Towards a Smart, Sustainable and Resilient Built Environment
8 - 10 November 2019 - Colombo

SYMPOSIUM

PROCEEDINGS

8th - 10th November 2019

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The 8th World Construction Symposium - 2019

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THEME:

TOWARDS A SMART, SUSTAINABLE AND RESILIENT BUILT ENVIRONMENT

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We particularly appreciate all the authors for selecting the 8th World Construction Symposium as a platform to disseminate their research work. Our special thanks also go to the eminent international and local scientific committee members for reviewing and offering constructive comments on the papers, which helped to ensure that the accepted papers for the symposium were of a high standard. We would like to extend our gratitude towards the chief guest, keynote speakers, session chairs, session coordinators, paper presenters and other invitees for their commitment and contributions towards the symposium. We also appreciate the event coordinators, resource persons, contributors and participants of the postgraduate workshop as well. Our special thanks go to Editor-in-Chief of BEPAM Journal and the team at Emerald Group Publishing for their contributions to the symposium. We are grateful to the Faculty of Graduate Studies, University of Moratuwa for sponsoring our keynote speaker under the grant scheme on "Funding for International Conferences and Symposia 2019". A special thank you goes out to all the sponsors who have provided sponsorships to bring this year's symposium to fruition. We are also thankful to all the government and other institutions and all our supporting partners who have supported the symposium in various ways.

Last but not least, a special thank you goes out to all our colleagues in the organising committee, symposium secretariat and the Department of Building Economics for devoting their time and efforts to make this 8th World Construction Symposium 2019 a success.

Editors
The 8th World Construction Symposium 2019
Colombo, Sri Lanka
November 2019

PREFACE

The 8th World Construction Symposium jointly organised by the Ceylon Institute of Builders (CIOB) and Building Economics and Management Research Unit (BEMRU), Department of Building Economics, University of Moratuwa is held from 08 – 10 November 2019 in Colombo, Sri Lanka. The symposium is held in partnership with Liverpool John Moores University, United Kingdom; Centre for Innovation in Construction and Infrastructure Development (CICID), The University of Hong Kong, Hong Kong; Indian Institute of Technology Madras (IIT Madras), India; Western Sydney University, Australia; Colombo School of Construction Technology (CSCT), Sri Lanka; and Built Environment Project and Asset Management (BEPAM): Journal, published by Emerald Group Publishing. This year's symposium marks the 8th milestone of the World Construction Symposium series, which has been held annually since 2012. The symposium provides a special forum for academic researchers and industry practitioners to share their knowledge, experience and research findings on the main theme of "Towards a smart, sustainable and resilient built environment".

We received a large number of abstracts and full papers for the symposium, all of which underwent a rigorous three-staged review process as detailed below:

1) All submitted abstracts were reviewed by the Scientific Committee Co-Chairs.
2) All submitted full papers were sent to at least two independent referees selected from the symposium scientific committee for double-blind peer review. Reviewers provided constructive comments with respect to the originality, significance, reliability, quality of presentation and relevance to the remit of the symposium of each paper. The Scientific Committee Co-chairs, who are the editors of the symposium proceedings, were responsible for final decisions on accepting or rejecting the papers based on these assessments.
3) At least one of the authors of all the accepted papers were required to register and orally present the paper in the symposium. Only papers presented at the symposium have been published in the proceedings.

After the rigorous double-blind review process, 62 papers were selected for publication. The authors of the selected papers are from a range of different countries including Australia, Hong Kong, Ireland, South Africa, Sri Lanka and United Kingdom. The papers cover a wide spectrum of areas such as: enhancing value in construction; waste management; retrofitting and adaptive re-use of buildings; smart and resilient built environments; innovation and smart technologies; challenges and policy gaps for sustainability; procurement solutions for construction; project management in construction; socio-economic considerations in construction; training and education in construction; green and affordable construction practices; and effective project delivery.

We as the Scientific Committee Co-chairs are committed to ensuring ethics in publication and quality of articles. Hence, priority was given to the quality and standard of papers rather than the number of papers presented at the symposium. The proceedings emerging from this symposium represent the result of the tireless efforts of all authors, reviewers, symposium organising committee members, associate partners, sponsors and we hope it would pave way for advancement of knowledge as we strive towards a smart, sustainable and resilient built environment.

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Prof. Andrew Ross

Professor of Construction Project Management
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Andrew Ross is Professor of Construction Project Management at LJMU and a Chartered Quantity Surveyor. His scholarly interests lie in the area of sustainability, organizational management with a focus on main contractor / supply chain relationships and procurement. He takes an interdisciplinary approach to his research and has been principal investigator for a research projects funded by Innovate UK, ERDF, Erasmus, British Council and RICS totalling over £2.0m. Over the last 30 years, his research students have investigated supply chain management, construction economics, cost modelling, cash management and cost value reconciliation. Andrew has published three textbooks, contributed book chapters and over 150 papers in peer-reviewed journals and conferences. A central theme of his research is to seek impact via collaboration with industrial partners. He has been instrumental in the national development of degree apprentice provision as a member of the construction trailblazer group. He has contributed to many national and international construction conferences and is a founder member of CIB TG 92 Wearable Sensor Technology.

Prof. Wei Pan

Executive Director of Centre for Innovation in Construction and Infrastructure Development (CICID)
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Ir Dr. Wei Pan is Executive Director of Centre for Innovation in Construction and Infrastructure Development (CICID) and Associate Professor at The University of Hong Kong (HKU). He is specialized in construction engineering and innovation, with interest covering prefabrication, modular integrated construction (MiC), sustainable and zero carbon building. He developed the 'dialectical system theory' to lead research on zero carbon building and modular construction. Dr. Pan was awarded Distinguished Young Investigator of China Frontiers of Engineering by Chinese Academy of Engineering and achieved HKU Engineering Knowledge Exchange Award 2019. Dr. Pan has authored over 200 publications and secured over HK$70 million research grants. He is Chartered Builder, Chartered Environmentalist, Fellow of Higher Education Academy, and member of Institution of Civil Engineers and Hong Kong Institution of Engineers. He has 25 years of working experience in academia and practice internationally.

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A CONCEPTUAL KNOWLEDGE VALUE CHAIN MODEL FOR CONSTRUCTION ORGANISATIONS ENGAGED IN COMPETITIVE TENDERING

K.G. Dewagoda[1] and B.A.K.S. Perera[2]

ABSTRACT

With the world heading towards a knowledge economy, knowledge is contemplated as a critical organisational resource that creates competitive advantage for construction organisations, especially when they engage in competitive tendering. Knowledge Value Chain Model (KVCM) is a viable mechanism that employs organisational knowledge for the organisations to acquire competitive advantage in competitive tendering. However, it has yet not been adopted although there is a dire requirement for it in the construction industry. Hence, this study developed a conceptual KVCM to facilitate the full exploitation of the knowledge available in a construction organisation so that it can function with competitive advantage during competitive tendering. This conceptual KVCM was developed by analysing the generic KVCMs mentioned in the extant literature. The analysis was followed by 15 expert interviews. It is recommended that to facilitate its pragmatic implementation, the KVCM be customised in the future as a Knowledge Value Chain (KVC) Framework by incorporating organisational characteristics.

***Keywords**: Competitive Advantage; Construction Organisations; Knowledge; Knowledge Management (KM); Knowledge Value Chain Model (KVCM).*

1. INTRODUCTION

Knowledge is the 'lifeblood of an organisation' which ensures the survival of the organisation within dynamic and competitive environments (Asrarulhaq and Anwar, 2016). Management of knowledge is vital for driving an organisation towards gaining a competitive advantage since knowledge is a strategic resource (Mahdi *et al*., 2019). An organisation acquires competitive advantage when it gains or generates specific characteristics to surpass its co-competitors (H. L. Wang, 2014). The value chain concept introduced by Porter (1985) disaggregates an organisation into value activities to act as "discrete building blocks of competitive advantage" (p.38). Competitive tendering is the most traditional and favoured procurement method adopted by the industry (Kang *et al*., 2018).

Betts and Ofori (1992) have defined construction organisations as business entities that are involved in any facet of construction (p.512). They have used the term 'construction organisation' to provide a deeper contextual meaning than what is implied by a

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'contractor' or a 'building company', although Tripathi and Jha (2018) have used the term "construction organisations" to indicate contracting organisations as well. The term "construction competition" is affiliated with competitive tendering undertaken by competing construction organisations that have profit maximisation as their prime goal (Reinschmidt and Kim, 2006). This competitiveness has compelled construction organisations to seek competitive advantage by boosting their organisational performance (Horta and Camanho, 2014).

Kivrak *et al*. (2009) have claimed that knowledge is indispensable for construction organisations to win tenders using competitive advantage. Yap and Lock (2017) have analysed the competitive advantage of construction organisations and the contribution to organisational performance made by their Knowledge Management (KM) practices. In these construction organisations, lessons learned are the key drivers of competitive advantage (Carrillo *et al*., 2013). However, the traditional way the contractors do business hinders knowledge integration and affects the decision making processes adversely (Saini *et al*., 2019). Yet, construction organisations do not value KM initiatives which can ultimately lead to a knowledge loss (Sun *et al*., 2019). Therefore, there is a critical need in construction organisations to use KM frameworks in order to systematically gain from the lessons learned (Ghasabeh and Chileshe, 2014).

Knowledge Value Chain Model (KVCM), a model that can identify value adding KM activities, is vital for fully exploiting the competitive potential of KM (Holsapple and Singh, 2001). It is a model of KM framework (Wong, 2004) that applies the value chain concept to knowledge (Powell, 2001). Almarabeh *et al*. (2009) have defined KVCM as a concatenation of intellectual tasks through which Knowledge Workers (KWs) can create a distinctive competitive advantage for their employers to reap social and environmental benefits. However, the literature mostly mentions the competitive advantage of manufacturing organisations and even the few studies conducted to ascertain the competitiveness of the tendering process have been unsuccessful as they have failed to address the competitive potential of organisations (Zhang *et al*., 2018). According to Resource Based View (RBV), knowledge is a valuable, rare, and inimitable resource that contributes to competitive advantage (Omerzel and Gulev, 2011). Since to exploit its resources and achieve its complete potential, an organisation has to organise itself (Barney, 1995), an appropriate mechanism that can exploit the knowledge base of a construction organisation through learning cycles to derive competitive advantage in competitive tendering has become essential. KVCM concept can, therefore, be proposed as a KM framework to recognise value creating KM activities of competitive tendering, thereby enabling organisational learning to move through the competitive edge. This study, thus, aimed to develop a KVCM for construction organisations engaged in competitive tendering so that they can gain competitive advantage.

2. KNOWLEDGE VALUE CHAIN (KVC) CONCEPT

Porter (1985) introduced the value chain to analyse the activities performed by an organisation and the interactions among them. KVCM applies the value chain concept to knowledge (Powell, 2001) and functions as a model of the KM framework (Wong, 2004). KVCM also demonstrates how the competitive position of an organisation can be ensured (M. C. Lee and Han, 2009). Different applications of KVCM in various fields have been explored. Some of those are 'Modified KVCM for new product development in a winery' (Wong, 2004); 'Knowledge Value Chain (KVC) framework implemented in supply chain management' (M. C. Lee and Han, 2009); 'Employement of KVC concept in research and development collaborations to impact on process innovation' (Un and Asakawa, 2015); and 'KVC framework as a conceptual model for organisational performance' (M. C. Lee, 2016). This study attempts to develop a KVCM for competitive tendering by reviewing the KVCMs mentioned in the literature.

3. TYPES OF KVCMS

Many KVCMS have been mentioned in the literature. In order to achieve the research aim, the study analysed 14 of them by categorising them as 'KVCMs based on KM frameworks', 'KVCMs based on Data-Information-Knowledge-Wisdom (DIKW) hierarchy' and 'other KVCMs'. Table 1 presents the names of the researchers who have developed each type of KVCM.

Table 1: Categorisation of KVCMs

KVCMs based on KM frameworks	KVCMs based on DIKW hierarchy	Other KVCMs
Weggeman (1997) (A)	Ermine (2013) (G)	Spinello (1998) (J)
C. C. Lee and Yang (2000) (B)	Powell (2001) (H)	Eustace (2003) (K)
Holsapple and Singh (2001) (C)	King and Ko (2001) (I)	Chen *et al*. (2004) (L)
L. C. Wang and Ahamed (2005) (D)		Y. Xu and Bernard (2010) (M)
Almarabeh *et al*. (2009) (E)		Roper *et al*. (2008) (N)
Carlucci *et al*. (2004) (F)		

The KVCMs under the category 'KVCMs based on KM frameworks' deal with KM activities while those under the category 'KVCMs based on DIKW hierarchy' deal with DIKW transformation. 'Other KVCMs' are the KVCMs that cannot be categorised under any of the other two categories. Each model was given a code between **A** and **N** to enable its easy identification during the review.

4. COLLATION OF MODELS

4.1 KVCMS BASED ON KM FRAMEWORKS

Some KVCMs that are based on KM frameworks such as those developed by C. C. Lee and Yang (2000), Holsapple and Singh (2001), and L. C. Wang and Ahamed (2005) are exact replicas of the Porter's value chain with the primary and secondary activities of the latter replaced with KM activities and associated supportive activities respectively. Although the other models under this category differ from Porter's model structure, they are also based on the core concept of the KVCMs of this category. All the models except that proposed by Carlucci *et al*. (2004) have precise KM activities. While Carlucci *et al*.'s (2004) model promotes the KM framework for the KVCM concept, it also continues beyond mere KM activities, which is an outstanding feature. On the other hand, the model proposed by Almarabeh *et al*. (2009) is exceptional since it promotes the DIKW hierarchy although it is a KVCM based on the KM framework. However, Ermine (2013) objected the KVCMs based on KM frameworks emphasising that cognitive activities are too complicated to be chained by the knowledge activities of the KVCMs acting on the knowledge assets of an organisation, which frequently are the models based on KM frameworks. KVCMs based on the DIKW hierarchy are thus deemed to chain the cognitive activities acting on the knowledge processes of organisations.

