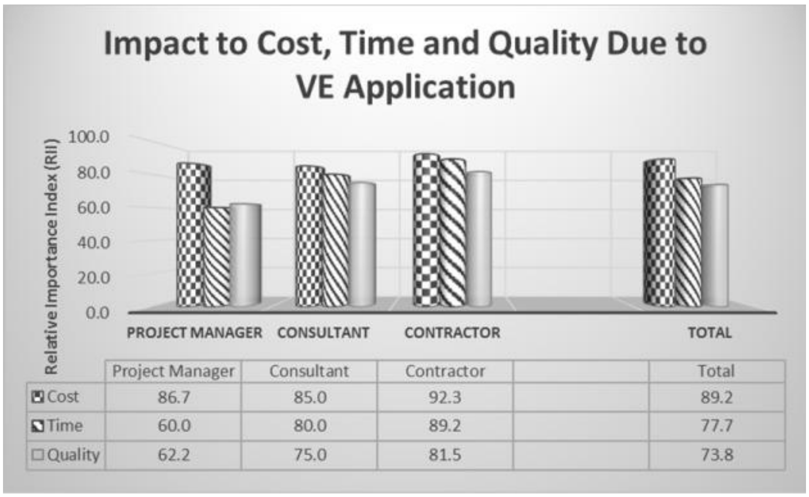


Figure 2: Impact to Cost, Time and Quality due to VE Application

As Figure 2 indicated, Sri Lankan stakeholders mostly consider about cost reduction in the project. Time comes to second and quality is the least. That can be grasped from the total section in Figure 2. According to RII, project manager organisation also give priority for the cost but offer same consideration for construction time and quality. Client's consideration more on quality is the reason for same level priority for time and quality. But, when consider about consultants and contractors, they want more cost and time reduction while maintaining quality of the project. RII figures indicated that consultants and contractors are keener on cost than time. They do not compromise quality due to the requirement of maintaining standards of the project. Case study findings revealed that most stakeholders consider client as the most significant person affected from VE proposals than contractor. Figure 3 indicate those findings according to RII.

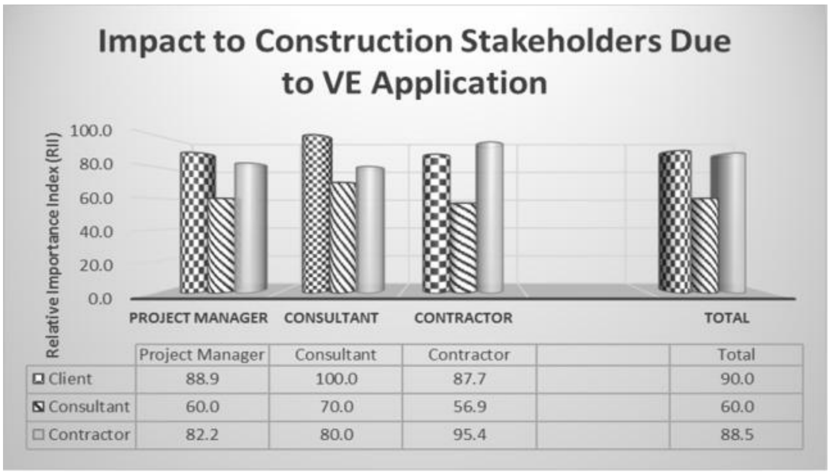


Figure 3: Impact to Construction Stakeholders due to VE Application

As indicated in Figure 3, both project managers (client, consultant mix) and consultants considered about impact to client than contractor and considered least impact to consultant. Altogether stakeholders considered that there is huge impact to both client and contractor due to VE technique and that can be grasped from total section in Figure 3.

According to respondents view, client is the foundation of the project. Client needs to have a good vision about the project, limitations and impacts to the project, methods of marketing the project and value additions to the project. There are both pros and cons for a client due to VE technique. One party getting benefit means other party gets less profit knowingly or unknowingly. Therefore clients need to beware of hidden ambitions of the contractor. In Sri Lanka, for government clients it is still not possible to achieve quick approvals for VE proposals and alternative proposals. Thus both clients and consultants in government projects do not encourage contractors for VE proposals.

Consultant is the person who takes care of works instead of the client. Consultant is accountable for loss of money, not achieving client requirements and project objectives. Therefore the consultant required to be very careful when reviewing and approving VE proposals given by the contractor. Otherwise the consultant needs to be responsible for the failure of the project. Due to reduction of consultancy fee, consultants do not like VE proposals. There must be a proper method to share benefits gained from VE technique among all stakeholders. Then all parties will be encouraged to suggest VE proposals.

Contractor is the person who do the construction part of the project according to scope and specifications. He is responsible to complete the project within the budget and time while achieving project objectives and client requirements. When the contractor gives a VE proposal, the design responsibility passes to the contractor and there onwards the contractor is responsible for the design and construction. That is a huge burden to the contractor. According to respondents, contractors are the people who gain more advantages in cost and time by applying VE technique in projects. Contractors hide their real objectives and promote other benefits which are not much important to contractors.

4.4. RECOMMENDATIONS TO IMPROVE AND ENCOURAGE VE APPLICATION

Research findings in this study can be summarized and demonstrated by using Table 2.

Table 2: Recommendations to Improve and Encourage VE Application

Recommendations to Construction Organisations	**Recommendations to National Level Construction Regulatory Bodies**
▪ Give incentives to consultant for VE proposals ▪ Give incentives to contractors when there is no design change	▪ Regulate VE technique by a law ▪ Introduce proper guideline and manual for VE technique
▪ Reduce contractor’s design responsibility ▪ Give more competitive advantages among other contractors	▪ Conduct awareness programs about VE technique to authorities and stakeholders (E.g. lectures, seminars and workshops)
▪ Give awards to organisations and project teams which are practicing VE technique	▪ Insert and implement ICTAD VE clause in every possible construction contract
▪ Approve green building certificate for VE technique applied projects	▪ Insert and implement VE clauses in client – consultant contracts
▪ Get reviews from VE consultants or third party consultants	▪ Introduce VE technique into syllabus of contract related courses in universities and institutes
▪ Get alternative proposals in pre-construction stage ▪ Give more time to consultants and contractors to review designs	▪ Reduce government regulations for projects which used VE technique ▪ Tax incentives for organisations which implement VE technique
▪ Improve communication within the site and give everyone a fair chance of presenting their idea	▪ Encourage application of VE technique in pre-contract stage
▪ Mutual understanding among stakeholders ▪ Publish sample VE techniques among stakeholders to get an idea	▪ Discourage overdesigns and encourage appropriate designs
▪ Promote VE technique through media like newspaper and TV ▪ Establish a good VE structure in construction related organisations	▪ Introduce better benefit sharing methods ▪ Government consultancy company to review designs and give approvals
▪ Introduce point system for VE proposals ▪ Introduce VE expert into the design team ▪ Encourage project staff to give proposals	

Recommendations which are suitable for construction organisations and national level construction regulatory bodies can be categorized into three main sectors and they are project level, organisational level and national level. There are related solutions for barriers to VE in construction industry and sometimes there are more than one solution for a barrier. For example "introduce proper guideline and manual for VE technique" is a common solution which is a solution to many barriers.

5. CONCLUSIONS

Recommendations which were emerged through analyses of empirical data can be used for implementation of regulations in the construction industry. Through this research it is identified that there is no any predefined way to apply VE technique in construction industry. When stakeholders identify the need of VE technique, they directly apply VE proposals to the project. Although Consultants consider quality of the original product and quality stated in specifications when they are going to measure the quality of the product for evaluation. It is revealed that in most of the time stakeholders do not consider about the life cycle cost of the project before application of VE technique. Lack of awareness of stakeholders and lack of government support are appeared to be the improper practice of VE technique within construction industry. As mentioned in literature synthesis, experts in construction industry highly believe that VE technique has significant importance to the industry. Findings of this research and literature findings of other researches revealed that the requirement of VE technique in projects is essential to construction industry.

6. REFERENCES

Abidin, N.Z. and Pasquire, C.L., 2007. Revolutionize Value Management: A Mode towards Sustainability [online]. *International Journal of Project Management*, 25(3), 275-282. Available from: http://www.researchgate.net/publication/248344960_Revolutionize_value_management_A_mode_towards_sustainability [Accessed 10 March 2014].

Ashworth, A., 2002. *Pre-contracts Studies.* 2nd ed. London: Blackwell Science Ltd.

Bowman, C. and Ambrosini, V., 2010. How Value is Created, Captured and Destroyed [online]. *European Business Review*, 22(5), 479-495. Available from: www.emeraldinsight.com/doi/abs/10.1108/09555341011068903 [Accessed 10 March 2014].

Cheah, C. Y. and Ting, S. K., 2005. Appraisal of Value Engineering in Construction in Southeast Asia [online]. *International Journal of Project Management*, 23(2), 151-158. Available from: www.sciencedirect.com/science/article/pii/S0263786304000808 [Accessed 10 March 2014].

Dell'Isola, A., 1997. *Value Engineering.* Kingston, Mass: R.S. Means Co.

Fan, S. and Shen, Q., 2011. The Effect of Using Group Decision Support Systems in Value Management Studies: An Experimental Study in Hong Kong [online]. *International Journal of Project Management*, 29(1), 13-25. Available from:

http://www.researchgate.net/publication/223623354_The_effect_of_using_group_decision_support_systems_in_value_management_studies_An_experimental_study_in_Hong_Kong [Accessed 10 March 2014].

Fong, P.S.W. and Shen, Q., 2000. Is the Hong Kong Construction Industry Ready for Value Management? [online]. *International Journal of Project Management*, 18(5), 317-326. Available from: http://ac.els-cdn.com/S0263786399000289/1-s2.0-S0263786399000289-main.pdf?_tid=77300e04-e0b7-11e3-b292-00000aab0f6b&acdnat=1400656613_e9947cf335a5f61c 5e549abee907331c [Accessed 31 July 2014].

Gudem, M., Steinert, M., Welo, T. and Leifer, L., 2013. Redefining Customer Value in Lean Product Development Design Projects [online]. *Journal of Engineering, Design and Technology*, 11(1), 71-89. Available from: www.emeraldinsight.com/doi/abs/10.1108/17260531311309143 [Accessed 31 July 2014].

Hamilton, A., 2002. Considering Value during Early Project Development: A Product Case Study [online]. *International Journal of Project Management*, 20(2), 131-136. Available from: www.berthamilton.com/article.pdf [Accessed 31 July 2014].

Kelly, J., Male, S. and Graham, D., 2004. *Value Management of Construction Project*. Oxford: Blackwell Publishing.

Kliniotou, M., 2004. Identifying, Measuring and Monitoring Value during Project Development [online]. *European Journal of Engineering Education*, 29(3), 367-376. Available from: http://www.researchgate.net/publication/245494321_Identifying_measuring_and_monitoring_value_during_project_development [Accessed 31 July 2014].

Leung, M.Y. and Liu, A.M., 2003. Analysis of Value and Project Goal Specificity in Value Management [online]. *Construction Management and Economics*, 21(1), 11-19. Available from: http://www.tandfonline.com/doi/abs/10.1080/0144619032000065081 [Accessed 31 July 2014].

Leung, M.Y., Ng, S.T. and Cheung, S.O., 2002. Improving Satisfaction through Conflict Stimulation and Resolution in Value Management in Construction Projects [online]. *Journal of Management in Engineering,* 18(2), 68-75. Available from: ascelibrary.org/doi/abs/10.1061/(ASCE)0742-597X(2002)18%3A2(68) [Accessed 31 July 2014].

Lozon, J. and Jergeas, G., 2008. The Use and Impact of Value Improving Practices and Best Practices [online]. *Cost Engineering*, 50(6), 26-32. Available from: http://cat.inist.fr/?aModele=afficheN&cpsidt=20476771 [Accessed 12 September 2014].

Luu, D.T., Ng, S.T. and Chen, S.E., 2003. Parameters Governing the Selection of Procurement System–An Empirical Survey [online]. *Engineering, Construction and Architectural Management*, 10(3), 209-218. Available from: www.emeraldinsight.com/doi/abs/10.1108/09699980310478458 [Accessed 12 September 2014].

Male, S., Kelly, J., Fernie, S., Gronqvist, M. and Bowles, G., 1998. *The Value Management Benchmark: Research Results of an International Benchmarking Study*. London: Thomas Telford.

Miles, L.D., 1972. *Techniques of Value Analysis and Engineering*. New York: Mcgraw-Hill.

National Research Council, 2009. *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*. Washington, DC: The National Academies Press. Available from: http://modular.org/marketing/documents/NRC_USConstructionIndustry_Report.pdf [Accessed 21 July 2014].

Norton, B.R. and McElligott, W.C., 1995. *Value Management in Construction: A Practical Guide*. New York: McMillan.

Othman, A.A.E., 2008. Incorporating Value and Risk Management Concepts in Developing Low Cost Housing Projects [online]. *Emirates Journal for Engineering Research*, 13(1), 45-52. Available from: http://cpas-egypt.com/pdf/Ayman_Othman/R/002.pdf [Accessed 03 September 2014].

Parker, D.E., 2001. *Determining building Worth*. Washington, D.C.: Donald E. Parker.

Potts, K., 2008. *Construction Cost Management.* London: Taylor & Francis.

Rameezdeen, R. and De Silva, S., 2002. Trends in Construction Procurement Systems in Sri Lanka. *Built Environment Sri Lanka*, 2(2). 2-9. Available from: http://dl.nsf.ac.lk/handle/1/8303 [Accessed 15 August 2014].

SAVE International, 2006. *Value Methodology Standards and Body Of Knowledge*. USA: The Value Society.

Stenstrom, C., Parida, A., Kumar, U. and Galar, D., 2013. Performance Indicators and Terminology for Value Driven Maintenance [online]. *Quality in Maintenance Engineering*, 19(3), 222-232. Available from: www.emeraldinsight.com/doi/pdf/10.1108/JQME-05-2013-0024 [Accessed 15 August 2014].

Thiry, M., 1997. *A Framework for Value Management Practice*. USA: Project Management Institute.

Wijewardana, C., Jayasena, H.S. and Ranadewa, K.A.T.O., 2013. Impact of Government Policies and Regulations When Adopting Alternative Procurement Methods [online]. In: *2nd World Construction Symposium 2013: Socio-Economic Sustainability in Construction,* 253-260. Available from: http://www.suranga.net/publications/2013_gov_policy_proc.pdf [Accessed 17 July 2014].

Zar, F.I.M., Razaee, Z.S. and Karbasian, M., 2011. A Fuzzy Case Based Reasoning Approach to Value Engineering [online]. *Expert Systems with Applications*, 38(8), 9334-9339. Available from: www.sciencedirect.com/science/article/pii/S0957417411001448 [Accessed 17 July 2014].

Zhang, X., Mao, X. and AbouRizk, S.M., 2009. Developing a Knowledge Management System for Improved Value Engineering Practices in the Construction Industry [online]. *Automation in Construction,* 18(6), 777-789. Available from: www.sciencedirect.com/science/article/pii/S0926580509000302 [Accessed 17 July 2014].