4.2 DATA-INFORMATION-KNOWLEDGE-WISDOM (DIKW) HIERARCHY

DIKW hierarchy demonstrates the distinction among knowledge, information, and data in the form of a hierarchy (Rowley, 2007). Nurulin and Skvortsova (2018) have considered data as observational results and measurements in both real and abstract worlds whereas Y. Wang (2015) considered data as the abstract representations of the real world. According to Nurulin and Skvortsova (2018), information is also a form of data that comes with ample descriptions, while according to Y. Wang (2015) information is a general form of abstract objects perceived by humans and represented by different systems. Wisdom is the strategic perspective of decision-making, which symbolises related cognitive capabilities of the Decision Maker (DM) (Nurulin and Skvortsova, 2018). Tuomi (1999) has argued that the DIKW hierarchy should actually be reversed contradicting the classical DIKW model. Another conceptualisation that has been forwarded by Spiegler (2000) states that DIKW relationship is a cyclical model in the form of a double hierarchy wherein data transforms to knowledge with information as the intermediate state with knowledge relapsing eventually to data with time, volume, reuse and application.

4.3 KVCMS BASED ON THE DIKW HIERARCHY

The model proposed by Ermine (2013) is based on conventional DIKW hierarchy. King and Ko (2001) and Powell (2001) have delineated DIKW transformation in customised or modified configurations. The KVCM presented by King and Ko (2001) is predetermined in the form of a conceptual framework for evaluating the advancement of KM processes of acquiring, disseminating, and utilising information and knowledge within a learning organisation and as a basis for planning and designing KM in a learning organisation. However, they conceded the linearity of the model as a limitation, since dissemination and feedback loops had not been set out. Powell’s (2001) model is the most significant model out of the group since it provides KW and DM classifications designating KWs to acquire and develop data up to knowledge and DMs to exploit such knowledge for strategic planning to gain competitive advantage.

4.4 OTHER KVCMS

Other models vary considerably from one another in terms of the model basis, model features, model structure and applications. Even though Spinello’s (1998) model has got certain characteristics of the Porter’s value chain, it is not exactly analogous to the Porter’s model. Its continuous knowledge flow in a circular motion in particular is a salient feature that deviates from Porter’s concept. Y. Xu and Bernard (2010) have designed their model to overcome the limitation of linearity by acquiring a multi-dimensional facet of the knowledge context. Moreover, the model controverts DIKW hierarchy and affirms that knowledge matures in terms of state and context rather than from its upward evolvement through the DIKW pyramid. On the other hand, Eustace (2003) has presented a new dimension of KVCM by integrating different perspectives of discrete interest groups into the Porter’s value chain system in terms of knowledge.

4.5 COMPARISON OF KVCMS DEVELOPED IN THE PREVIOUS STUDIES

When the KVCMs of the three categories are compared, it is revealed that each model has its own distinct features, each of which either curtails or compliments the others. Table 2 summaries these features.

Table 2: Summary of the KVCMs analysed

KVCM \ Feature	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Applicability to a specific functional unit	Affirmative	Overlooked	Overlooked	Overlooked	Overlooked	Affirmative	Overlooked	Overlooked	Significant	Overlooked	Overlooked	Overlooked	Affirmative	Overlooked
Replacement of primary activities with KM activities	Affirmative	Significant	Significant	Significant	Significant	Affirmative	Objected	Affirmative	Affirmative	Affirmative	Affirmative	Affirmative	Irrelevant	Irrelevant
Replacement of secondary activities with KM activities	Overlooked	Overlooked	Overlooked	Overlooked	Significant	Overlooked	Objected	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Irrelevant	Irrelevant
Existence of support activities	Overlooked	Significant	Significant	Significant	Overlooked	Overlooked	Irrelevant	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Irrelevant	Irrelevant
Segregation into the two compartments assigned to KWs and DMs	Overlooked	Overlooked	Overlooked	Overlooked	Significant	Overlooked	Overlooked	Significant	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked
Understanding among KWs and DMs	Irrelevant	Irrelevant	Irrelevant	Irrelevant	Significant	Irrelevant	Irrelevant	Significant	Irrelevant	Irrelevant	Irrelevant	Irrelevant	Irrelevant	Irrelevant
Endorsement of the conventional DIKW hierarchy	Overlooked	Overlooked	Overlooked	Overlooked	Affirmative	Overlooked	Significant	Affirmative	Affirmative	Overlooked	Overlooked	Overlooked	Objected	Overlooked
Endorsement of an enhanced/extended DIKW hierarchy	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Significant	Affirmative	Overlooked	Overlooked	Overlooked	Objected	Overlooked
Establishment of feedback loops	Overlooked	Overlooked	Overlooked	Overlooked	Affirmative	Overlooked	Overlooked	Affirmative	Overlooked	Affirmative	Overlooked	Affirmative	Overlooked	Overlooked
Emphasis placed on lessons learned practices	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Significant	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked
Correlation of KM activities with the DIKW hierarchy	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked	Overlooked

Significant **Affirmative** **Overlooked** **Objected** **Irrelevant**

Features tabulated in Table 2 are considered as crucial in developing a KVCM for competitive tendering. It is noteworthy that in the previous models most of the decisive features such as KW/DM classification, DIKW hierarchy, feedback loops, and lessons learned practices have been overlooked. It has to be further noted that pitfalls could be avoided by establishing synergy through correlation of KM activities with the DIKW hierarchy, which is not present in any of the previous KVCMs.

5. RESEARCH METHODOLOGY

Critical reviewing of literature is an integral part of a research which is vital for the creation and fine-tuning of the research goals (Saunders *et al*., 2009). Therefore, this study too included a literature review, which was followed by 15 face-to-face semi-structured interviews conducted with practicing Chartered Quantity Surveyors (QSs) who had more than 10 years of experience in tendering. Each interview spanned for about 45-60 minutes. Purposive sampling was used to select the interviewees considering their knowledge and experience in the field as well as their availability for the interviews and their willingness to participate in the interviews (Etikan *et al*., 2016). The data collected were analysed manually using content analysis, since then the data volume to be handled can be minimised and also be categorised to enhance their contextual meaning (Bengtsson, 2016).

6. DEVELOPMENT OF THE CONCEPTUAL KVCM

The KVCM for competitive tendering in construction organisations was developed incorporating the above mentioned characteristics identified from the perspective of a construction organisation. The strategy was to incorporate into the new KVCM, the noteworthy features of the already available KVCMs and refining them further to suit the context, based on the expert interview findings. The new KVCM was based on Powell's (2001) model because of the strong resemblance of the latter to the tendering unit structure of construction organisations. Accordingly, the KVCM developed consisted of two sub-divisions, namely 'Knowledge Production' (KP) and 'Knowledge Utilisation' (KU) with their responsibilities assigned to 'KW's and 'DM's respectively. It also comprises a chain with 'States' for which cross links have been established to a set of activities termed 'Activities' which progress towards 'Competitive Advantage'. States delineate an extended DIKW hierarchy. Activities are classified as 'Primary Activities', 'Secondary Activities' and 'Support Activities'. A 'Feedback Loop' for lessons learned has been established along with 'Understanding' among KWs and DMs. Figure 1 presents the final outcome.

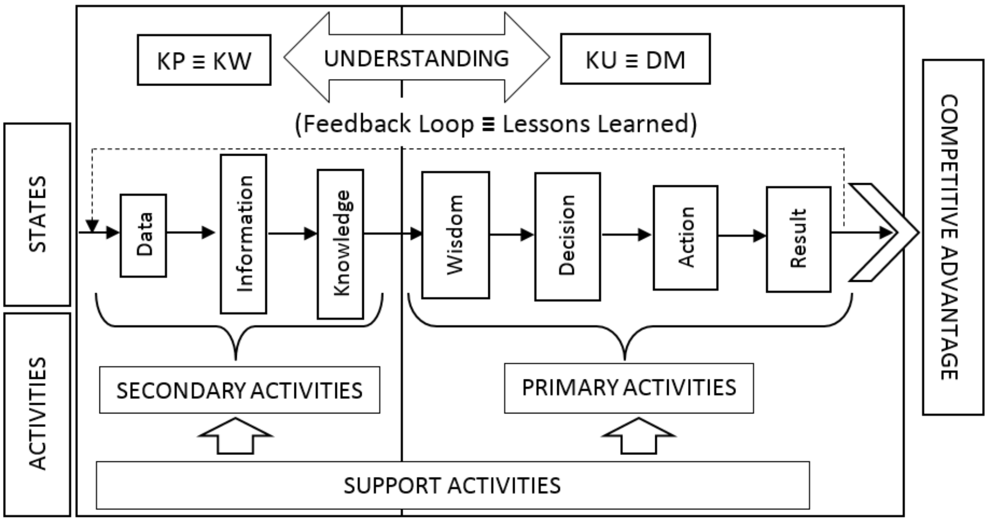

Figure 1: KVCM for competitive tendering in construction organisations

Sources that contributed to the attributes of the KVCM are tabulated in Table 3.

Table 3: Sources of the attributes of the KVCM

Attribute	Source
Sub-dividing as 'KP' and 'KU'	Adapted from Powell (2001) and J. Xu *et al*. (2010)
'KW' and 'DM' Assignment	Adapted from Powell's (2001) model
Terms 'States' and 'Activities'	Adapted from Powell's (2001) model
'States' of the KP Side	Based on Ermine's (2013) model and DIKW Hierarchy
'States' of the KU Side	Adapted from Powell's (2001) model
Linear Chaining of the Stages	Adapted from all models except Spinello's (1998) model

Attribute	Source
'Primary' and 'Secondary' Activities	Adapted from Almarabeh *et al*.'s (2009) model
'Support activities'	Adapted from all KVCMs based on Porter's value chain model except Almarabeh *et al*.'s (2009) model
'Understanding'	Adapted from Powell (2001) and Almarabeh *et al*. (2009)
'Feedback Loop'	Adapted from Spinello (1998), Powell (2001), and Chen *et al*. (2004)

The sub-division of the KVCM into two compartments was based on the two sets of activities given in the Powell's (2001) model, namely 'Knowledge Acquisition' and 'Knowledge Application'. The terminology used for KP and KU was adapted from J. Xu *et al*. (2010). KP considers knowledge as an organisational asset embedded in the 'business product', whereas KU focusses on the economic aspects (J. Xu *et al*., 2010). J. Xu *et al*. (2010) were of the view that the two terms focussed on the physical aspects of knowledge embellishing knowledge in a business setting. Therefore, the adapted nomenclature justifies the DIKW transformation in a profit-oriented organisation which in this study is a construction organisation. Powell's (2001) model distinguishes between 'States' and 'Actions' with 'States" as "stages of processing" and 'Actions' as "transformation needed to move to the next stage of processing" (p.3). This feature is incorporated in the KVCM using the terminology 'Activities' in order to circumvent confusions with the state 'Action'.

The first four states of KVCM resemble the DIKW chain, which is a significant feature in Ermine's (2013) model. States of the KU side which succeed 'Wisdom' are 'Decision', 'Action', and 'Result' which are similar to what is given in the Powell's (2001) model. However, 'Intelligence' in the Powell's (2001) model has been replaced with 'Wisdom'. According to Ermine (2013), 'Wisdom' includes both individual wisdom and organisational wisdom. Therefore, the term 'Wisdom' is expected to be more explanatory in an organisational setting, even if it complements 'Intelligence'. Nurulin and Skvortsova (2018) have introduced 'Understanding' amidst knowledge and wisdom within the DIKW hierarchy to ensure a smooth transition of the states. 'Understanding' is the ability to create new knowledge from existing knowledge, while 'Wisdom' is the "evaluated understanding" (Grzegorzewski and Kochanski, 2019, p.18). According to Powell (2001), 'Shared Understanding' between a KW and DM governs the quality of the process. Besides, it would not be fruitful, if KWs' efforts were dedicated on a task that DMs are not interested in strategically implementing (Powell, 2001). Almarabeh *et al*. (2009) have also remarked that a pitfall in 'Common Understanding' would result in the failure to achieve the activities at the expected quality. Hence, 'Understanding' between a KW and DM is established as an integral component of the KVCM.

In Almarabeh *et al*.'s (2009) model, all generic activities are KM activities assigned distinctly to KW and DM. Thus, activities of this KVCM are categorised as 'Primary Activities' and 'Secondary Activities'. The postulation of knowledge related infrastructure or enablers was adopted from KVCMs based on the KM framework (except Almarabeh *et al*.'s (2009) model) and those were referred to as 'Support Activities'. Feedback loops are not straightforward except in Powell's (2001) model. However, knowledge circulation in Spinello's (1998) model is circular, which implies continuous feedback. Chen *et al*. (2004) have included 'Two-way contribution' in their model, which is another intimation of feedback. King and Ko (2001) have considered the shortfall of feedback loops as a limitation of their model. Nevertheless, the feedback loop is an indispensable component of the KVCM developed in this study. Most importantly, the intention was to correlate KM activities with state transformation, which is absent in all of the other KVCMs. This feature was introduced to upgrade the KVCM through collaboration.

7. DISCUSSION

Even though the term 'Knowledge' is used to indicate knowledge circulation, what is actually processed is data and not knowledge (Garrick and Chan, 2017). The KVCM developed is consistent with this notion as it illustrates DIKW transition in the model. According to Ye (2016), DIKW hierarchy is transferable from being a hierarchy to being a logic chain. KVCM has disintegrated the DIKW hierarchy into a chain with extended states of Decision, Action and Result. Spiegler (2000) put forwarded the concept of double hierarchy of the DIKW relationship in the form of a cyclical model. The KVCM developed in this study incorporates a feedback loop which is an important feature that promotes lessons learned practices. The strategic implementation of knowledge in an organisation is guaranteed by feedback loops in respect of learning, since they proliferate organisational learning (Versiani *et al*., 2018). Accordingly, feedback loops in the KVCM imply the concept of organisational learning. In addition, KP and KU compartments have been entrusted to KWs and DMs respectively. This terminology of KW and KP was prominent in the models of both Almarabeh *et al*. (2009) and Powell (2001). Besides, in L. C. Wang and Ahamed's (2005) model, the terms 'Knowledge Provider' and 'Knowledge Seeker' imply a corresponding notion. While Nonaka considered all employees of an organisation as KWs, Drucker considered only the employees with 'specialised knowledge' as KWs (Gao *et al*., 2008). Nevertheless, this study uses Nonaka's concept in order to ensure a comprehensive approach and considers all employees involved in competitive tendering as KWs who contribute to the KVCM.