WATER EFFICIENCY TECHNIQUES AND STRATEGIES FOR SUSTAINABLE USE OF WATER DURING CONSTRUCTION PHASE OF BUILDING PROJECTS

K.G.A.S. Waidyasekara* and Lalith de Silva
Department of Building Economics, University of Moratuwa, Sri Lanka

R. Rameezdeen
School of Natural and Built Environment, University of South Australia, Australia

ABSTRACT

A significant wastage and misuse of water in construction sites has been identified as a critical problem by previous researchers. However this aspect has not been well explored in the current literature. Therefore, this paper aims to explore the appropriate techniques and strategies to be adopted in construction sites for efficient water use. Moreover, the ways and means of sustainable use of water in construction projects is suggested. Various techniques and strategies of efficient water use were identified through a literature review and taken to the professionals involved in construction through a structured questionnaire survey to identify and rank their relevance to construction. Data was analysed through descriptive statistics and non-parametric tests using SPSS software. The findings of this study highlight the top five applicable water efficiency techniques to be: water audits, water leak detection and monitoring systems, pressure reduction valves, high pressure trigger operated spray gun hoses and sub-metering.The top five applicable strategies were: monitoring and supervision, implement environmental policies on natural resources, enhance water awareness among workers, assign responsibility and targets among the site staff and introduce water action plan at the beginning of the project.In addition, the paper discusses the professionals' views on practical implications of improving the uptake of water efficiency techniques and strategies. Cost was identified as the main barrier for implementing water efficiency practices in Sri Lanka.

Keywords: *Construction; Strategies; Techniques; Water efficiency.*

1. INTRODUCTION

"Development of new sustainable competencies and technologies will present fundamental challenges for virtually every industry in the recent decades (Hart, 1995: 1003)". There is a growing need for the construction sector to adopt principles of sustainability in their policies and day to day activities (Walton *et al*, 2005; Xing *et al.*, 2007). Henceforth, Architects, Surveyors, Engineers, Project managers and other professionals who are responsible for decisions are expected to use sustainable solutions throughout the different stages of a construction project (Xing *et al*, 2007). As the construction stage transfers the design into reality, it involves the utilization of variety of natural resources including water. Therefore, activities happening during the construction stage have a close association with environmental impacts including generation of waste and pollution (Shen *et al.*, 2007).

Baxter *et al.*, (2004) categorised impacts of a project into economic, environmental, natural resources consumption and social. Natural resources such as water, fossil fuel, and land are amongst the most important to consider in sustainability assessment (Xing *et al.*, 2007). Waidyasekara *et al*, (2013) compared eleven sustainability assessment tools and found only two, namely Building Research Establishment's Environmental Assessment Method (BREEAM) of UK and Green Rating for Integrated Habitat Assessment (GRIHA) of India, have included water efficiency during construction phase in their assessment criteria. Since construction is considered to be a water intensive industry, its inclusion in

* Corresponding Author: E-mail - anulk15@yahoo.com

environmental assessment tools will be an effective way of controlling it. For instance, the simple step of effectively monitoring water use on site will deliver direct benefits to all concerned. It is a known factor that water resource are scarce and water efficiency and conservation are increasingly being discussed as a way of protecting this valuable natural resource. Construction industry is becoming very sensitive to the need to be more environmentally responsible and is seeking ways and means of conducting itself to minimize negative environmental impacts (Kibert, 1994). Nevertheless, the strategic forum for construction (SFfC) has identified that relatively little work has been carried out on water sustainability on construction sites as water use is generally considered to be a low priority by its stakeholders (Waylen *et al.,* 2011). Strategies for Sustainable Construction published in 2008 highlighted the issues of water use and included number of targets (Waylen, *et al.,* 2011). Waste and Resource Action Programme (WRAP) found water efficiency practices during construction can save £200,000 per year on water costs to a large scale contractor in UK (McNab, *et al.,* 2011).

In Sri Lanka, various sustainability techniques and management skills have been implemented in construction projects to achieve project goals. However, literature provide evidence that water efficient techniques and strategies are yet to become commonplace (Waidyasekara *et al,* 2014).

In order to identify the importance of water efficiency and the ways and means of implementing it during construction, more research is necessary in the Sri Lankan context. Therefore, this study aims to obtain views from professionals on water efficiency techniques, and strategies for sustainable use of water during construction. This study refer to sustainable use of water as optimum use of water resource (i.e reduce water wastage and inefficient activities/processes) with minimum damage to ecosystem in view of preserving it for future generations.

2. LITERATURE REVIEW

2.1. WATER MANAGEMENT, WATER EFFICIENCY AND WATER CONSERVATION

Water is one of the most important resources related with human life and economic activities. Reducing water use both save money and preserve this invaluable natural resource. Recent environmental research has warned that water resources are under pressure and current levels of water abstraction are unsustainable in many countries. In the coming years the combined effects of climate change, increasing population growth and rapid industrial developments will put further pressure on water resources. Thus, water management, efficiency and conservation are essential elements in sustainability.

Optimum use of water covers both conservation and efficiency and includes planning, monitoring and controlling. Water resource management try to optimize the use of water and minimize the environmental impacts associated with its use (Biswas, 2008). As Brooks (2007) argues, water efficiency (WE) and water conservation (WC) are two different concepts although interchangeably used in the literature. Dexter (2011) describes that conservation demands to do less by sacrificing the needs whereas efficiency deals with doing more with less. Similarly, National Cleaner Production Centre (NCPC) of Sri Lanka (2012) observes that WE focuses on achieving the same result with the minimal amount of water usage while WC aim towards reducing the wastage of water. Thus, water conservation relies on individuals to change their behaviour to achieve results; while water efficiency encourages using best available technology and innovative ideas to achieve long-term water sustainability without sacrificing the present needs (Dexter, 2011). In addition to the reduction in loss and waste, the concept of water efficiency is also supported by innovative ideas and modern technologies such as reuse, recycle, and alternative sources. Therefore, as stated by Dexter (2011) water efficiency is a smart investment for future, which is the most significant water management strategy instead of solitary water conservation. In addition, Cohen et al. (2009) described that management of water quality is also a part of water management. Department of energy of United States (2011) identified that managing available water resources and satisfying water demand (water quantity) are also basic principles of a good water management. Waste and Resource Action Programme (WRAP) identified four principles of water efficiency as: monitor and manage, reduce use, minimize water and replace potable water with grey or rainwater (McNab *et al.,* 2011). According to the definition given by WRAP, water efficiency overlaps with some characteristics of water conservation. Thus, based on the existing literature, the authors identified key activities that fall under the water management with a filtering process as illustrated in Figure 1. These key activities are not fully independent as it could be seen closely linked each other to fulfil the objective of water management while it is being controlled by external factors such as behaviour, policies, rules and regulations, and cost for a better output. It is clear that water management is very broad and it covers many aspects. This study refers to water efficiency instead of water management as it aligns with the four principles identified by WRAP in addition to WE's general explanation.

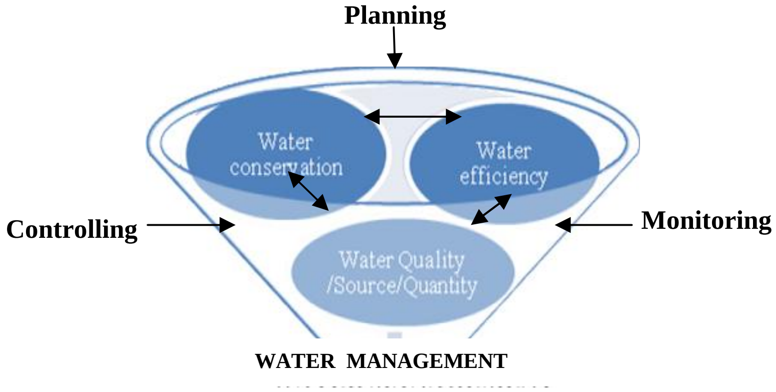


Figure 1: Key Activities of Water Management Process

2.2. WATER EFFICIENCY TECHNIQUES, TECHNOLOGIES AND STRATEGIES

Techniques and technologies are closely related but have different meanings. Aggazy (1998) explained techniques to mean a display of practical abilities that allow one to perform easily and efficiently in a given activity (be it purely material or bound to certain mental attitudes). Technology, on one hand, as being included in the domain of technique, while on the other, set off by specific traits (Aggazy, 1998). Technology is the application of scientific principles and people have different techniques of making use of the same technology. Bourg (2010) clearly stated that human factor is critical to obtaining the desired results from water conservation strategies. According to the United States General Services Administration (1999), successful water management consider both technical (installing efficient fixtures) and human (behaviour and expectations) aspects. Installing a retrofit device or replacing outdated technology or fixtures alone might not produce expected water savings unless user behaviour is improved.