8. CONCLUSIONS AND THE WAY FOREWORD

The KVCMs developed in the past have been proposed for generic organisations with a holistic view. Since it was found that the concept would also be applicable to construction organisations, this study attempted to narrow down its scope to a specific function; competitive tendering. Accordingly, attention was focused specifically on competitive tendering rather than on the construction organisation as a whole. On the other hand, each individual KVCM that has been proposed so far has its own merits and demerits. Hence, synergy among these models would reduce the drawbacks and increase the benefits. The conceptual KVCM developed in this study contains the dominant features of the previously proposed KVCMs to minimise the drawbacks of those models and tailor their features to suit competitive tendering within construction organisations. However, it incorporates only the characteristics of the 14 models that were reviewed. It is also confined to estimating and pricing a tender by a construction organisation. Another limitation of the study is that the conceptual KVCM developed has not been validated using rigorous scientific methods. Nevertheless, the unique characteristics of these models include the feedback loop symbolising organisational learning and the correlation of the KM processes with the DIKW hierarchy. It has to be further noted that the

'Activities' of the KVCM have not been distinctly defined since certain features of construction organisations affect the KM processes. Therefore, it is recommended that the pragmatic implementation of the KVCM be made in the form of a 'KVC framework' to engage knowledge for value creation in competitive tendering so that competitive advantage could be gained. It is recommended that further studies be done to develop a KVC framework based on the primary, secondary and support activities of the KVC to suit the inherent features of the different genres of organisations.

9. REFERENCES

Almarabeh, T., Abuali, A. N., Alsharrab, S. and Alkareem, A., 2009. Value chain model in knowledge management. *International Journal of Recent Trends in Engineering, 2*(2), pp.196-198.

Asrarulhaq, M. and Anwar, S., 2016. A systematic review of knowledge management and knowledge sharing: Trends, issues, and challenges. *Cogent Business and Management, 16*(4), pp.1-15.

Barney, J. B., 1995. Looking inside for competitive advantage. *The Academy of Management Executive, 9*(4), pp.49-61.

Bengtsson, M., 2016. How to plan and perform a qualitative study using content analysis. *NursingPlus Open, 2*, pp.8-14.

Betts, M. and Ofori, G., 1992. Strategic planning for competitive advantage in construction. *Construction Management and Economics, 10*(6), pp.511-532.

Carlucci, D., Marr, B. and Schiuma, G., 2004. The knowledge value chain: How intellectual capital impacts on business performance. *International Journal of Technology Management, 277*(27), pp.575-590.

Carrillo, P., Ruikar, K. and Fuller, P., 2013. When will we learn? Improving lessons learned practice in construction. *International Journal of Project Management, 31*(4), pp.567–578.

Chen, Y. L., Yang, T. C. and Lin, Z. S., 2004. A study on the modeling of knowledge value chain. *SPE Asia Pacific Conference on Integrated Modelling for Asset Management.* Kuala Lumpur, Malaysia: Society of Petroleum Engineers.

Ermine, J. L., 2013. A knowledge value chain for knowledge kanagement. *Journal of Knowledge and Communication Management, 3*(2), pp.85-101.

Etikan, I., Musa, S. A., and Alkassim, R. S., 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), pp.1-4.

Eustace, C., 2003. A new perspective on the knowledge value chain. *Journal of Intellectual Capital, 4*(4), pp.588 - 596.

Gao, F., Li, M. and Clarke, S., 2008. Knowledge, management, and knowledge management in business operations. *Journal of Knowledge Management, 12*(2), pp.3-17.

Garrick, J. and Chan, A., 2017. Knowledge management and professional experience: the uneasy dynamics between tacit knowledge and performativity in organizations. *Journal of Knowledge Management, 21*(4), pp.872-884.

Grzegorzewski, P. and Kochanski, A., 2019. From data to reasoning. In P. Grzegorzewski, A. Kochanski, and J. Kacprzyk, *Soft Modeling in Industrial Manufacturing.* Springer, Cham, pp.15-25.

Holsapple, C. W. and Singh, M., 2001. The knowledge chain model: Activities for competitiveness. *Expert Systems with Applications, 20*(1), pp.71-98.

Horta, I. M. and Camanho, A. S., 2014. Competitive positioning and performance assessment in the construction industry. *Expert Systems with Applications, 41*(4), pp.974–983.

Kang, B. G., Elbashier, M., Tang, L., Jin, R. and Tang, S., 2018. Competitive tendering for construction projects in Sudan. *Journal of Fundamental and Applied Sciences, 10*(3S), pp.828-835.

King, W. R. and Ko, D. G., 2001. Evaluating knowledge management and the learning organization: An information/ knowledge value chain approach. *Communications of the Association for Information Systems, 5*(1), pp.14.

Kivrak, S., Arslan, G., Dikmen, I. and Birgonul, M. T., 2008. Capturing knowledge in construction projects: Knowledge platform for contractors. *Journal of Management in Engineering, 24*(2), pp.87-95.

Lee, C. C. and Yang, J., 2000. Knowledge value chain. *Journal of Management Development, 19*(9), pp.783-794.

Lee, M. C., 2016. Knowledge management and innovation management: Best practices in knowledge sharing and knowledge value chain. *International Journal of Innovation and Learning, 19*(2), pp.206-226.

Lee, M. C. and Han, M. W., 2009. Knowledge value chain model implemented for supply chain management performance. *Fifth International Joint Conference on INC, IMS and IDC*, Seoul, South Korea, pp.606-611.

Mahdi, O. R., Nassar, I. A. and Almsafir, M. K., 2019. Knowledge management processes and sustainable competitive advantage: An empirical examination in private universities. *Journal of Business Research, 94*, pp.320-334.

Nurulin, Y. and Skvortsova, I., 2018. Conceptual model of information support for taking decisions. *IV International Scientific Conference "The Convergence of Digital and Physical Worlds: Technological, Economic and Social Challenges",* Rīga, Latvia: International Conference Society, Health, Welfare.

Omerzel, D. G. and Gulev, R. E., 2011. Knowledge Resources and Competitive Advantage. *Managing Global Transitions,* 9(4), pp.335-354.

Porter, M. E., 1985. *Competitive advantage.* New York: Free Press.

Powell, T., 2001. The knowledge value chain: How to fix it when it breaks. *KnowledgeNets 2001: Proceedings of the 22nd National Online Meeting,* New York City: Information Today Inc., pp.1-14.

Reinschmidt, K. F. and Kim, H. J., 2006. A dynamic competition model for construction contractors. *Construction Management and Economics, 24*(9), pp.955-965.

Roper, S., Du, J. and Love, J. H., 2008. Modelling the Innovation Value Chain. *Research Policy, 37*(6-7), pp.961-977.

Rowley, J., 2007. The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science, 33*(2), pp.163-180.

Saini, M., Arif, M. and Kulonda, D. J., 2019. Challenges to transferring and sharing of tacit knowledge within a construction supply chain. *Construction Innovation, 19*(1), pp.1471-4175.

Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. 5th ed. England: Pearson Education Limited.

Spiegler, I., 2000. Knowledge management: A new idea or a recycled concept? *Communications of the Association forInformation Systems, 3*(14).

Spinello, R., 1998. The knowledge chain. *Business Horizons, 41*(6), pp.4-14.

Sun, J., Ren, X. and Anumba, C. J., 2019. Analysis of knowledge-transfer mechanisms in construction project cooperation networks. *Journal of Management in Engineering, 35*(2), pp.1-13.

Tripathi, K. K. and Jha, K. N., 2018. An empirical study on factors leading to the success of construction organizations in India. *International Journal of Construction Management, 18*, pp.1-18.

Tuomi, I., 1999. Data is more than knowledge: Implications of the reversed knowledge hierarchy for knowledge management and organizational memory. *Journal of Management Information Systems, 16*(3), pp.103-117.

Un, C. A. and Asakawa, K., 2015. Types of research and development collaborations and process innovation: The benefit of collaborating upstream in the knowledge chain. *The Journal of Product Innovation Management, 32*(1), pp.138–153.

Versiani, A. F., Rezende, S. F., Magalhaes, A. T. and Vaz, S. L., 2018. The relationship between strategy making and organizational learning. *Revista Brasileira de Gestao de Negocios, 20*(2), pp.157-177.

Wang, H. L., 2014. Theories for competitive advantage. In H. Hasan, *Being Practical with Theory: A Window into Business Research*. Wollongong, Australia, pp.33-43.

Wang, L. C. and Ahamed, P. K., 2005. The knowledge value chain: A pragmatic knowledge implementation network. *Handbook of Business Strategy, 6*(1), pp.321-326.

Wang, Y., 2015. Formal cognitive models of data, information, knowledge, and intelligence. *WSEAS Transactions on Computers, 14*(3), pp.770-781.

Wong, H. K., 2004. Knowledge value chain: Implementation of new product development system in a w inery. *The Electronic Journal of Knowledge Management, 2*(1), pp.77-90.

Xu, J., Houssin, R., Caillaud, E. and Gardoni, M., 2010. Macro process of knowledge management for continuous innovation. *Journal of Knowledge Management, 14*(4), pp.573-591.

Xu, Y. and Bernard, A., 2010. Knowledge value chain: An effective tool to measure knowledge value. *International Journal of Computer Integrated Manufacturing, 23*(11), pp.957-967.

Yap, J. B. and Lock, A., 2017. Analysing the benefits, techniques, tools and challenges of knowledge management practices in the Malaysian construction SMEs. *Journal of Engineering, Design and Technology, 15*(6), pp.803-825.

Ye, F. Y., 2016. Measuring knowledge: A quantitative approach to knowledge theory. *International Journal of Data Science and Analysis, 2*(2), pp.32-35.

Zhang, N., Deng, X., Zhao, X. and Chang, T., 2018. Exploring the sources of contractors' competitive advantage on international high-speed railway construction projects. *International Journal of Civil Engineering*, 17(7), pp.1115-1129.

Mendis, A.P.K.D., Samaraweera, A., Kumarasiri, D.M.G.B.T., Rajini, D. and Madhuwanthi, H.A.S., 2019. A culture-based solution for construction and demolition waste management in Sri Lanka: A literature review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 13-22. DOI: doi.org/10.31705/WCS.2019.2. Available at: https://2019.ciobwcs.com/papers

A CULTURE-BASED SOLUTION FOR CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN SRI LANKA: A LITERATURE REVIEW

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ABSTRACT

Construction projects consume bulky amounts of materials, natural resources, and energy and at the same time generate unacceptable level of solid wastes. There are strategies implemented in order manage the construction and demolition wastes in Sri Lanka. However, most of those have become unsuccessful due to the policy makers being unable to consider the cultural factors stemming from socio-economic factors, while implementing such strategies. Thus, this paper aims at deriving a culture-based solution for construction and demolition waste management in Sri Lanka. This aim is achieved through a broad literature review. As per the extent literature, the main cultural manifestations describing the cultural context of Construction and Demolition (C&D) waste management include values, attitudes and behaviours. Accordingly, Sri Lankans hold many positive values, however majority of attitudes and behaviours are of negative in nature. According to literature, these cultural manifestations exists in a hierarchical order with attitudes being influenced by values and behaviours being influenced by attitudes. Nevertheless, positive values of Sri Lankans are not reflected through the attitudes and behaviours of C&D waste management, requiring thorough empirical studies to justify the dynamisms of value-attitude-behaviour hierarchy in Sri Lankan context. In addition, if these cultural manifestations related to C&D waste to be managed, a reverse cycle to the value-attitude-behaviour hierarchy should be considered, which is introduced as 'cycle of culture management' through this paper.

Keywords: *Attitudes; Behaviours; Cultural Values; Construction and Demolition Waste; Waste Management.*

1. INTRODUCTION

In a world headed for an urbanised future, the construction sector is becoming one of the most imperative sectors worldwide (Mahpour, 2018), consuming a hefty amount of materials, natural resources, and energy and at the same time generating unacceptable level of solid waste (Karunasena and Samarasingha, 2015). Hence, the Construction and

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Demolition (C&D) waste management has turned out to be an important matter that has engrossed extensive attention of the world (Karunasena and Samarasingha, 2015). This situation is more critical for developing countries compared with developed countries, where constructions persist as focal economic activities of developing countries (Yuan and Shen, 2011). Sri Lanka, which is also a developing country, is experiencing waste management as a crisis over a long time. With the expansion of the population and economic development, waste generation has also been increased. Proper management of solid waste is a must to eliminate the risk to human and environment (Karunarathne, 2015). According to the Interim Report of Construction Waste Management (COWAM) Project: Vision for 2018 by Galle Municipal Council (2008), the real requirement of proper C&D waste management was aroused after the Tsunami in year 2004.

Begum *et al*. (2009) and Teo and Loosemore (2001) stress that due to the labour-intensive nature of construction activities leading to number of behavioural impediments are likely to influence waste levels significantly. Lingard *et al*. (2000) further explain that a considerable extent of reduction, reuse and recycling of C&D waste can be attained depending on motivational influences on the behavioural patterns of construction work force. Mwiinga (2014) has stated that cultural values impact the awareness of people in managing waste. Although, authorities have introduced lot of sustainable methods to properly manage the waste, the effect of the attitudes and behaviour has been ignored by such policy makers. Awareness campaigns are very significant drivers to change the behaviour and attitudes of the people about the importance of managing waste (Mbeng *et al*. 2009).

As indicated by Karunarathne (2015), still, Sri Lankans are not aware about, why waste management is of great importance and the author further mention that people need attitudinal change to overcome this problem. Although there are lot of awareness programs on the importance of managing waste, yet they have not touched the minds and hearts. Milfont *et al*. (2010) explain that according to value-attitude-behaviour model, relationship between perceived behaviour of the environment and values and ecology is influenced by the environmental attitudes. These studies suggest the importance of focusing on cultural manifestations to bring in a proper solution for waste management, however, a proper mean of doing so us not addressed in the extent literature. Accordingly, this research aims to derive a culture-based solution for construction and demolition waste management in Sri Lanka through a literature review. In order to achieve the aim, initially the construction waste management practices in Sri Lanka and the cultural manifestations of community in waste management in general will be discussed. Then, the linkage between cultural manifestations (values, attitudes and behaviours) of people will be reviewed. Consequently, the cultural values, attitudes and behaviours of community in C&D waste management will also be discussed. Ultimately a culture based conceptual framework for managing C&D waste in Sri Lanka will be developed using the extent literature.

2. CONSTRUCTION WASTE MANAGEMENT PRACTICES IN SRI LANKA

Most of the Asian states including Sri Lanka do not have precise regulations intended for managing C&D wastes, although many countries have some separate sections for C&D waste within their waste management regulations and related policies (Nitivattananon and Borongan, 2007). Thus, Sri Lankan C&D waste management procedures are mainly limited to landfilling and open dumping (Karunasena and Rathnayaka, 2014). Nitivattananon and Borangan (2007) state that in Sri Lanka, reuse and recycling such as door frames and Cabok are practiced up to some degree. However, after Tsunami in year 2004, management of these C&D wastes comes into consideration with the formation of a C&D waste recycling plant through the Construction Waste Management (COWAM) Project in Galle (Karunasena and Samarasingha, 2015). However, it is problematic, because with the development of construction industry, a single COWAM plant alone is not capable to manage C&D waste (Karunasena and Rathnayake, 2014). Moreover, despite the hard systems and procedures, these policy frameworks and systems do not address the cultural aspects in managing C&D waste.

3. CULTURAL MANIFESTATIONS OF COMMUNITY IN WASTE MANAGEMENT

The world suffers from numerous environmental problems that requires to be addressed at the individual level and requires individuals to develop their attitudes that lead them to environmental support behaviour (Ahmed *et al*. 2009). The establishment and change of attitudes are intertwined. People always adopt, modify and abandon attitudes to adapt to changing needs and interests, but, simple education cannot change attitudes. Accepting a new attitude depends on who grants the knowledge, the way it is presented, how people are perceived, the credibility of the communicator, and the conditions for acquiring knowledge. Social science research suggests that knowledge about a topic may increase and people might even change attitudes, but the steps to develop behaviour and practices depend on a compound set of social and psychological factors (Desa *et al*. 2011). Rewards and intensified behaviours, opinions and attitudes may be repeated and eventually incorporated into our personal values and everyday behaviour. The wise usage of rewards and reinforcements can increase the chances of an individual being recognised to repeat an ideal and can also motivate others to adopt this attitude (Gagne, 2003).

In order to achieve successful waste management, not only the local authorities should provide infrastructure, but also public awareness, attitudes, knowledge and behaviour should also be considered (Akbar *et al*. 2015). Teo and Loosemore (2001), stress that the composition of the construction sector itself impacts the attitudes and behaviours of the people involved. According to these researchers, the construction projects reward productive workers and bonuses are been rewarded for timely completion. Hence, the attitudes and behaviours of people are moulded in a way to obtain rewards even by preceding waste management practices. Further, active involvement of subcontractors for a shorter period in a project creates complexities in procedures to be adapted for waste management. Jayawardane (1994) indicates that the material wastage by labour (subcontract) is greater than by the direct labour. For the effective execution of waste management practices on a construction project, communal effort and shared responsibility from all parties tangled in it is important. This highlights the attitudinal differences of subcontract labourers and direct labourers. According to Teo and Loosemore (2001), attitudes concerning waste management vary from one organisation to another, depends on the waste management regulations and policies and culture. In addition, different occupational groups have diverse attitudes towards generation and management of waste. Different studies have been conducted to assess the factors affecting these behaviours, including attitudes, knowledge, and practices in waste management (Akbar *et al*. 2015; Laor *et al*. 2018). In overall, clear differentiation of these cultural manifestations such as values, attitudes and behaviours in C&D waste management context is yet to be unveiled.

4. THE LINKAGE BETWEEN CULTURAL VALUES, ATTITUDES AND BEHAVIOURS OF PEOPLE

The linkage between cultural values, attitudes and behaviours of people will be discussed in detail in this section, together with a comparison of cultural manifestations in pairs.

Values - Out of different cultural manifestations such as behaviours, attitudes, artefacts, norms and so on, the most dominant feature of culture may be the existing value emphasised in a society (Hofstede, 1980; Schwartz, 2006). These values highlight common understanding of what is desirable and good in cultural morals. Cultural values emphasis and rationalise individual and collective beliefs, goals and actions. The underlying values of cultural values in societies are expressed in institutional arrangements and policies, norms and everyday practices. For an example, a cultural value of triumph and ambition can be mirrored in highly competitive economic systems, educational practices and conflicting legal systems that drive children to succeed (Schwartz, 2011). Further, Schwartz (2011) stresses that peoples' values stem from biological and psychological needs related to social adjustment and survival. Accordingly, at the level of society, cultural values which derive from the functional requirements that societies face in order to survive (Morales *et al*. 2018). Another significant characteristic of cultural value orientation is that, they are comparatively steady (Schwartz *et al*., 2000; Hofstede, 2001). However, in contrast, Samarasinghe (2012) has pinpointed that social adaptation to epidemics, improvements in technology, increased wealth, interactions with other cultures, and other external factors are leading to changes in cultural values. According to Rabinowicz and Rønnow-Rasmussen (2004), pro-attitudes influence in creating cultural values. Moreover, considering the context specific nature of values, researchers emphasise the need to conduct research separately for developed and developing countries (Diekmann and Franzen, 1999).

Attitudes - Attitude is described as a hypothetical structure that signifies whether a person likes or dislikes anything. Attitude is the judgment of "attitude objects" (people, places, tasks, events, skills, and so on). Attitude evolves over time and stems from the inner framework of beliefs and values (Jung, 1971). There are individuals, who might have the skills and knowledge to finish the task, but only a positive attitude towards the particular task will motivate, the intention to participate and complete the task (Kumar, 2018).

Values vs. Attitudes - Traditionally, values or primitive beliefs are seen as a fundamental aspect of self-concept, and a form of "fundamental truths" in reality (Sherif and Cantril, 1947; Rokeach, 1968). Many researchers have not yet conceptually differentiated values and attitudes, but some have recognised the importance of understanding the relationships that exist between more abstract and more specific evaluations (Sherif and Cantril, 1947; Nordlund 2009). Knowles (1975) states that always values and attitudes interact with the peers, family, and the society and people seems to intuitively 'like' those, who is sharing share their core values. Coordinating the value system is the reason for the success of any kind of relationship, whether it is personal, educational or professional. The researcher pin point that to achieve excellence and competence, people not only need to be capable to teach and assess skills and knowledge, but also requires to teach and assess attitudes.

Furthermore, people should be able to distinguish core values that support attitudes in order to achieve excellence. This indicates that values impact attitudes in a cultural context.

Behaviours vs. Values - In 1976, Edward T. Hall developed the iceberg theory of culture. Hall (1976) believes that if the culture of a society is an iceberg, then only some aspects are observable above the surface of the water, but a larger part is unseen beneath the surface. The author further stresses that the external part of culture is what we can see, which is the tip of the iceberg, which includes behaviour. The internal part of culture is laying below the surface of society, which includes beliefs and the values and modes of thinking that constitute behaviour (Akbari, 2016). Schein (2004) indicates that values are demonstrated through behaviour of people. Accordingly, there is a possibility of values influencing the behaviour of people.

Attitudes vs. Behaviours - Solomon *et al*. (2006) indicate that an attitude is based on the observed behaviour. Attitudes of people towards observed behaviour also has an impact on judgment. Behaviour can also be fake. A person may show ritual behaviour and fallacious obedience, when they require a positive opinion or else if they feel they are being observed for their performance. This may specify an attitude, but the spectator needs to explain the difference between the false behaviour of the true attitude and its implied attitude (Kumar, 2018). Therefore, a person, who is constantly discussing and accepting everything his or her supervisor says may not necessarily agree, but may very well try to gain favour. Herzberg (2008) has pinpointed that individuals need a positive attitude in order to be motivated and involved in the task. This shows the forward link of attitudes impacting the behaviour.

Herzberg (2008) further states that attitude stems from the core values and beliefs, which people hold internally. Consequently, it can be specified that beliefs are assumptions and beliefs that we believe are true, based upon past experiences. Values are founded on concepts, things and people's valuable ideas. Behaviour is the expression of these internalisation systems (attitudes, beliefs, and values) (Kumar, 2018).

The model of Homer and Kahle (1988) assumes an intellectual hierarchy of value-attitude-behaviour. Values influence behaviour indirectly or directly through attitudes conferring to this model. Yet, the main characteristic of the model is to highlight the intermediating role of attitudes on behavioural relations and values (Homer and Kahle, 2004). Thus, the model infers a hierarchy of cognitions, where the effects theoretically flow from more abstract cognition (i.e., value) to medium cognition (i.e., attitude) to a specific behaviour. Therefore, the model can be visually portrayed as a causal sequence: value → attitude → behaviour. Even though the value-attitude-behavioural intellectual hierarchy model has been applied to the varies extents (Shim *et al*., 1999), such as describing professional attitudes (Shim *et al*., 1999), the model is being mainly using for studies on environmental issues. Subsequently, it is worth looking into cultural values, attitudes and behaviours of community in C&D waste management.

5. CULTURAL VALUES, ATTITUDES AND BEHAVIOURS OF COMMUNITY IN C&D WASTE MANAGEMENT

Studies, which are led in a cross-cultural context depict that environmental protection is usually accepted in both developed and developing countries (Milfont and Schultz, 2016). When understanding of specific environmental issues, cross-cultural differences exist on the impact of environmental orientation on environmentally friendly behaviour (Milfont *et al*., 2006). Kaplan, *et al*. (2019) have shown different structural circumstances associated with waste management, such as recycling systems, while cultural factors, affect the degree to which people partake in environmentally friendly behaviours, such as waste minimisation and recycling. In addition, the influence of personal motivations and preferences, such as the effect of environmental orientation and values on environmentally friendly behaviour, is also culturally different. Therefore, more efforts should be made to develop research models that consider these cultural factors highlighting the cultural manifestations of values, behaviours and attitudes in C&D waste management for efficient and effective management of such waste. Table 1 presents the cultural values, attitudes and behaviours of Sri Lankan community, extracted from general and C&D waste related literature.

Table 1: Values, attitudes and behaviours of community related to C&D waste management in Sri Lanka

Values related to C&D waste management	Attitudes related to C&D waste management	Behaviours related to C&D waste management
• Acceptance of workability of waste management alternatives and disposal practices • Ensure integrated, economically feasible and environmentally favourable waste management measures for the country • Maximise resource recovery to minimise the amount of waste from disposal • Minimise adversative environmental impacts • Reusing the resources available in the collected garbage to the maximum before final disposal • Interaction with outside institutions and communities • Public education and personnel training	• *Local authorities are not managing their solid waste properly* • *'We dump – They collect'* • *Lack of credibility in decision makers, waste managers, control mechanisms and decision processes for waste facility setting and operation* • Fear of damage to the environment	• *Open dumping Open burning and land filling* • *Not segregating the waste* • *Unplanned industrialisation and urbanisation* • *High waste generation* • *Malfunctioning of existing waste management systems* • *No use of advanced technologies*

Sources: Kulatunga *et al*. (2006), Begum *et al*. (2009), Wijetunga (2014), Karunarathne (2015), Eheliyagoda (2016), Gunaruwan and Gunasekara (2016)

According to Table 1, it is apparent that Sri Lankans hold many positive values with regard to C&D waste but, majority of attitudes and behaviours take a negative stance (negative attitudes and behaviours are indicated in *italics* in Table 1). These lists are not exhaustive, however, provide a general overview of the cultural manifestations of Sri Lankan community in C& D waste management. Nevertheless, according to the values-attitudes-behaviour hierarchy, attitudes are influenced by values, and behaviours and influenced by attitudes. Although many positive values are held by Sri Lankans, such values are not reflected through the attitudes and behaviours as described by values-attitudes-behaviour hierarchy. Thus, a proper empirical study is required digging further into values, attitudes and behaviours of Sri Lankans related to C&D waste management to interpret the dynamisms along the value-attitude-behaviour hierarchy.

6. CULTURE BASED CONCEPTUAL FRAMEWORK FOR MANAGING C&D WASTE IN SRI LANKA

The previous sections discussed the linkage between values, attitudes and behaviours in general and related to C&D waste management context in Sri Lanka. Such discussions revealed a path to manage C&D waste through a cultural perspective as depicted in Figure: a culture based conceptual framework for managing C&D waste in Sri Lanka. According to this framework, values, attitudes and behaviours exist in a hierarchical manner as discussed in Section 4 of this paper. Within that hierarchy, values related to C&D waste management impact (influence) the attitudes correlated to C&D waste management and such attitudes further impact (influence) the behaviours related to C&D waste management. Otherwise, behaviours depend on attitudes and attitudes depend on values. This primary linkage between values, behaviours, and attitudes is represented through thick dotted arrows in Figure 1. However, managing values, attitudes and behaviours could be achieved only in a reverse cycle to the values-attitudes-behaviour hierarchy as indicated through thick black arrows in Figure 1. These cyclical links were derived through the discussion at Section 4 as described below:

- Behaviour of the society influences the creation of good attitudes in people for managing waste (Management of A through B).
- Pro-attitudes influence in creating cultural values (Management of V through A).
- Socially accepted cultural values influence in changing bad behaviours of people into good behaviours (Management of B through V)

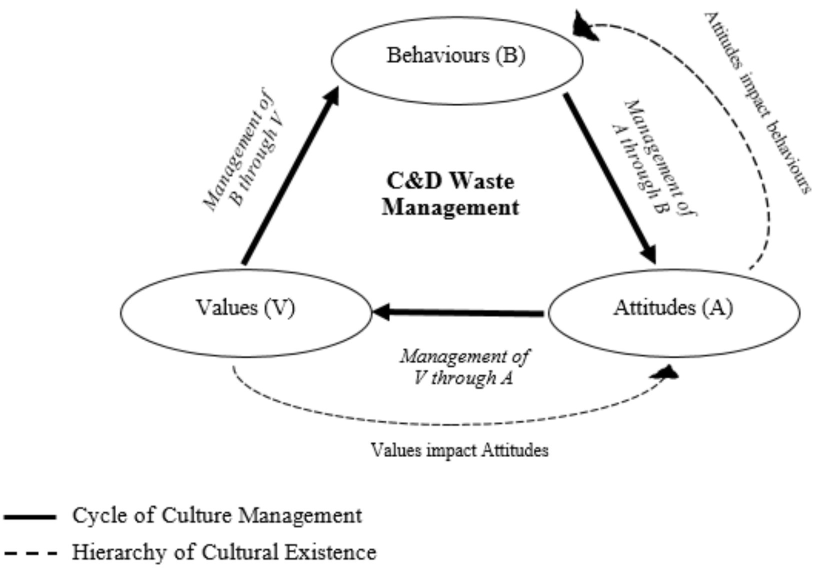

Figure 1: Culture based conceptual framework for managing C&D waste in Sri Lanka

Accordingly, the conceptual framework in Figure 1 argues that if C&D waste to be managed properly in Sri Lanka, such mechanism should not overlook the cultural values, attitudes and behaviours of society related to C&D waste. Further, such a culture-based management could be achieved by focusing on the cycle of culture management.

7. CONCLUSIONS

Minimisation and management of C&D waste have been accentuated in terms of enhancing performance while attaining the sustainable goals of the construction sector. This literature review aimed at deriving a culture-based solution for C&D waste management in Sri Lanka through reviewing waste management practices in Sri Lanka, cultural manifestations of community waste management and trying to identify a linkage between values, attitudes and behaviours of people in C&D waste management.