Water management strategies are categorised into three areas as: reducing losses, reducing water quantity and reusing water. According to Department of Energy (DOE) of USA (2011) water efficiency implementation starts with understanding of water use facility and water use pattern and then developing a water management plan. As Cohen *et al.* (2009) highlighted, effective water management offers economic, environmental and social benefits also. Technologies and techniques will help achieve certain strategies to make efficient use of water in certain instances. Water efficiency tool allow the user to identify targets for water efficiency in building designs and to compare and specify certain water appliances (McNab, 2011).Water efficient plumbing fixtures, waterless urinals, low-flow and sensored sinks, taps and showers, dual flushing systems, water efficient dishwashers and washing machines, water efficient landscaping and irrigation systems, water recycling and reuse measures, gray water and process recycling are some technologies, and techniques commonly used to reduce water use in a building (Bourg, 2010; McNab,2011). Thus, it could be observed that certain overlaps exist with techniques, technologies and strategies. The study refers techniques instead of using terms of technologies and techniques.

2.3. SUSTAINABLE CONSTRUCTION AND SUSTAINABLE USE OF WATER RESOURCE

Previous studies have shown that construction industry and its activities have significant effects on the environment (Shen *et al.* 2007; Ding *et al.* 2004; Sjostrom and Bakens, 1999; Kibert, 1994). Construction activity makes extensive use of natural resources, energy, and water (Balio, 2003). Although various techniques and management skills have been used in construction projects to improve sustainable performance, these techniques seem not being effectively implemented due to the fragmentation and poor coordination among construction stakeholders (Shen *et al.*, 2007). Moreover, Shen et al (2007) identified lack of consistency and a holistic approach to help participants implement sustainable construction practice at various stages of a project. Theo (2003) emphasizes the importance of commitment of the management staff for its success. The first step in the process of establishing evaluation tools or techniques is to set forth the issues that are encompassed by sustainable construction. Kibert (1994) identified common issues in sustainable construction (SC) and categorized them into four main groups as shown in Table 1. This shows water use during construction as a sub- theme in sustainable construction. Table 2 illustrates key principles of SC.

Table 1: Issues of Sustainable Construction (SC)

Main Issues	Sub-issues
Resources	Energy Consumption **Water Use** Land Use Materials Selection
Healthy environment	Indoor Environmental Quality Exterior Environmental Quality
Design	Building Design Community Design
Environmental effects	**Construction Operations** Life Cycle Operation Deconstruction

Source: Kibert (1994)

Table 2: Principles of SC

Sustainable Construction Principles
Minimize resource consumption (Conserve)
Maximize resources reuse (Reuse)
Use renewable or recyclable resources'
Protect the natural environment
Create a healthy, non-toxic environment
Pursue quality in creating the built environment

Source: Kibert (1994)

There is no motivation for conservation of air and water since they are not privately owned (Daly, 1993). In the past, the criteria for energy and water resources were not connected to one another, to materials selection, or to the other issues of sustainable construction (Kibert, 1994). Water was just considered to be another input in construction projects (Kibert, 1994). Kibert separated construction industry into two layers. Layer one consists of parties who has the most influence on the physical content and creation of the built environment: architects, engineers and builders. Layer two consists of sustainable construction which is just one component of creating an overall sustainable environment. As stated by Kibert (1994), construction industry must change its historical methods of operating with little or no regard for environmental impacts. It should embrace a new mode where environmental concerns should become a centerpiece of its efforts.

Water is as an integral part of the ecosystem, a natural resource and a social and economic good (Zbigniew and Kundzewicz, 1997; Gleick, 1998). Gleick et al. (1995 cited Gleick, 1998) offers a working definition of sustainable water use as "the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it". The current study refers sustainable use of water as optimum use of water resource (i.e reduce water wastage and inefficient activities/processes) with minimum damage to ecosystem and preserve it for future generation. Zbigniew and Kundzewicz (1997) explain that the availability of water in adequate quantity and quality is a necessary condition for sustainable development. In addition, knowledge and understanding of freshwater resources is also essential for sustainable development. A case study of the UK construction industry conducted by Jones et al. (2006) indicates that the consideration of corporate social responsibility (CSR) can also help to reduce costs by efficient water use.

2.4. CONSTRUCTION SECTOR FOCUSED WATER EFFICIENCY TECHNIQUES AND STRATEGIES

The benefits of water efficiency are identified in construction industry. Water conservation techniques and strategies are often the most overlooked aspects of a whole –building design strategy (Bourg, 2010).Thus implementation of water saving initiatives within a building is increasingly becoming a priority and wide range of technologies and measures are employed to reduce the amount of water consumed by buildings. Even industries like agriculture and manufacturing are talking about water efficient techniques and technologies. Similarly, identifying water saving techniques to reduce water use in construction sector also can be beneficial. The Strategic Forum for Construction (SFfC) Water sub-group, Waste and Resource Action Programme (WRAP), and Construction Industry Research and Information Association (CIRIA) are the main research bodies conducting research on water use on construction sites. As stated by Waidyasekara et al (2012), there is a vacuum in the area of water management body of knowledge during the execution phase of a construction project in Sri Lanka.

A study conducted by SFfC of Waste and Resources Action Programme (WRAP) on water audits on construction sites in UK found that the largest barrier to improve water efficiency on site was the lack of quantitative information due to the use of unmetered stand pipes and faulty water meters. Thus they have suggested to utilize robust metering and monitoring systems on site to overcome this issue (McNab et al., 2011). Tam and Lee (2007) suggested that it is necessary to encourage and educate the staff on monitoring of water usage, water reusing and recycling systems, and the use of wastewater treatment during construction. Further WRAP identified key opportunities to reduce water use on site as (i) good housekeeping (ii) monitoring and targeting (iii) use abstracted water where available (iv) specifying water efficient taps, and fittings and (v) use water efficient plant and equipment (McNab, 2011). They showed that savings in the tune of ~90%, ~ 40% and ~30%, respectively for dust suppression, wheel washing and road sweeping by selecting efficient plant and equipment. Further, WRAP identified following water efficient techniques: pressure reduction valves, flow regulators/restrictors, use of aerated and spray tap/shower fittings which improve perceived user experience, and two-stage taps with water brakes, sub-metering, fix dripping taps and leaking taps, motion-sensor operated taps, grey / rainwater systems for reducing potable water consumption, auto shut-off of flow to toilet areas when unoccupied. Similarly the SFfC water group identified following water efficient techniques: water audit systems, leak detection systems, fit trigger guns to hoses, vacuum toilets, pressure reducing valves, closed looped water recycling, admixtures, water hierarchy which look at alternative sources for potable water, reduce, reuse, and recycle (Waylen et al., 2011). Water audit determines the amount of water loss from a distribution system due to leakage and other reasons such as theft, unauthorized or illegal withdrawals from the system and the cost of such losses to the utility. Water action plan seeks to address reducing water usage by encouraging and promoting water activity to obtain better information.

Further, SFfC water subgroup identified best practices for water efficiency by incorporating water efficient construction practices at pre-design and tender stage and incorporate water efficient construction sites into sustainability assessment systems (BREAM, LEED, GreenSL). SFfC group further mentioned that chemical additives are an option to assist in reducing the volume of water needed and waterless systems are other innovative options. It was identified high pressure low volume efficient spray pattern to reduce water use and closed loop systems (re-use of washout water from concrete batching plants). Fernando (2007) shows that applying 're-use' concept in the batching plant process, 2m^3 per day can be re-used. This result derived through one case study conducted in Sri Lanka and the water used for cleaning the batching plant is subjected to filtering process and reuse for concrete production. The Australian Industry Group (2006) identified water efficient strategies as water saving action plan, high pressure cleaning, storm water reuse, filters, ensure that water efficiency methods induced in tender and contractual documents. Modern techniques such as curing compounds, sprinkler techniques, pre-cast construction methods, dry partitions work, pre- mixed concrete and pre-mixed mortar and more steel intensive construction recommend in order to reducing water volume in a site (Ramachandran, 2004). Further same author mentioned that workers participation, recognition, team belonging, management commitment and leadership, effective training impact on water efficiency at site level. As McNab et al., (2011) stated, creating a culture within the construction sector that changes staff's attitude and behaviour to accept ownership of water efficiency is fundamental to improving the use of water in an efficient manner.