It is identified through literature that there are three substantial manifestations of culture as; values, attitudes, and behaviours. Since the construction industry is labour-intensive, the values, attitudes and behaviours of the people affect its growth and thus, the minimisation of C&D waste is not an exemption. Moreover, an effective change in the values, attitudes and behaviours of the construction workforce is important to achieve the maximum benefits from C&D waste management practices. According to the popular literature, Sri Lankans hold many positive values in C&D waste management, while many attitudes and behaviours are of negative in nature. Existence of these three manifestations is explained through the value-attitude-behaviour hierarchy. According to this hierarchy, values influence attitudes, while attitudes influence behaviours. Although many positive values are held by Sri Lankans as per the popular literature, such positive nature is not reflected through the attitudes and behaviours of Sri Lankans in C&D waste management. Therefore, a thorough empirical study is required to explain the dynamisms of value-attitude-behaviour hierarchy in Sri Lankan context.

In addition, a culture based conceptual framework (refer Figure 1) was derived in this paper to better manage C&D waste in Sri Lankan context. According to this framework, it is argued that management of values, attitudes and behaviours in C&D waste management should take a reverse cycle to the value-attitude-behaviour hierarchy, which is named in this paper as cycle of culture management. Further research stemming out of this paper is to develop mechanisms to operationalise the cycle of culture management in C&D waste management in Sri Lanka.

8. REFERENCES

Ahmed, M. S. (2009). The impact of reward and recognition programs on employee's motivation and satisfaction: an empirical study. *International Review of Business Research Papers*, 5(4), pp.270-279.

Akbar, A., Alavi, N., Goudarzi, G. and Teymouri, P., 2015. Resources, conservation and recycling household recycling knowledge, attitudes and practices towards solid waste management. *Resources, Conservation & Recycling*, *102*, pp.94-100.

Begum, R., Siwar, C., Pereira, J. and Jaafar., 2009. Attitude and behavioral factors in waste management in the construction industry of Malaysia Resources. *Conservation and Recycling, 53*(6), pp.321-328.

Desa, A., Ba, N. and Yusooff, F., 2011. A Study on the knowledge, attitudes, awareness status and behaviour concerning solid waste management. In *Procedia Social and Behavioral Sciences*, pp.643-648.

Diekmann, A. and Franzen, A., 1999. The wealth of nations and environmental concern. *Environment and Behaviour*, *31*(4), pp.540-549.

Eheliyagoda, D., 2016. Assessment of a Planned Municipal Solid Waste Management System in Sri Lanka. *Journal of Applied Science and Environmental Management*, *20*(1), pp.58-61.

Gagne, M., 2003. The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and emotion*, *27*(3), pp.199-223

Galle Municipal Council., 2008. Interim Report of COWAM Project: Vision for 2018. Galle.

Gunaruwan, T. L., and Gunasekara, W. N., (2016). Management of municipal solid waste in Sri Lanka: A comparative appraisal of the economics of composting. *NSMB Journal of Management*, *2*(1), pp.27–45.

Hall, E. T., 1976. *Beyond culture [online]* .1st ed. New York: Doubleday. Available from https://monoskop.org/images/6/60/Hall_Edward_T_Beyond_Culture.pdf.

Herzberg, F., 2008. One more time: How do you mortivate emloyees? *Harvard Business Review*, *81*(1), pp.87–96.

Hofstede, G. H., 1980. *Culture's consequences: International differences in work-related values* [online]. Thousand Oaks: CA: Sage. Available from https://us.sagepub.com/en-us/nam/cultures-consequences/book665.

Hofstede, G. H., 2001. *Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations* .2nd ed. Thousand Oaks: Sage Publications.

Homer, P. M. and Kahle, L. R., 1988. A structural equation test of the value-attitude-behavior hierarchy. *Journal of Personality and Social Psychology*, *54*(4), pp.638–646.

Homer, P. M. and Kahle, L. R., 2004. A structural equation test of the value attitude behaviour hierarchy. *Journal of Personality and Social Psychology*, *54*(4), pp.638–646.

Jayawardane, A.K.W., 1994. Are we aware of the extent of wastage on our building construction sites?. *Engineer*, *20*(2), pp.41-44.

Jung, C. G., 1971. *Psychological Types: Collected Works* [Online]. In: Read, H., Fordham, M., Gerhard, A. and Mcgiure, W. (ed). 2nd ed. Princeton: NJ: Princeton University Press. Available from https://www.jungiananalysts.org.uk/wp-content/uploads/2018/07/C.-G.-Jung-Collected-Works-Volume-6_-Psychological-Types.pdf

Kaplan, K., Henn, L., Park, J. and Kurman, J., 2019. What predicts household waste management behaviors? Culture and type of behavior as moderators. *Resources, Conservation & Recycling*, pp.11–18.

Karunasena, G. and Rathnayake, U., 2014. Construction and demolition waste management gaps in construction industry. *Proceedings of the 7th FARU International Research Symposium*, pp.97-104.

Karunasena, G. and Samarasingha, I., 2015. Construction and Demolition Waste Recycling: The Case of Construction Waste Management (COWAM) Project. *The 4th World Construction Symposium 2015: Sustainable Development in the Built Environment*, pp.203-2013.

Karunarathne, L., 2015. Municipal Solid Waste Management (MSWM) in Sri Lanka. In *National Symposium on Real Estate Management and Valuation 2015*. ResearchGate. Available from: https://www.researchgate.net/publication/284722213_Municipal_Solid_Waste_Management_MSWM_in_Sri_Lanka.

Knowles, M. M., 1975. *Self-directed learning: A guide for learners and teachers*. New York: Association Press.

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, 71*(1), pp.57-72.

Kumar, M., 2018. The relationship between beliefs, values, attitudes and behaviours [Online]. Available from: https://owlcation.com/social-sciences/Teaching-and-Assessing-Attitudes.

Laor, P., Suma, Y., Keawdounglek, V., Hongtong, A., Apidechkul, T. and Pasukphun, N., 2018. Knowledge, attitude and practice of municipal solid waste management among highland residents in Northern Thailand. *Journal of Health Research*, *32*(2), pp.123-131.

Lingard, H., Graham, P. and Smithers, G. (2000). Employee perceptions of the solid waste management system operating in a large Australian contracting organization: implications for company policy implementation. *Construction Management*, pp.383-393.

Mahpour, A., 2018. Prioritizing barriers to adopt circular economy in construction and demolition waste management. Resources. *Conservation and Recycling* (134), pp.216-227.

Mbeng, L. O., Probert, J., Phillips, P. S. and Fairweather, R., 2009. Assessing public attitudes and behaviour to household waste management in Cameroon to drive strategy development. *Sustainability*, 1(3), pp.556–572.

Milfont, T. L., Duckitt, J. and Cameron, L. D., 2006. A cross-cultural study of environmental motive concerns and their implications for proenvironmental behavior. *Environment and Behaviour*, *38*(6), pp.745–767.

Milfont, T. L., Duckitt, J. and Wagner, C., 2010. A Cross-cultural test of the value attitude behaviour hierarchy. *Journal of Applied Social Psychology*, *40*(11), pp.2791–2813.

Milfont, T. L. and Schultz, P. W., 2016. Culture and the natural environment. *Current Opinion in Psychology*, *8*, pp.194–199.

Morales, C., Holtschlag, C., Masuda, A. D. and Marquina, P., 2018. In which cultural contexts do individual values explain entrepreneurship? An integrative values framework using Schwartz's theories. *International Small Business Journal*, pp.1–27.

Mwiinga, F., 2014. *Perceptions of solid waste management and the role of environmental education among selected residents of Choma township of Southern Zambia [*The University of Zambia. Available from http://dspace.unza.zm:8080/xmlui/bitstream/handle/123456789/3792/Main Document.pdf

Nitivattananon, V. and Borongan, G., 2007. Construction and Demolition Waste Management: Current Practices in Asia. *Proceedings of the Internatonal Conferance on Sustainable Solid Management*, pp.97-104.

Nordlund, A., 2009. *Values, attitudes, and norms* [Online], Available from: https://www.slu.se/globalassets/ew/org/centrb/f-for/pdf/2009-nordlund-values-attitudes-and-norms.pdf.

Rabinowicz, W. and Rønnow-Rasmussen, T., 2004. The strike of the demon: on fitting pro-attitudes and value. *Ethics*, *114*(3), pp.391-423.

Rokeach, M., 1968. *Beliefs, attitudes, and values: A theory of organization and change*. San Francisco: Jossey-Bass. Available from: https://archive.org/details/beliefsattitudes00rokerich/page/n239.

Samarasinghe, R., 2012. The Influence of Cultural Values and Environmental Attitudes on Green Consumer Behaviour. *International Journal of Behavioral Science*, *7*(1), pp.83–98.

Schein, E.H., 2004, *Organisational Culture and Leadership*, Jossey-Bass, San Francisco, CA.

Schwartz, S. H., 2006. A Theory of cultural value orientations: Explication and applications. *Comparative Sociology*, *5*(2), pp.137–182.

Schwartz, S. H., 2011. *Values: Cultural and individual*. *Fundamental questions in cross-cultural psychology* [Online] New York: US: Cambridge University Press.

Schwartz, S. H., Bardi, A. and Bianchi, G., 2000. Value adaptation to the imposition and collapse of communist regimes in East-Central Europe. *Political Psychology*, pp.217–237.

Sherif, M. and Cantril, H., 1947. *The psychology of ego‐involvements [online]*. New York: Wiley. Available from: https://doi.org/10.1002/1097-4679(194807)4:3%3C314::AID-JCLP2270040323%3E3.0.CO;2-X.

Shim, S., Warrington, P. and Goldsberry, E., 1999. A personal value based model of college students' attitudes and expected choice behavior regarding retailing careers. *Family and Consumer Sciences Research Journal*, *28*, pp.28–51.

Solomon, M., Bamossy, G., Askegaard, S. and Hogg, M. K., (2006). *Consumer behaviour: A european perspective* (3rd ed.). London: Pearson Education.

Teo, M.M.M. and Loosemore, M., 2001. A theory of waste behaviour in the construction industry. *Construction Management and Economics*, *19*(7), pp.741-751.

Wijetunga, S., 2014. *Community views and attitudes for waste management improvement in a higher education institute: Case study*. University of Ruhuna.

Yuan, H. and Shen, L. (2011). Trend of the research on construction and demolition waste management. *Waste Management, 31*(4), pp.670-679.

Atapattu, A.H.A.T.L., Abenayake, M., Dilakshan, R. and Sandupama, A.V.P.U., 2019. A framework for regulatory bodies to control informal building construction in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 23-32. DOI: doi.org/10.31705/WCS.2019.3. Available at: https://2019.ciobwcs.com/papers

A FRAMEWORK FOR REGULATORY BODIES TO CONTROL INFORMAL BUILDING CONSTRUCTION IN SRI LANKA

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ABSTRACT

Socio financial and environmental affectability due to the construction improvements and its relativity with comprehension of building property advancement leads construction to become trendy activity in the society. In order to obtain the major roles in the economy of country construction conducted in to two segments called formal and informal. When render wider perspective on construction activities, there are highly considerable rate of failing, short coming, quality deficiencies etc. Building regulations facilitates to overcome and guarantee socially adequate levels of well-being, security, welfare and convenience for building tenants. This research undertaken using mixed method approach including pilot survey, questionnaire survey and expert interviews. From fifty (50) respondents to questionnaire survey, thirty eight (38) were identified as informal building constructions. It was employed to investigate the extend of obtaining the permits in building construction projects and discrepancies, deformations, laid significances on professional selection and considerations laid on design and construction stage. From the statistical analysis of the survey conducted identified addressable key areas to minimise informal construction activities, which causes deterioration in building constructions. In order to overcome that, eight (8) expert interviews were conducted among the professionals in relevant subject area. Gathered qualitative data were analysed using content analysis techniques. Consequently, the requirement of regulatory bodies to minimise the informal construction were identified which directly or indirectly influence positively on quality of buildings and defect free environment. Finally, framework demarcates the building informality, causation to building performance due to informal construction and building defects along with the remedial actions.

Keywords: *Building Collapse; Building Defects; Informal constructions; Regulatory Bodies.*

1. INTRODUCTION

Construction, renovation and maintenance works on buildings and infrastructures are categorised under the scope of construction sector in any country (Hughes *et al*., 2012). Further, buildings are used for many purposes such as residential, commercial,

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institutional, educational, and industrial to obtain requirements of people (Adnam *et al*., 2009). Couple of year back the building construction industry in Sri Lanka began to present booming after passing the decades with terrorism and large disasters such as Tsunami (Chandrasena, 2010). Further, Chandrasena (2010) stated within recent period of time there are number of building construction projects arising and to be start due to the economic growth, resettlement and urbanisation. Due to the long-life cycle of the building involvement of different stakeholders in different phases of building are common in building projects (Konig and Cristofaro, 2012).

There are two types of building construction such as, formal building construction and informal building construction (Mlinga and Lema, 2011). The formal segment involving the traditional designers and the informal part comprising of improvised designers (Yeboah, 2012). Further, formal designers take after the acknowledged standards of acquiring endorsements and register with the Construction Industry Development Authority (CIDA) (Lerociyani *et al*., 2013). On the other hand, informal constructions are playing a major role in economy of developing countries by implementing more job opportunities to the range of unskilled to specialized workers and cheap approaches to achieve shelter even for the low-income level (Mlinga, 2001).

In developing countries, a major role in construction industry is fulfilled by informal construction sector (Wells, 2007). Importance of informal sector in less developed countries has been recognized by governments and international agencies (Gerxhani, 2004). As informal contractors are not registered in CIDA and informal contractors mainly engage in housing and building construction industry (CCI, 2017). According to Wells (2007) in developing countries, informal contractors carry out almost all construction in rural areas and 50% of all construction in urban areas. Most informal contractors are individually owned and male dominated enterprises (Ahzahar *et al*., 2011). In addition to that, informal contractors mainly employ temporary workers who work on a casual basis and less permanent workers (Mlinga and Lema, 2011). Informal developers have problems in many categories (Ludlow and Neuhold, 2017). In order to obtain the building permit approval, it is probable that they get the signatures of an architect and an engineer to obtain the clearance from the local authority (Jewel *et al*., 2005).

The advantages and disadvantages of the informal construction industry can be derived in terms of economic, social and political factors. Accordingly, the cost of labour is relatively less in the informal sector when compared to the formal sector and consequently a downward pressure is exerted on the labour expenses in the formal market as well (Wetlesen, 2011). However, various deformation can be experienced in the major economic indicators such as the unemployment rate, inflation rate, due to the activities of the informal sector (Overa, 2004).

More employment opportunities are emerged to the society with the interference of the informal sector; therefore, the living conditions of the people are improved (Chong *et al*., 2008). On the other hand, the employees of the informal sector are not deemed to pay any taxes or other social security contributions, which may be unjust for the formal sector employees (Mlinga and Wells, 2002). Through the informal construction sector, the public dissatisfaction and the social tension that may arise due to the monopoly of the formal sector can be eliminated (Blades *et al*., 2011). As the informal sector activities may not always be included to the calculation of the Gross Domestic Product, or other economic indications, the incorrect statistics might provide a deceptive image to the policy and decision makers (Ludlow and Neuhold, 2017).

Even though, there is an issue regarding the informal construction activities (Sandaratne, 2002). Building regulations are legitimate instruments proposed to guarantee that structures, when built as per the controls, give socially adequate levels of wellbeing, security, welfare and convenience for building tenants (Pedro *et al*., 2009). Due to the absence of regulatory body to inspect the ongoing construction projects for the guarantee of ongoing construction is carrying on accordance with the relevant norms and standards specified (CCI, 2017). Thus, it creates more opportunities of building disasters such as collapsing in shorter period from the construction and therefore there is a requirement of providing proper regulative actions by the statutory bodies (CCI, 2017).

2. RESEARCH METHODS

First a semi-structured interview was conducted in order to validate the literature findings from a professional who involved with the building construction regulations. Then a questionnaire was distributed among 64 building owners in Central province with buildings less than four floors. Out of these, 50 responses were received. Due to the time constraints and accessibility buildings were selected from above mentioned area. Thereafter, eight un-structured expert interviews were conducted among professionals involved in the subject related area to identify suggestions to mitigate informal building constructions in Sri Lanka.

Types of the buildings: The sample comprises with 68% residential buildings, 26% commercial buildings and 6% of industrial buildings (refer Figure 1).

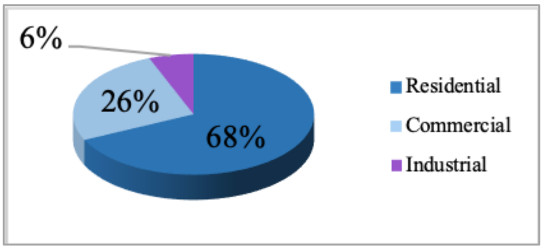

Figure 1: Types of buildings

Age of building: According to Figure 2, 14% of the buildings age 0-10 years, 36% of the buildings age 10-20 years, 30% of the buildings age 20-30 years, 12% of the buildings age 30-40 years.

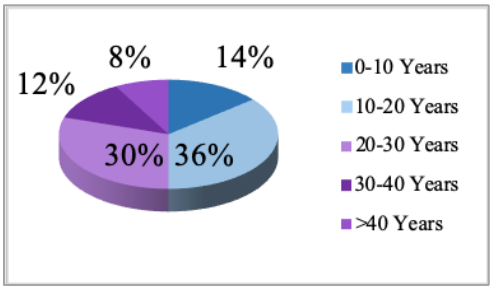

Figure 2: Age of buildings

Expert interviews were conducted among eight professionals working in Sri Lanka related to the construction industry. The factors, which were discussed through expert interviews are further discussed under following sub sections.

Table 1: Details of interviewee participants

Interviewee code	Profession	Type of Organization	Designation	Experience (Years)
IA	Administration	Regulatory	Deputy Director	20
IB	Administration	Regulatory	Deputy Director	20
IC	Chartered Arch.	Regulatory	Director	25
ID	Chartered Arch.	Regulatory	Deputy Director	18
IE	Chartered Arch.	Regulatory	Deputy Director	25
IF	Chartered Eng.	Regulatory	Director	28
IG	Chartered Eng.	Contractor	General Manager	30
IH	Chartered Eng.	Contractor	Project Manager	17

3. RESEARCH FINDINGS

3.1 INTERPRET INFORMALITY OF BUILDING CONSTRUCTION

In order to interpret the informality in building construction, level of obtaining certain approvals, regulatory actions and other requirements were disclosed though the samples selected. Figure 3 demonstrates that 100% of the respondents has obtained Development permit for construction. Next, 28% of the respondents had worked according to the approved plans while 66% of the respondents had not work along with the approved plans. In addition, changes to the plans with approvals were done by 12% of the respondents and 88% of the respondents had not approved the changes that arose after the approvals.

Thereafter, examined the level of acquiring Certificate of Completion COC to the buildings and 56% has acquired COC while 44% had not acquired COC. Even after receiving the COC some building owners tend to continue building construction activities illegally. With that context, 82% of the respondents had not done any developments after acquiring COC and 18% of the respondents has done changes to their buildings. Finally, illustrates whether the contractors of selected building samples were registered under CIDA or not. According to the respondents, 24% of the contractors were registered under CIDA and remaining 76% was not registered under CIDA.

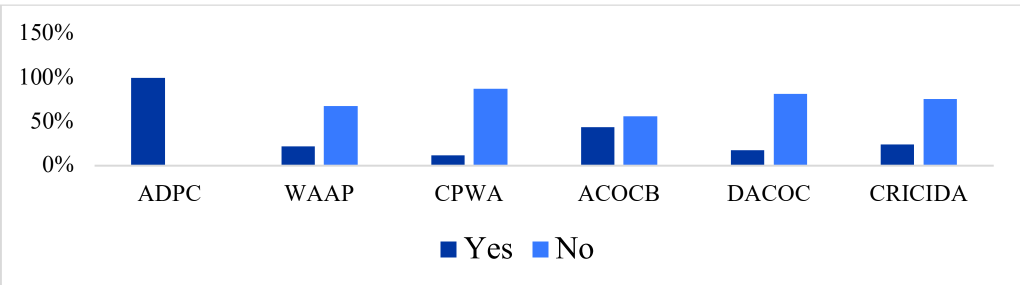

Figure 3: Level of followed regulatory procedures

Legend: ADPC- Acquired Development Permit for Construction, WAAP-Work According to Approved Plan, CPWA-Carried out changes to the Plan with Approvals, ACOCB- Acquired COC for Building, DAACOC-Development after Acquiring COC, CRICIDA- Contractor Registered in CIDA

Using above details, the informal and formal building constructions in the building sector was determined. The situations where development permits were not obtained, construction work were not conducted according to the approved plans, changes were carried out to the plan without approvals, COC were not acquired to the buildings at completion, development after acquiring COC and where the involved contractor is not registered under CIDA were considered as features in the informal constructions. Therefore, the selected sample was divided into informal constructions and formal constructions as shown in Figure 4.

Therefore, according to the above differentiation the selected sample of 50 buildings were divided. From the selected 50 sample, 38 were identified as informal building constructions.

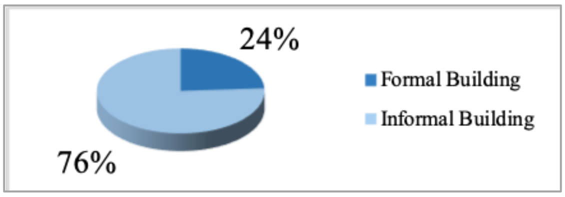

Figure 4: Differentiating informal and formal constructions

3.2 REASONS TO INFORMALITY IN BUILDING CONSTRUCTIONS

Through the questionnaire survey, respondents presented their reasoning for not complying to the regulatory requirements.

- Reasons for not taking approvals for the changes carried out

Reasons not to comply work with approved plan:

The clients' main reasons for not compiling to the approved plan was changes in the requirements. Thereafter, the second most consideration was to minimise the cost. Then moderate opinion on not compiling to the approved plan was the client objective for design was only to acquire approvals. The least concerns not to comply with approved plan was contractor implemented changes and space optimisation respectively. With such determinations, clients do not tend to take approvals for changes carried out after receiving approvals.

Reasons for not taking approvals for the changes carried out:

Most respondents' rationale was that they did not concerned about this factor. Secondly, the decision of not taking approvals were due to the time consumption. Since the changes were illegal the respondents did not want to take approvals to their changes considered as the third common answer among the respondents. Respectively reluctance to be served by government organisations and clients were not aware were least concerned factors on not taking approvals for changes according to the sample respondents.

- Reasons not to acquire COC

The most common reason not to acquire COC is client do not have generic need to obtain COC. Accordingly, second most common reasoning was additional cost required and reluctance to be served by government organisation. Elaborating that, clients do not mentally positive about the service given by the government organisation. Therefore, they do not tend to acquire their services. Seven number of responses received stating that clients did not concerned about acquiring changes. Subsequently, four responses stated that they had not approved the changes carried out.

- Reasons to development after acquiring COC

Two reasons were identified concerning the development carried out after acquiring COC. The most common cause for construct beyond the regulations and the other cause identified was changes in the requirements.

3.3 SUGGESTIONS TO INCREASE FORMALITY IN THE INFORMAL BUILDING CONSTRUCTIONS

Mainly these suggestions are focuses on two categories. One is towards clients to improve awareness and other on regulatory bodies to increase the active involvement of the regulatory bodies through professionals to minimise informal construction in order to drive out the adverse effects such as building defects and collapses.

Acquiring COC for building constructed is existing regulations in the construction industry. Even though that practice less in the society. In order to establish acquiring COC experts suggested to issue COC through periodical reinvestigations. Further, from the client side the mechanisms to aware people should improve. Moreover, regulatory bodies can take step ahead and restrict providing service connections to the building without COC. Even though it requires proper coordination and effective mechanism between the regulatory bodies and service providers.

However, even after acquiring COC, people tend to carry out development activities. Therefore, experts suggested to carry out the periodical reinvestigations even after the construction stage. However, factors such as client ignorance, time consumed required to be addressed. In additions, contractors also required to motivated to register under CIDA for control the contractors' effect on the Sri Lankan construction industry. In enhance the formality in the construction this is another major requirement. Even though client side support to promote registering contractors in CIDA is very less because there consideration on the selection of contractor laid least focus on the CIDA registration. Further, formality can be increased through usage of the contract document. The factors evolved though the questionnaire survey stated not usage of contract document as a cause to failure outcome in the informal building construction. Therefore, regulations were focused to adopt regulations strictly to increase the use of contract document and aware informal contractor.

3.4 PROFESSIONAL INVOLVEMENT IN INFORMAL CONSTRUCTIONS

In the informal construction sector, the professionals' involvement is mostly concerned in order to take approvals, license endorsement or necessary clearance from the local authorities (Jewell *et al*., 2005). The findings emerged through this study had similar idea and further elaborated cost of professional consultancy service is the most critical influence to not involved professionals. Experts interviewed in this research tied that opinion stating professionals mostly involved only to the planning activities in the informal building constructions.

However, to enhance the quality of the building facility it is required the involvement of the construction professionals to the construction stage of the building. Further, experts suggested to periodical certification to the construction stage buildings in order to ensure the quality of the construction delivery. Even though this certification systems can fail to deliver proper services. Therefore, professional bodies proposed to tie up the professionals to conduct proper functioning. Other than that, professional involvement can be integrated to the informal construction through integrating competent professionals responsible for their competent areas.

According to the questionnaire survey findings, "Cost of professional fees" was a major concern of clients when selecting consultants. Further, qualification of the professionals was another criterion of concern. On the other hand, experts stated that client engaged with informal construction activities are mostly unaware about the qualified professionals. However, experts suggested national involvement by controlling professional fees and providing incentives to low income people to obtain professional services. In local context, "Cost on contractor selection" with RII value of 0.93 was identified as the most crucial factor on the selection of contractor to the industry, which was similarly stated in literature. Subsequently, findings showed that client considered 'Quality of the work carried out' as a critical factor with RII of 0.77. This statement was confirmed through the experts' opinion, which stated Sri Lankan construction clients are more cost oriented. Casual basis and temporary workers were more common in the informal construction (Mlinga and Lema, 2011). Therefore, lesser standards of working can be identified in informal constructions according to the existing literature. When selecting the contractors but the consideration on 'Sufficiency of resources' was less with RII of 0.34. That elaborates even the local client concern quality of buildings they do not concern about other root causes for quality work. Moreover, contractors registered under CIDA has to pay several taxes. Further, literature existing elaborated in international context cost of registration to regulatory bodies are higher therefore small contractors does not tend to register Accordingly, findings displayed that the 'Registered in CIDA' for contractor as non-crucial factor with RII value 0.21 on the selection of the contractors in the informal construction industry. Research findings from expert interviews elaborated there is a need of professional enhance involvement to the construction industry. Further, experts suggested to enhance involvement of the professionals through establishing legal responsibility on the professionals with the activities such as designing, material suggesting, structural designing and plan approving.

3.5 EFFECT OF REGULATORY BODIES FOR INFORMAL BUILDING CONSTRUCTION IN SRI LANKA

Currently, CIDA, Urban Development Authority (UDA) and Local authorities are governing the construction activities in the local context. Since the informal constructions are deep rooted to the local construction context, some of the experts stated that it is difficult to drive out informal construction from the industry. Additionally, almost all the constructions carried out in the country not regulated through these regulatory bodies. Other than that informal construction activities are mostly, do not follow rules and regulations stipulated by the statutory bodies.

Experts interviewed stated that in relation to the construction rules and regulations, there is a requirement of control mechanisms in the Sri Lankan construction industry. Further, they suggested that it should initiated at the early construction stages and flows throughout the building life cycle in order to maintain standards of building and its functionality.

Table 2: Action procedure of suggested regulatory body

Stage	Action
Design stage	Do pre investigation and check deign quality. Then provide approval. Take design responsibility
Construction stage	In each milestone should visit site and certify construction conditions
Operation and maintenance stage	Should inspect the completed construction project at handing over stage. Regulatory body to periodically inspect the buildings to check whether changes done had obtained approvals, maintenance done up to the standards and whether there are defects Along with that, such regulatory body considered to force getting approvals for changes, maintain regular maintenance, take remedial actions to defects and instruct to demolish if the construction building is illegal

Experts opinion about informal construction is it should be driven out in the construction practice. Moreover, identified few options that can be followed in order to drive out this wrong practice. Current regulations should change, increase reinvestigation and changes should be made to thinking patterns in society.

4. THE CONCEPTUAL FRAMEWORK TO CONTROL INFORMAL BUILDING CONSTRUCTION IN SRI LANKA

The conceptual framework was developed from the research findings on the demarcations of the building informality, causations to building performance due to informal construction and building defects, which identified along with the remedial actions. Other than that, the conceptual framework integrated the strategies to minimise the building informal constructions and building defects and collapses and showed the relationships in between. The developed framework is illustrated in Figure 5.