As Savenije and Van der Zang (2002) suggest, water pricing is an important instrument to break the vicious circle of the 'free water dilemma'. Zbigniew and Kundzewicz (1997) and Horn (2012) emphasized the necessity of increasing water prices to appropriate levels in order for it to be taken seriously by the consumers. Environmental Management System (EMS) can provide a framework to achieve and to demonstrate a desired level of environmental performance (Tse, 2001, Wu, 2003). Baloi (2003) highlights, EMS enables companies to respond to environment challenges and legislative/regulatory requirements proactively. The establishment and implementation of ISO 14001, EMS requires a total commitment and cooperation of all parties involved in the supply chain (Chen and Wong, 2000). However, Tam and Le (2007) observed that construction organizations' poor response to EMS is attributed mainly to their lack of environmental consciousness. Mactavish and Greenhalgh (2013) show that through effective management of resources on site, 15-25% of reduction in water use could be achieved. However, the same authors highlighted that historically, cost has always been the language that captures the concentration of investors and clients and their project teams were required to respond. Perhaps in the future, metrics such as tonnes of carbon or litres of water saved will gain equal attention in cost evaluation.

3. RESEARCH METHODOLOGY

The aim of this research is to identify applicable water efficiency techniques and strategies for efficiency water usage during construction phase. Further, the paper will discuss limitations on uptake of water efficiency technique and strategies in the construction industry. Both quantitative and qualitative approaches were integrated to achieve the research aim. A questionnaire survey was undertaken in order to get a broad view on water efficiency methods that are relevant for the construction industry. It consisted of both closed and open ended questions. Although, some overlap could be seen with techniques and strategies, the study identified 17 techniques (TEchs) and 14 strategies (STrgs) popularly used in the construction industry based on the literature review.

Data were collected using an online survey method among professionals working for contractors and consultants such as Project Managers (PM), Civil Engineers (CE), Quantity Surveyors (QS) and Architects (ARCHT) who have more than ten years of experience. The sample consisted of 105 professionals, 54 belonging to contractors and 51 consultants. Figure 2 and 3 illustrates the experience of these respondents.

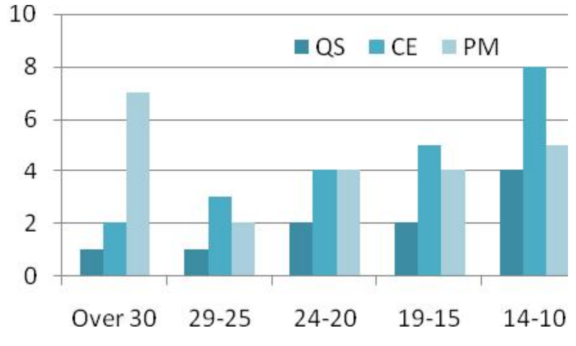


Figure 2: Experience of the Contractor Group

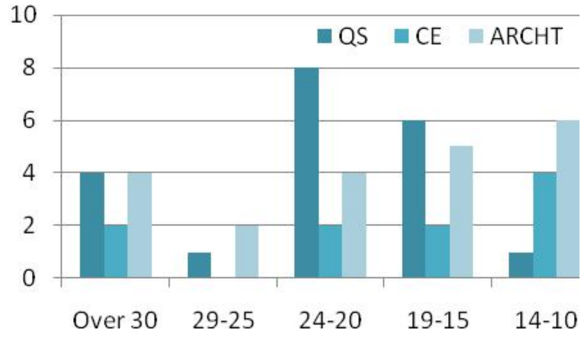


Figure 3: Experience of the Consultant Group

The statistical software of SPSS (Statistical Package for Social Science) version 22.0 was used during the data analysis. Cronbach alpha was used to check the internal consistency and the reliability of the data set. Descriptive statistics such as frequencies and percentages were used as while a non- parametric tests, namely, Mann Whitney and Kruskal- Wallis H were used to determine whether there is a significant difference between the average responses among these groups (between the contractor and consultant as well professional groups). The criterion for accepting or rejecting the hypothesis was set at .05. If the asymptotic significance level (p-value) is less than .05, the null hypothesis was rejected. Qualitative data that originated from open-ended questions of the questionnaire survey were also included in the discussion.

4. RESEARCH FINDINGS

4.1. FINDINGS OF THE QUESTIONNAIRE SURVEY

Out of the 105 responses, over 27% of them had more than 25 years' experience while 23% between 20-24 years, 23.8% between 15-19 years and 25.7% between 10-14 years, respectively. Respondents were asked to give their views on why water efficiency practices were not considered by stakeholders during the construction phase. More than 88% of respondents believed that the main reason was 'low priority given for water efficiency management'. Lack of integration of water efficiency practices during i) pre-design and ii) construction stages were considered by more than 80% respondents. 78% respondents agreed 'Value of water is hidden to construction parties' and 'less awareness of new technologies' while 73% believe adoption of water efficiency TEchs and strategies will add cost to a contractor and 59% believe that it is an additional cost to a client.

Literature shows that many techniques can be used to achieve efficiency of water use during construction. The main purpose of the survey was to obtain the perception of the respondents on the applicability of above water efficiency techniques for the Sri Lankan construction industry. They were asked to rank their applicability on a Likert scale as shown in Table 3.

Table 3: Likert Scale for level of applicability

Scale	1	2	3	4	5
Level of applicability	Very low	Low	Neutral	High	Very High

4.2. WATER EFFICIENCY TECHNIQUES (TECHS) APPLICABLE FOR USE DURING CONSTRUCTION PHASE

A total of seventeen (17) potential water efficiency TEchs have been included in the survey. As noted previously, prior to performing the analysis, Mann-Whitney U test was performed to determine whether there was a statistically significant difference between the average responses of the contractor and consultant group. The results show that there is a significant difference between the average response of TEch16 (water efficient taps) [Asymp.sig. (2-tailed)=.04]. Except that all the other TEchs have no significant difference between the groups. Therefore, Tech16 was analyzed separately and all other TEchs under one sample. When reporting ordinal data (non-parametric), median is considered to be more appropriate for the central tendency and equivalent parametric test focuses on mean of the data set. The study used a proportion of responses in each category, which is considered as being the most appropriate and more informative than the use of median. Table 4 summarized the survey results.

Table 4: Applicability on Water Efficiency TEchs

Ref.	Techniques for Efficient Water use During Construction	Level of Applicability					TR	H &V.H
		1	2	3	4	5		
		%	%	%	%	%		%
TEch1	Admixtures /chemical additives	7.6	12.4	3.8	51.4	24.8	105	**76.19**
TEch2	Closed loop systems (waste of one product is used for another process)	1.9	14.3	1.9	60.0	21.9	105	**81.90**
TEch3	Curing agents	9.5	4.8	3.8	39.0	**42.9**	105	**81.90**
TEch4	Dust suppression vehicles -bowsers with sprinklers	18.1	11.4	1.9	51.4	17.1	105	68.57
TEch5	Efficient showers : Low-flow showerheads	4.8	12.4	2.9	61.9	18.1	105	**80.00**
TEch6	Fan misting systems for dust suppression	22.9	12.4	16.2	31.4	17.1	105	48.50
TEch7	High pressure trigger operated spray gun hoses for concrete cleaning & wheel washers	4.8	2.9	-	48.6	**43.8**	105	**92.38**
TEch8	Low flush cisterns/urinals/waterless urinals	1.0	9.5	5.7	63.8	20.0	105	**83.81**
TEch9	Pressure reducing valves	-	1.0	6.7	65.7	26.7	105	**92.38**
TEch10	Rainwater collection and reuse	8.6	8.6	1.0	31.4	**50.5**	105	**81.90**
TEch11	Sprinkler systems for curing concrete work	1.9	14.3	9.5	61.0	13.3	105	74.29
TEch12	Sub-metering systems	-	6.7	1.9	53.3	38.1	105	**91.43**
TEch13	Vacuum toilets	22.9	24.8	7.6	37.1	7.6	105	44.70
TEch14	Washing bay for wheel washers	23.8	11.4	1.9	43.8	19.0	105	62.86
TEch15	Water audit methods	1.9	-	-	49.5	**48.6**	105	**98.10**
TEch17	Water leak detection and monitoring systems	-	1.9	1.0	38.1	**59.0**	105	**97.14**
1:Very Low 2: Low 3: Neutral 4: High 5: Very high TR: Total Respondent								

Note: H - High V.H – Very High

The empirical data shows that 59% of respondents reported that water leak detection and monitoring systems (TEch16) to be the most applicable TEch followed by TEch10 (50.5%), TEch7 (43.8%) and TEch3 (42.9%), respectively. Furthermore, Table 5 summarises the percentages reported 'very high' and 'high' applicability TEchs by the respondents. Accordingly, almost ten (10) TEchs were reported by 80% respondents as applicability for the construction phase (the top five TEchs are highlighted in Table 5). These top water efficiency TEchs well matches with the literature review. Therefore, it is important to look at current extent of application of these water efficiency TEchs uses in construction sites in Sri Lanka.

Table 5: The Top Five Applicability Water Efficiency Techs for Construction Phase

Ref.	TEchs	High%	V. high %	High% + V. high %
TEch15	Water audit	49.5	48.6	98.1
TEch17	Water leak detection and monitoring systems	38.1	59.0	97.1
TEch9	Pressure reducing valves	65.7	26.7	92.4
TEch7	High pressure trigger operated spray gun hoses for concrete cleaning and wheel washers	48.6	43.8	92.4
TEch12	Sub-metering systems	53.3	38.1	91.4

Note: V.high: Very high

The highest percentages for 'very low' were for TEchs of 'Washing bay for wheel washers' (23.8%) , 'Fan misting systems for dust suppression' (22.9%) and 'Vacuum toilets' (22.9%). Although, literature shows that a typical vacuum system can reduce potable water consumption for toilets by 68% and it is highly efficient than the traditional methods, respondents were not very favourable for that option. 72.2% of contractor and 58.8% of consultant-based professionals reported 'high' or 'very high' for applicability of water efficiency taps (Tech16) to be relevant for construction. On the other hand, 17.6% participants from the consultancy group and 23.5% from contractors have given 'very low' for applicability of water efficiency taps (TEch16) respectively. The results seem to show that consultants are less favourable on TEch16 compared to the contractor group.

It is important to note that the results of Kruskal-Wallis H test showed that there were no significant differences of views between the professional groups: Project Managers, Civil engineers, Quantity Surveyors and Architects. The value of the asymptotic significance level (2 tailed) for all items were greater than .05. Accordingly, Null hypothesis (no variance between groups) was not rejected. Moreover, Cronbach's Alpha was 0.764. This shows high internal consistency and reliability within the measurement used for each variable.

4.3. STRATEGIES FOR LOW WATER USAGE DURING CONSTRUCTION PHASE

Fourteen strategies were included in the questionnaire survey and respondents were asked to rank them on their applicability for water efficiency for construction on a likert scale as given in Table 3. As a first step Mann-Whitney non- parametric test was conducted to establish whether there are any differences between the responses of contractor and consultant group. It is important to note that the value of the asymptotic significance level (2 tailed) for all the strategies were greater than 0.05. This indicates that there was no significant difference between the groups. It was considered all participants to be a single sample and the results are summarized in Table 6. As shown in Table 6, 'Monitoring and supervision' (Strg14), 'Introduce water action plan initially' (Strg7), and 'Assign responsibility and targets among the site staff' (Strg1) were recognized as 'very high' strategies applicable by majority of respondents. The results summarize the combined percentage of 'Very high' and 'High' responses for applicability of each strategy. Figure 4 illustrates the applicability strategies reported by more than 80% of respondents.

Table 6: Strategies for Low Water Usage During Construction Phase

Ref.	**Strategies for Low water usage during construction phase**	**Level of applicability**					**TR**	**H & VH**
		1 %	**2** %	**3** %	**4** %	**5** %		%
STrg1	Assign responsibility and targets among the site staff	-	-	9.5	57.1	**33.3**	105	**90.5**
STrg2	Develop a builder guidebook for builders and add steps to reduce water in construction	-	-	10.5	62.9	26.7	105	**89.5**
STrg3	Integration of pre-cast or prefabricated construction methods	1.0	14.3	15.2	50.5	19.0	105	69.5
STrg4	Integration of steel intensive construction methods	1.9	19.0	21.9	46.7	10.5	105	57.1
STrg5	Integration of dry wall partitions instead of brick and block walls	1.0	15.2	20.0	41.9	21.9	105	63.8
STrg6	Integration of pre-mixed concrete and pre-mixed mortar	1.0	23.8	37.1	35.2	2.9	105	38.1
STrg7	Introduce water action plan initially	-	1.9	8.6	49.5	**40.0**	105	**89.5**
STrg8	Implement environmental policies on natural resources (EMS/ Sustainability assessment systems)	-	1.0	6.7	65.7	26.7	105	**92.4**
STrg9	Integrate water efficient techniques during the pre-design and tender stage (rainwater/recycling)	-	2.9	14.3	55.2	27.6	105	**82.9**
STrg10	Introduce penalty system for unsustainable practices by site staff	1.9	3.8	26.7	49.5	18.1	105	67.6
STrg11	Increase of unit rate	2.9	33.3	40.0	20.0	3.8	105	23.8
STrg12	Implement licensed water abstraction system (Surface water/ tube well)	6.7	9.5	63.8	20.0	-	105	20.0
STrg13	Monitoring and Supervision	-	-	4.8	55.2	40.0	105	95.2
STrg14	Water awareness among workers (posters, meetings, Toolbox talking)	-	1.9	6.7	58.1	33.3	105	91.4

1:Very low 2: Low 3: Neutral 4: High 5: Very high TR: Total respondent

It could be observed that a close relationship exist between water efficiency TEchs and STgs. For instance, Strg 8 (Implement environmental policies on natural resources) related with the importance of implementing TEch 2 (Closed loop systems) and TEch10 (Rainwater collection and re-use). Although literature based evidence show that the licensed abstraction is a common strategy practiced in other countries, majority of respondents reported as neutral position on this aspect (STrg12) with an average rating of 63.8%. On the other hand, increase of unit rate (STrg11) was considered by majority as not applicable. Among water efficient construction methods (STrg3, STrg4, STrg5, and STrg6), the use of pre-cast (STrg3) and dry partitions (STrg5) were favoured over steel construction and pre-mixed concrete/mortar by majority of respondents.

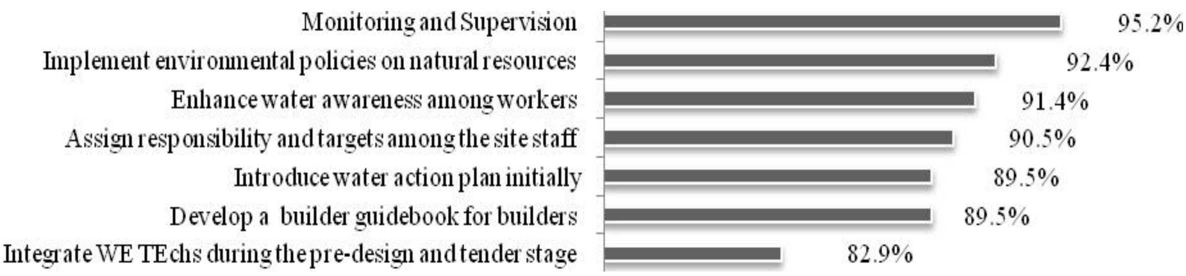


Figure 4: The Top Strategies Applicable for the Construction Phase in terms of Low Water Usage

The Kruskal-Wallis H test results show that except STrg 3 and STrg 5, there were no significant differences of views between the professional groups. Cronbach's Alpha was 0.662. This shows high internal consistency and reliability within the measurements used for each variable.