5. CONCLUSIONS AND RECOMMENDATIONS

According to the findings, from the research informal building constructions deep rooted in the Sri Lanka. Event there are already established regulatory bodies to govern the construction industry there is a need of controlling the informal constructions. In this research context, the clients who directly employee the skilled and non-skilled labourers and construct own buildings mostly houses were not considered to the selected research area. However, this research recommends the followings in order to drive out informal construction practices,

Firstly, informal constructions should be driven out from the construction industry. In order to that, need to change the existing rules and regulations and expand the professionals' involvement through investigations have to be carried out in the design, construction and operation stages without limiting it to planning stages.

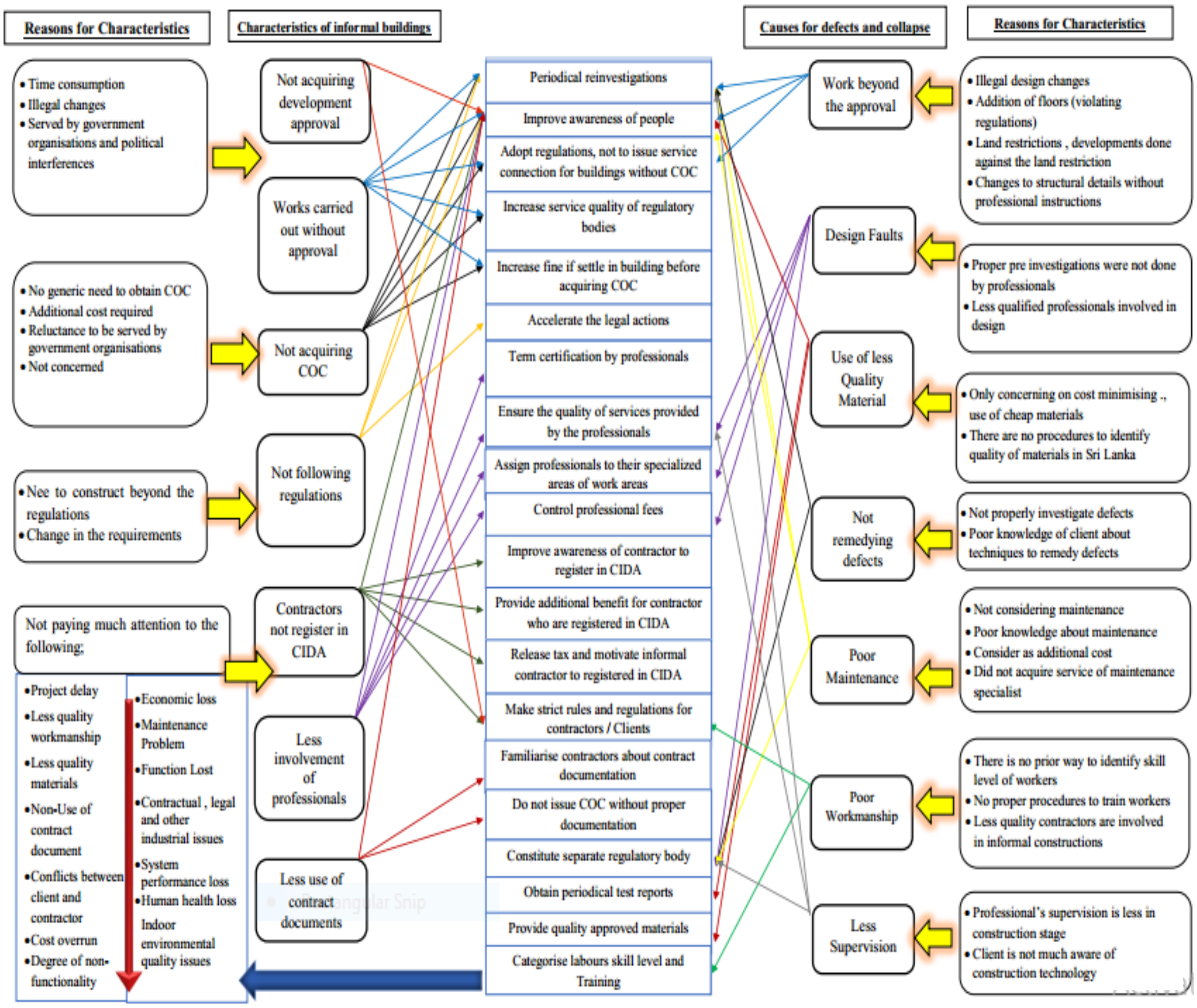

Figure 5: Conceptual framework to control informal building construction in Sri Lanka

Generally, informal building construction practices not acquire COC at the completion of the construction. Therefore, in order to promote COC acquiring regulatory bodies can be integrated with the national service providing bodies such as water and electricity and adopt regulations to demand COC for providing services. Professional involvement should be properly addressed the informal building constructions with the collaboration of the professional bodies existing. The professional bodies should have guided and categorise professionals under their specialised areas in order to provide comprehensive solutions to the informal construction activities in the local context.

Legal action taking processes should be sped up in order to erase the conventional ideas of the clients such as reluctance to obtain national services provided due to lengthy time taking procedures. In terms of contractors, should implement mechanisms like tax exemptions to attract them to follow regulations such as registering in CIDA. Furthermore, separate regulatory body can be established in order to involve with the construction activities from the project inception stage to the disposal stage. Through continuous controlling mechanisms can improve the standards of the building constructions as well as improve the building functionality. Above suggestions are categorised with causations and characteristics of the informal building construction in the conceptual framework to control informal building construction in Sri Lanka.

6. REFERENCES

Adnam, Y. M., Dand, M. D., Ahmad, A. B., Anic, A. B., and Aziz, D. 2009. Determining the criteria for the classification of purpose built office buildings in Malaysia. *Pacific Rim Property Research Journal,* 15(2), pp.225-243

Ahzahar, N., Karim, N. A., Hassan, S. H., and Eman, J., (2011). A study of contribution factors to building failures and defects in construction industry. *Procedia Engineering,* 20, pp.249-255.

Blades, D., Ferreira, F. H., and Lugo, M. A. (2011). The informal economy in developing countries an introduction. International Association for Research in Income and Wealth. Malden: Blackwell publishing

Chamber of Construction Industry Sri Lanka. (2017, June). Eyes and ears of key construction issues. *Construction review, 15*(27), pp.1 . Available from http://www.ccisrilanka.org/2017/06/30/cci-bulletin-june-2017/#june-2017/page1

Chandrasena, G.L., 2010. Importance of quality assurance in the building construction industry of Sri Lanka. *National Building research organization: Sri Lanka*.

Chong, A., Galdo, J., and Saavendra, J. (2008). Informality and productivity in the labor market in Peru. *Journal of Economic Policy Reform*, 11(4), pp.229-245. doi:10.1080/17487870802543480

Gerxhani, K. (2004). Informal sector in developed and less developed countries: A literature survey. *Public Choice*, 120(3/4), pp.267-300. doi:10.1023/b:puch.0000044287.88147.5e

Hughes, D., Wiliams, T. and Ren, Z., 2012. Differing perspectives on collaboration in construction. *Construction Innovation,* 12(3), pp.355-368

Jewel, C., Flanagan, R., and Cattell, K. (2005). The effects of the informal sector on construction. *Construction Research Congress*. doi:10.1061/40754(183)78

Konig, H. and Cristofaro, M. L., 2012. Benchmarks for life cycle costs and life cycle assessment of residential buildings. *Building Reserch & Information,* pp.558-580

Lerociyani, J., Jeevanarth, T., Thushyanthy, S. and Dissanayake, P., 2013. *Informal construction sectar and Its Efects on the construction industry of Sri Lanka*. University of Moratuwa, Sri Lanka.

Ludlow, N. P., and Neuhold, C. (2017). The Informal Construction of Europe. *In proceedings with the 13th History of European Integration Research Society (HEIRS) Conference*. Luxemburg

Mlinga, R. S. and Lema, N. M., 2011. *Informal contractors in Tanzania-their characteristics and reasons for informality.* Botswana, s.n.

Mlinga, R. S., and Wells, J. (2002). Collaboration between formal and informal enterprises in the construction sector in Tanzania. *Habitat International*, 26(2), pp.269-280. doi:10.1016/s0197-3975(01)00048-0

Overa, R. (2004). The creation of African urban livelihoods in between the formal and informal city. *Forum for Development Studies*, 32(2), pp.423-429

Pedro, J. B., Meijer, F. and Visscher, H., 2009. The Portuguese building regulation system: a critical review. *International Journal of Law in the Built Environment,* 1(2), pp. pp.156-171

Sandaratne, N., 2002. *The informal sector in Sri Lanka its nature and extent and the Impact of globalisation*, Colombo.

Wells, J. (2007). Informality in the construction sector in developing countries. *Construction Management and Economics*, 25(1), pp.87-93. doi:10.1080/01446190600601339

Wetlesen, A. (2011). Legal empowerment of workers in the informal economy: the case of the construction industry in Tamil Nadu, India. *Journal of Asian Public Policy*, 3(3), pp.294-308.

Yeboah, I. E., 2012. What is informal about the informal sector? culture and the construction of development in sub Saharan Africa. *East African Geographical Review,* 20(1), pp.1-10.

Koshitha, D. and Sridarran, P., 2019. A framework to enhance productivity through human attitudes. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 33-44. DOI: doi.org/10.31705/WCS.2019.4. Available at: https://2019.ciobwcs.com/papers

A FRAMEWORK TO ENHANCE PRODUCTIVITY THROUGH HUMAN ATTITUDES

Danuka Koshitha[1] and Pournima Sridarran[2]

ABSTRACT

Government expenditure is rising yearly. Maintenance expenses of government building and their services also contributes to this expense. So, productive maintenance within the government sector is increasingly required in order to optimise the costs on maintenance and its output. Management of good attitudes within the human resource of public sector's maintenance departments is an essential factor to enhancing productivity of building maintenance. Thus, it is necessary to develop and manage good attitudes to achieve productive maintenance. Hence, the aim of the research is proposing a suitable framework for attitude management and development in public sector organizations in Sri Lanka. The importance of the attitudes and the reasons for difficulty in developing attitudes is discussed in the paper. The attitude of an employee has been identified under four basic categories and a qualitative research approach was adopted to accomplish the research objectives through semi-structured interviews involving 15 respondents under 3 cases. Cross-case analysis was used to analyse findings and finally a framework was developed to manage good attitudes of staff. Productive maintenance refers to maximum and optimum output from minimum resources and productive human resource plays the most important role. It is made up of three key competencies; good skills, good knowledge and good attitudes. Good attitudes are important in maintaining other two competencies. Finally, a framework for attitude management and development have been developed based on reliable suggestions for proper attitude management within maintenance departments of public sector organisations and several recommendations were suggested to overcome current barriers in the industry.

Keywords: *Human Attitudes; Maintenance Department; Productive Maintenance; Public Sector Organisations.*

1. INTRODUCTION

Building maintenance is the ongoing process of sustaining operations and performance of building systems in accordance to the intention of occupant's changing needs, and optimum efficiency levels (Portland Energy Conservation Inc., 1997). Maintenance management encompasses many functions that relating to keeping something in a proper condition without breakdowns. Further it can be described as facilitating the environment to keep operable to standards required by the users (Allen, 1993). Every person is a manager; knowledge, skills, and attitudes are the key competencies of management (Bandaranayake, 2012). In the training and education context, competency is described as a measurable set of knowledge, skills, and attitudes that need to complete a task

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efficiently and effectively (Hoe, 2017). These are the main factors affecting for effective maintenance of building services by human resource (Tsang, 2002).

Attitudes are very important for the manager's value system and beliefs towards self, task, and others in the organisation (Carmeli, 2003). Attitudes are somewhat emotional, but essential, because of acquisition of knowledge and skills and determination of how the manager applies their techniques and knowledge in total management including non-core activities depends on the attitudes. These non-core activities are basically consisting with building maintenance works. Basic attitudes of an employee are generally integrated with feelings, thoughts, and behaviours. Thus, attitude management is important to maintenance employees as they determine human behaviours and provide insight into the motivating values of them with their beliefs. All actions that perform by human resource generally associate, good knowledge with head, good skills with hands, finally good attitudes with heart (Hoe, 2017).

Sri Lankan private sector companies give high preference for both educational and professional qualifications including attitudes when looking for qualifications of candidates for career opportunities (Wickramasinghe, 2007). Public sector organisations generally operate without considering market competition. Productivity of public sector organisation's maintenance departments and employee individual performances are low compared to private sector organisations of the same industry in Sri Lanka (Dhammika, 2013). Basically, this is due to lack of good attitudes of public sector staff (Prabaharan and Panchanatham, 2016). It is very essential to change the mind-set of people in public sector organisations in Sri Lanka. Contribution of most management and career development programs basically focus on knowledge and skill development, since it is much harder to teach attitudes (Hoe, 2017). There is low contribution by public sector in order to manage and develop attitudes including maintenance departments. Hence, the aim of the research is to analyse the current status of Sri Lankan public sector organisations and develop a framework to enhance the productivity of building maintenance in public sector organisations of Sri Lanka through human attitudes.

2. LITERATURE REVIEW

2.1 BUILDING SERVICES AND THEIR IMPORTANCE

Building Services are the main supportive system of the building in order to achieve the needs of the occupants who work or live within the building premises (The Chartered Institution of Building Services Engineers, 2018). Having quality building services are one of the key features of productivity of the organisation. Furthermore, authors have mentioned that quality building services pave the way for a comfortable built environment. According to Hensen and Lamberts (2012), to achieve high individual human productivity, good building services are needed. As mentioned by Mendes *et al.* (2001), building services are needed to achieve building performance mandates and increase the quality of the building and services provided by the building. It will increase the employee and customer satisfaction by supplying quality building integrated services (Atkin and Brooks, 2015). Each and every physical organisation is situated in buildings (Fuentes *et al.*, 2010). Every work that need to carry out in order to achieve organisational goals and objectives are handled and controlled within building premises. Improper maintenance and operations of building services lead the path for energy wastages, poor building performance, tenant complaints, and further environmental damages (Neale *et* *al*., 2010). Efficient and effective timely maintenance and accurate management of building services and buildings prevent their deterioration and keep them in a productive condition. Maintenance of building services is the most important factor in the management of building services. Furthermore, the author has mentioned that each and every system must have to maintain well in order to maximum output and performance from them.