4.4. PERCEPTIONS ON UPTAKE OF WATER EFFICIENCY TECHNIQUES AND STRATEGIES

Perceptions of the respondents conveyed through the open ended questions are reported below. Few respondents opined that water efficiency TEchs/STrgs should be initiated from an early design stage in order to maximise savings in the most cost-effective way. Cost was mentioned as the main barrier for implementing some of the Techniques and strategies during the construction phase. For example, the use of curing agents, admixtures, sprinkler systems, rainwater harvesting etc, would be hampered by the cost involved in these. One of the civil engineers shared his experience and observed that "*Water curing is more effective than membrane curing. Water curing delays the initiation of corrosion more than the membrane curing*".

It is important to note that the existing literature give evidence to the effect that there is less consideration on environment during construction. However, many respondents highlighted the importance of implementing environmental policies to conserve natural resources, rainwater (or storm water) collection and storage during construction. In contrast, few respondents observed that space limitation on site and cost are barriers of rainwater collection. Increasing the price for water has been identified by some scholars as the best strategy to control water usage. However, the results show that majority of respondents are neutral with regard to water pricing (STrg11) in Sri Lanka. However, a project manager observed that "*treated water should not be provided free of charge under any circumstance. This leads to severe misuse*". Many respondents believe that cost of water is the main reason for such less attention on water efficiency during the construction phase. An Architect mentioned that "*many Sri Lankans lack of knowledge on the value of water and conservation methods. It can be controlled by introducing water pricing strategies*. Another engineer stated that "*people are much obliged to conserve water if they have sound awareness about scarcity of drinking water*". However, some quantity surveyors stated, "*water management is one of the neglected areas by the middle and top management of construction projects. Water quality test reports and approval for shallow tube wells should be included in tender documents*". However, majority of respondents reported (63.8%) are neutral on 'implement licensed water abstraction system (Surface water/ tube well)' (STrg12). One of consultant quantity surveyors claimed that "*if water is expensive for construction then the use may get reduced but the cost of construction would increase. Then high cost may induce new technologies and innovation*". Few respondents said it is practical to use pre-mixed concrete and mortar as a water efficiency strategy.

'Integration of water efficiency TEchs during the design and tender stage' (STrg9) is one of the highly applicable strategies reported by the respondents. The importance of this strategy further proved with comments made by few respondents during the survey. For instance, one comment was *to implement better water management system, it is very important to have awareness of users and its requirements should be included to condition of contract*. Other comments were, *the management is paying a less attention in the area of water usage during the pre -construction stage as well as during the construction stage at present in Sri Lanka; still there are no sustainable solutions for the water management at tender stage or any proposals or the innovations introduced by the consultants / or responsible parties whenever they are doing designs or the practice in construction; the requirements for water efficient practices need to be identified in Tender Document otherwise if the Contractors have to incur any additional cost to implement water efficient practices they will not allow for such costs when pricing tenders and take the risk of winning the tender and loosing during implementation. This should be resolved and implemented by an authorized government body or the relevant institutes which are engaged with construction industry as a compulsory requirement in the country.*

In general, majority of respondents reported that nature of project, scope of construction, location, water source, project team attitude and behaviour, cost, and other environmental and logistics mainly impact on water efficiency TEchs and STrgs. Although, approximately more than 90.5% respondents were agreed with STrg1, at present responsibility of individual is not established at site level as stated by few respondents. Few respondents shared their previous experience in terms of use of water efficiency TEchs during the construction phase.

Case I**:** *"The labour accommodations had long tanks filled with potable water for bathing and washing. Instead of that introduced showers and taps and as a result water bill came down by more than 70 %".*

Case II: *An unskilled labourer was rewarded for proposing reduction of cistern capacity by introducing one litre water filled glass bottle inside the cistern."*

Case III*: "The batching plant water run-off and the truck wash water were passed through sedimentation and settling a tank and a filtering process and this water was then re-used for curing work. Ultimately these practices changed the attitudes and wrong practices of the workers as well.*

5. CONCLUSIONS AND WAY FORWARD

This paper focused on applicability water efficiency techniques and strategies for sustainable use of water during the construction phase in Sri Lanka. The survey approach was used to fulfil the study aim with questionnaire survey conducted among professionals such as Project Managers, Civil Engineers, Quantity Surveyors and Architects who have more than ten years experience belonging to contractors and consultants. This study used descriptive statistics, and non-parametric tests to analyze the responses of questionnaire data using the statistical software of SPSS version 22.0. The results of Mann - Whitney U test ($p > 0.05$) showed that there is no significant difference of average responses of the two groups and the data were analyzed considering all participants as a single sample. The results show that the top five applicability water efficient TEchs as water auditing, water leak detection and monitoring systems, pressure reducing valves, high pressure trigger operated spray gun hoses and sub-metering. All these TEchs were accepted by more than 90% of the respondents. Vacuum toilets and fan misting dust suppression systems were not in favour for building construction sites. The top five applicability strategies were: monitoring and supervision, implement environmental policies on natural resources, enhance water awareness among workers, assign responsibility and targets among the site staff and introduce water action plan at the beginning. Majority of respondents do not agree with the increase of water price, and were neutral on implementing licensed water abstraction system in Sri Lanka. Main reasons for less consideration on water efficiency practices during construction phase were, namely, low priority given by the industry, and not integrating water efficiency techniques and strategies during the pre-design and construction stages as identified by the respondents.

It was found that initial planning and management of water and water efficiency techniques and strategies used on construction sites encourage minimal environment risks associated with construction activities. According to the empirical data, nature of project, scope of construction, location, water source, project team attitude and behaviour, and other environmental and logistics related to the project impact on use of water efficient techniques and strategies. In addition, cost was mentioned as the main barrier for implementing efficiency TEchs and STrgs during the construction phase although identified by the respondents as applicable. This study looked at a broader view on applicability of water efficiency techniques and strategies for construction industry by its professionals. It is important to look at the application of these water efficiency techniques and strategies in building construction sites in Sri Lanka. Therefore, the next step of the study is to use case study approach to explore the empirical data found from survey with real scenarios selecting few cases from ongoing building construction projects.

6. REFERENCES

Agazzy, W., 1998. From techniques to technology: the role of modern science.*Phil &Tech*, 4(2),1-9.

Australian Industry group, 2006. *Water saving factsheet: Textile industry (AIG7082)* [online]. Available from http://pdf.aigroup.asn.au/environment/7082_WPA_fact_sheet_TEXTILE.pdf [Accessed 12 August 2013]

Baloi, D., 2003. Sustainable construction: challenges and opportunities. In: Greenwood, ed. *19th Annual ARCOM Conference*, 3-5 September 2003. University of Brighton: Association of Researchers in Construction Management, 289-97.

Baxter, T., Bebbington, J. and Cutteridge, D., 2004. *Sustainability Assessment Model: Modelling Economic, Resource.* London: Earthscan.

Biswas A.K., 2008. Integrated Water Resources Management: Is It Working?, Water Resources Development, 24(1), 5–22, March 2008

Bourg, J., 2010.*Water conservation* [online]. Available from http://www.wbdg.org/resources [Accessed 20 October 2013]

Brooks, D.B., 2007. An operational definition of water demand management. *International Journal of water resource management,* 22(4), 521-528.

Cohen, R., Ortez, K. and Pinkstaff, C., 2009. *Increasing water efficiency in California's Commercial, Indusrial Institutional (CII) Sector* [online]. Available from: http//www.nrdc.org/water/cacii/files/cii.pdf [Accessed 28 October 2013].

Daly, H.E., 1993. *Introduction to essays toward a steady-state economy*. Massachusetts: The MIT Press.

Dexter, J., 2011. *Land use tools to protect groundwater: Water efficiency standards.* Washington: Environment Law and Policy Center.

Department of Energy, 2011. Domestic water conservation technologies. Washington: New Technology Demonstration Program, (DOE/EE-0264).

Ding, G.K.C., 2008. 'Sustainable construction-the role of environmental assessment tools', *Journal of Environmental Management,* vol. 86, no. 3, pp. 451-464.

Fernando, S.R.S., 2007. *Towards the sustainable construction through Managing water,* Unpublished dissertation (B.Sc.). University of Moratuwa, Sri Lanka.

Gleick, P., 1998. Water in crisis: paths to sustainable water use. *Journal of ecological applications*, 8(3), 571-579.

Jones, P., Comfort, D. and Hillier, D., 2006. Corporate Social Responsibility and the UK construction industry. *Journal of Corporate Real Estate*, 8(3), 134-150.

Hart, S.L., 1995. A natural –resource –based view of the firm. *Academy of Management review* ,4(20), 986-1014

Horne, J.,2012. Economic approaches to water management in Australia. *International journal of water resource development*, 29(4), 1-18.

Kibert, C. J., 1994. Establishing principles and a model for sustainable construction. In: Kibert, C.J., ed. *1st International Conference of CIB TG 16 on Sustainable Construction*, Florida 6-9 November 1994. USA: Tempa, 3–12.

Mactavish, A. and Greenhalgh, L., 2013. *Sustainability: Resource efficiency, Sweett Group June* [online]. Available from http://www.building.co.uk/sustainability-resource-efficiency/5056886.article [Accessed 25 March 2014].

McNab, D.J., Lynch, M. and Young, P., 2011. *Auditing of water use on construction sites-Phase I*[Online]. Waste and resources action Programme (WRAP): Mabbett & Associates Ltd. Available from: http://www.strategicforum.org.uk/pdf/Final_Report_in_WRAP_Template_FINAL_13_Jul_2011_132e1f6ea11053.pdf [Accessed 24 May 2014].

National Cleaner production Center, Sri Lanka. 2012. *What is watrefficicny?*[online] Available from http://www.ncpcsrilanka.org/water_efficiency.html [Accessed 22 October 2013]

Ramachandran, K., 2004. How much water should buildings consume?, The Hindu, *National News Paper,* 07 February.

Savenije, H. and Van der Zaag, P., 2002, Water as an economic good and demand management paradigms with pitfalls, International water resources association. *Water International*, 27(1), 98-104

Sjostrom, C. and Bakens, W., 1999.Sustainable construction: why, how and what. *Building Research and Information*, 27(6), 347–353.

Shen, L.Y., Hao, J.L., Tam, V.W.Y., and Yao, H., 2007. A checklist for assessing sustainability performance of construction projects.*Journal of civil engineering and Management,* 8(4), 273–281.

Tam, V.W.Y. and Lee, K.N., 2007.Assessing Environmental Performance in the Construction IndustrySurveying.*Built Environment,* 18 (2), 59-72.

Tse, Y.C.R., 2001. The implementation of EMS in construction firms: case study in Hong Kong. *Journal of Environmental Assessment Policy and Management*, 3(2), 177-194.

Theo, C.H., 2003. A study of management attitudes to a performance approach to construction worker safety. *Journal of construct*, 4(1).87.

Waidyasekara, K.G.A.S., De Silva, M.L. and Rameezdeen, R., 2014. A critical review of water studies in construction industry.In: *3rd world International Conference on Sustainability and development in Built environment: The way forward*, Colombo 20-22 June 2014. 01-12.

Waidyasekara K.G.A.S, De Silva M.L and Rameezdeen, R., 2013. Comparative study of green building rating systems: In terms of water efficiency and conservation. In: *2nd second world construction symposium 2013. Socio-economic sustainability in construction: Practice, policy and research*, Colombo 14 -15 June 2013. 108-117.

Waidyasekara K.G.A.S, De Silva M.L and Rameezdeen, R. ,2012.Value of sustainable use of water in construction industry.In**:** *2nd International conference on Sustainable Built environment,* Kandy 14th -16 December 2012. 1-13

Waylen, C., Thornback, J. and Garrett, J., 2011. *Water: an action plan for reducing water usage on construction sites* [online]. London: Forum for construction (SFfC). Available from: www.strategicforum.org.uk/pdf/SCTG09-WaterActionPlanFinalCopy.pdf [Accessed 25 March 2014].

Walton, J.S., El-Haram, M., Castillo, .H., Horner, R.M.W., Pricce, A.D.F. and Hardcastle, C., 2005. Integra ted assessment of urban sustainability. *Journal of Engineering Sustainability*, 158, 57-66.

Wu, Y.W., 2003. *The foreground of green building development* [online]. Available from: http://www.zhb.gov.cn [Accessed 10 September 2013)

Xing, Y., Horner, R.M.W., El-Haam, M.A., and Bebbington, J., 2009. A framework model for assessing sustainability impact of a built environment. *Science Direct,* 33(1), 209-224.

Zbigniew, W. and Kundzewicz, W., 1997. Water resources for sustainable development. *Hydrological Sciences Journal*, 42(4), 467-480.

The Ceylon Institute of Builders (CIOB) www.ciob.lk

Established in 1961, the Ceylon Institute of Builders (CIOB) is the premier institute for Building Professionals in Sri Lanka with a strong network of Engineers, Architects, Surveyors and similar allied professions who work to inspire, encourage, educate and train students, builders, and professionals in the country. The institute welcomes young entrants and mature professionals with or without a background in construction to achieve professional level careers in the country. They are provided with a well structured development programme that eventually lead to gaining corporate membership of the institute.

University of Moratuwa – Department of Building Economics www.becon.mrt.ac.lk

The Department of Building Economics, University of Moratuwa, Sri Lanka was founded in 1983. It is currently the pioneer Sri Lankan institution to offer programmes in Quantity Surveying, Facilities Management, Project Management, Construction Law and Dispute Resolution and Occupational Safety and Health Management. Building Economics and Management Research Unit (BEMRU) is the research arm of the Department of Building Economics which specializes in research in Building Economics and Management in the country as well as internationally.

International Council for Research and Innovation in Building and Construction (CIB) www.cibworld.nl

The CIB acts as a global network for international cooperation and information exchange in building and construction research and innovation. CIB collaborates with organisations around the world supporting the development of the industry, while facilitating international knowledge transfer on topics of interest. It covers the technical, economic, environmental, organizational and other aspects of the built environment during all stages of its life cycle.

Liverpool John Moores University (LJMU) www.ljmu.ac.uk

Ranked in the top 400 universities world-wide in the Times Higher Education World University Rankings 2013-14, the exceptional student experience LJMU offers is founded on high quality teaching, ground-breaking research and dedicated staff throughout the University.

Centre for Infrastructure & Construction Industry Development (CICID) of the Department of Civil Engineering of the University of Hong Kong www.civil.hku.hk/cicid

The Centre for Infrastructure & Construction Industry Development (CICID) of the Department of Civil Engineering of the University of Hong Kong, was established in November 2002. The aims include fostering continuous improvements, while targeting excellence in the construction industry in general and infrastructure development in particular, through the development of innovative strategies and techniques.

CIB W92 & CIB TG72

CIB W92 and CIB TG72 brings knowledge and expertise in the fields of procurement systems and public-private partnerships respectively.

Indian Institute of Technology, Madras www.iitm.ac.in

Indian Institute of Technology Madras is one among the foremost institutes of national importance in higher technological education, basic and applied research. The Institute has sixteen academic departments and a few advanced research centres in various disciplines of engineering and pure sciences, with nearly 100 laboratories organised in a unique pattern of functioning.

Colombo School of Construction Technology (CSCT) csct.edu.lk

The CSCT was established in 2008, with the motto 'Sapientia et Doctrina', which is Latin for Wisdom & Learning. It strives to create a learning environment to nurture the development of critical thinking skills; support innovation; and develop knowledge and expertise of our students. CSCT faculty have expertise in a broad range of specialties and have developed curriculums in each of the programs that meet the needs of the construction industry.