Productivity is the efficient use of resources, labour, capital, materials, energy, information, in the production of various goods and services. Productive maintenance refers to combination of two major elements, efficiency in maintenance and effectiveness in maintenance (Keh *et al*., 2006). The optimum collaboration of both efficiency and effectiveness is a must in achieving optimum productive maintenance (Manzoor, 2011). Efficient maintenance refers to the quality of being able to do a task by using each and every optimum resource input (Sheth and Sisodia, 2002). Further authors have mentioned that it can be included minimum input of time and effort to a certain maintenance work or doing things right. Effectiveness refers to degree in which an organisation realizes its goals and it refers to the effectiveness of any work. Effective maintenance refers to capability of producing the desired output in a certain time or doing the right thing.

Productive resources are essential in productive maintenance, identified as, productive physical resources, productive informational resources and productive human resource (Tavitiyaman *et al*., 2011). Among them, productive human resource is most essential to achieve effectiveness and efficiency in productivity and it is the most important resource to be managed and optimised. There are key competencies that needed to be accomplished by a productive human resource which identified as good skills, good knowledge and good attitudes (Baartman and de Bruijn, 2011). Among these key competencies, good skills can be developed by practice, good knowledge can be developed by education (Bandaranayake, 2012). Development of good attitudes is the most difficult factor and optimisation of good skills and good knowledge is also have impact from the good attitudes of human resource. Therefore, attitudes are the most difficult and important factor to be developed in achieving productive maintenance as the final output. Good attitudes of human resource divided into four main categories; towards organisation; towards people; towards job and towards intimate (Bandaranayake, 2012). Collaboration of these four types will enhance good attitudes of a human resource.

Achieving optimum maintenance output from the maintenance tasks performing in the organisation refers to productive maintenance (Chan *et al*., 2005). Minimum resource allocation, standard procedure accomplishment, minimum wastages in completing the tasks should be addressed accurately (Al-Najjar and Alsyouf, 2000). Productive maintenance maximises the equipment effectiveness throughout the lifetime of the equipment. To achieve productive maintenance, it is needed to ensure the efficiency and effectiveness of each task of maintenance activity with respected to all resources (Almeanazel, 2010). Efficient maintenance refers to use of minimum resources to accomplish the maintenance job in maximum productivity by adopting all standard procedures that should be adopted (Quintana and Ortiz, 2002). Effective maintenance refers to conducting of accurate maintenance activity suits for situations in accordance with the standards given in an accurate way (Ismail, 2014).

According to Ajzen (2005), "attitudes are a disposition to respond favourably or unfavourably to an object, person, institution or event". The tendency to react and respond negatively or positively toward an idea, person, object or situation is also a definition of Attitudes (Redman *et al*., 2012). Furthermore, authors have stated that attitudes influence choice of action perform by individuals according to the way of responding to challenges.

2.1.1 Human Resource Management towards Productiveness

Human resource management is a basic function of the strategic policy of an organisation (Michael, 2006). Further, author has mentioned that Human Resource is an individualistic resource and it should manage individually by common systems. Being recognised as an asset rather than a cost is, for ordinary employees, admittedly a step in the right direction (Inkson, 2008). Generally, in human resource management, it is a must to go through individual task analysis and individual development. Further, authors have mentioned that through analysis, the individual requirement of skills, attitude and knowledge can be identified. Development of good and positive attitudes is a must in productive human output (Wright *et al*., 2003). Furthermore, author has mentioned that human attitudes have a direct impact with productiveness of organisation. There is a direct relationship between employee attitude and productiveness of job, employee attitude is basically based on employee job satisfaction towards organisation (Saari and Judge, 2004).

In real nature, nothing man-made is indestructible, but doing repairs at required intervals will manage its performance while extending useful life and it is called maintenance (Kelly, 2006). Further author has mentioned that maintenance is a definition for those activities which needed to upkeep a facility in a status of as built while continuing its original productive capacity. Attitudes of the maintenance workers have a high considerable impact on the behaviour of the organisation or behaviour of the business cycle in achieving objectives (Wright *et al*., 2003). Further authors have mentioned that human attitudes include behavioural, cognitive and affective components and these attitudes are very important in employee participation for their intended job roles.

Practising proper attitude management practices within an organisation will ensure the loyalty of the workers towards the organisation and their job roles. It will lead to achievement of competitive advantage in the organisational context and achievement of organisational objectives and goals easily (Ordóñez de Pablos and Lytras, 2008). Reduction of wastages and achievement of efficiency and effectiveness in maintenance broader aspect (Pfeffer, 2010). Proper attitude management practices will enhance high individual performance ratio achievement incensement of job performances and organisational performance. It will Increase the loyalty of workers and customers by maintaining an appropriate working environment (Gagné, 2009). Finally, it will lead to reduction of unnecessary costs and wastages on building services (Birdi *et al*., 2009).

According to the Ministry of Finance (MOF) Sri Lanka (2017), Sri Lankan government sector covers all most all the industries in Sri Lanka. Further, MOF (2017) stated that, the expenditure of the public sector is higher than the revenue of the public sector organisations. Performance measurement, individual performance measurement and analysis of government employees are not practising well in Sri Lanka (Dhammika, 2013). Furthermore, the author has mentioned that the productivity of public sector organisations and employee individual performances are low respecting to private sector organisations of the same industry in Sri Lanka including maintenance departments. It is very essential to increase the productivity of the employees in public sector (Pidd, 2012). According to author, it can be easily done by making an appropriate working environment, with productive building service. It is essential to increase the maintenance productivity in public sector organisations, in order to have optimum output (Almeanazel, 2010). Therefor it is essential to develop and manage attitudes of maintenance staff of public sector in Sri Lanka (Velnampy, 2008). Furthermore, author mentioned that currently there are no proper system and weight for the field of attitude development and management even though it is essential.

3. RESEARCH METHOD

In order to achieve the aim, which is to develop a framework to enhance attitudes and ensure attitude management of people in the field of maintenance in building services of public sector buildings, a qualitative research approach has been undertaken. Multiple case studies have been conducted in 3 public sector buildings. Case A is one of the main organisations, which directly supports the international trade and foreign affairs of Sri Lanka, Case B organisation is an important government organisation which contributed to control the finance of the country. Case C is a leading government organisation under local authority. It contributes to control the infrastructure to a certain area and five respondents were selected for data collection from each organisation. 5 semi-structured interviews were conducted in each case with management and supervisory level workers to obtain their opinion. Altogether, 15 interviews were conducted. Data analysis has been undertaken by using the manual data and cross case analysis technique. Scope of this study is limited to maintenance departments of public sector organisations. A framework has been developed to achieve effective human attitude management and development by going through all literature, collected data and generated information, by covering all areas of job roles.

4. DATA ANALYSIS AND FINDINGS

All the buildings are leading government sector buildings under ministries and local authorities which built recently. Building service maintenance is carried out by the in-house maintenance staff under the maintenance division of the organisations. Table 1 shows the details of the selected cases.

Table 1: Selected case details

Description	Case A	Case B	Case C	
No. of buildings	1	1	2	
Building Type	Office	Office	Library	Office
No. of stories	12	5	5	4
Year started operations	2010	2015	2009	2012
Years in operation	8	3	9	6

4.1 IMPORTANCE OF PRODUCTIVE MAINTENANCE

Maintenance is everywhere in buildings and their systems and in order to run an organisation smoothly, doing maintenance correctly is important (Lind and Muyingo, 2012). As an initial step of developing the framework for improving positive attitudes of maintenance staff of public sector organisations for better attitude management and productive maintenance, interviewees were questioned about the importance of maintenance and productive maintenance for an organisation. All respondents demonstrated similar meanings on maintenance as a very important process for any type of an organisation or building to have a higher productivity from their operations. Maintenance prevents breakdowns and further it will help to achieve organisational objectives as planned by reducing operational breakdowns and compromising in operational works. Furthermore, maintenance of building systems creates a quality and comfortable working environment for workers.

4.2 RELATIONSHIP BETWEEN GOOD ATTITUDES AND PRODUCTIVE MAINTENANCE

Productive maintenance is taking an optimum output from the maintenance activities that is performed within the organisation. For productive maintenance, it is a must to have productive resources. Basically, productive resources are integrated with, productive physical resources, productive human resources and productive informational resources (Tavitiyaman *et al*., 2011). The productive human resource plays a key role among the productive resources. To be a productive human resource, there should be three key competencies; namely, skills, knowledge and attitudes. All respondents asserted similar ideas. They highlighted attitudes as the most important factor among the key competencies as it is connected with interpersonal behaviours and the good attitudes are the most difficult factor to be developed in humans, among the three factors, good skills, good knowledge and good attitudes. Respondent 'IC-C-03', stated that "*attitudes differ from one person to another. Sometime living background, personal thoughts, constitutional factors differ from person to person, therefore it is difficult to develop*". Respondents 'IC-A-04' and 'IC-B-01'also stated the ideas similar to respondent 'IC-C-03'. Respondent 'IC-A-01' stated that "*changing the interpersonal views of people is difficult*". Respondent 'IC-B-04' delivered similar ideas with respondent 'IC-A-01'. Further respondent 'IC-A-02' stated that "*Changing the disciplines and feelings of people is difficult*". Six respondents out of fifteen agreed with the idea of changing the traditional thinking, personal habits and behaviours are difficult.

4.3 ATTITUDE DEVELOPMENT THROUGHOUT THE JOB ROLE OF MAINTENANCE STAFF

As mentioned by the all respondents, transfers and appointment for the jobs in public sector is mainly done by government acts and procedures. Therefore, preliminary stages of human resource management steps are not followed generally. In development of attitudes of maintenance staff of public sector organisations is difficult to do by going through human resource management functions. It can be easily done by covering all aspects, by attitude management through following categorisation which was identified through literature. They are developing attitudes about organisation, about job, about people around, and developing intimate attitudes. All respondents agreed to the above categorisation and following would be the strategies that can adopt in order to develop attitudes on above basic categorisation. The declared strategies are as follows by the relevant respondents to develop the attitudes about the organisation in maintenance departments of public sector organisations (see Table 2).

Table 2: The declared strategies by the respondents to develop attitudes about the organisation

	DESCRIPTION	IC-A-01	IC-A-02	IC-A-03	IC-A-04	IC-A-05	IC-B-01	IC-B-02	IC-B-03	IC-B-04	IC-B-05	IC-C-01	IC-C-02	IC-C-03	IC-C-04	IC-C-05
1	Conducting review meetings	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Appreciation on what they have done			√		√			√			√				
3	Giving bonuses and incentives	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	Good grievance handling procedure for workers			√	√		√				√	√			√	√
5	Welfare activities for workers	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	Supplying occupational medical facilities and insurance	√						√					√		√	
7	Arranging flexible work shifts	√		√		√	√		√		√					√
8	Arranging workshops on professional development secessions	√		√	√	√					√	√			√	
9	arranging proper complaints management system			√	√			√		√						
10	Giving organisational product benefits	√	√	√	√	√			√							

Table 3 shows the declared strategies by the respondents of three cases that should adopt to enhance the attitudes towards other people in maintenance departments of public sector organisations

Table 3: Strategies that should be adopted in order to enhance the attitudes of the employees on other people

	DESCRIPTION	IC-A-01	IC-A-02	IC-A-03	IC-A-04	IC-A-05	IC-B-01	IC-B-02	IC-B-03	IC-B-04	IC-B-05	IC-C-01	IC-C-02	IC-C-03	IC-C-04	IC-C-05
1	Arranging meetings	√		√		√	√				√	√	√		√	√
2	Arranging get together and functions	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
3	Arranging charity works	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
4	Conducting training programmes	√		√	√		√			√	√	√			√	√
5	Conducting team works	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
6	Arranging trips and entertainment events	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

Table 4 shows the declared strategies by the respondents of three cases that should adopt to enhance the attitudes on job role of people in maintenance departments of public sector organization

Table 4: Strategies stated by respondents to enhance attitudes on job role

	DESCRIPTION	IC-A-01	IC-A-02	IC-A-03	IC-A-04	IC-A-05	IC-B-01	IC-B-02	IC-B-03	IC-B-04	IC-B-05	IC-C-01	IC-C-02	IC-C-03	IC-C-04	IC-C-05
1	Giving required authority and responsibility	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
2	Giving decision making power	√	√	√		√	√	√	√		√	√		√		√
3	Making flexibility in job		√	√	√		√		√	√			√	√		√

	DESCRIPTION	IC-A-01	IC-A-02	IC-A-03	IC-A-04	IC-A-05	IC-B-01	IC-B-02	IC-B-03	IC-B-04	IC-B-05	IC-C-01	IC-C-02	IC-C-03	IC-C-04	IC-C-05
4	Allocating required number of subordinates	√	√					√	√					√		
5	Maintaining good facilities related to job	√	√		√	√			√	√	√	√	√	√	√	

Table 5 shows the declared strategies by the respondents that should adopt to enhance the intimate attitudes of people in maintenance departments of public sector organisations.

Table 5: Strategies that should be adopted to develop intimate attitudes of employees

	DESCRIPTION	IC-A-01	IC-A-02	IC-A-03	IC-A-04	IC-A-05	IC-B-01	IC-B-02	IC-B-03	IC-B-04	IC-B-05	IC-C-01	IC-C-02	IC-C-03	IC-C-04	IC-C-05
1	Conducting review meetings		√	√	√	√	√		√	√	√	√	√	√	√	√
2	Allowing on the job training	√	√	√	√	√		√	√	√			√		√	
3	Conducting CPDs and workshops	√	√	√			√	√	√		√	√	√	√	√	
4	Personal helping programmes	√					√		√						√	√
5	Arranging self-motivation programmes		√	√	√	√	√	√	√	√				√	√	√

4.4 DEVELOPMENT OF THE FRAMEWORK

Framework was developed to enhance management of attitudes within the maintenance departments of public sector organisations by considering on the findings from the research (see Figure 1). Framework is bounded by basic four types of attitudes that a worker of a maintenance department of public sector organisation is having. Importance of good attitudes of maintenance workers of public sector organisation identified and further, the strategies to develop attitudes also identified in the top section. At the bottom section, why it is difficult to develop attitudes, current barriers in attitude management and development in maintenance departments of public sector organisation and strategies to overcome the barriers are identified and showed.

5. DISCUSSION

The conceptual framework shows the relationship of productive maintenance and the good human attitudes. As mentioned by Bandaranayake (2012), Human attitudes of any kind of a employee can be basically devided in to the mentioned categories as, attitudes about organisation, attitudes about job role, attitudes about people and finally intimate attitudes. It was confermed by every respondent and every respondent stated similar meanings on, by these main four types, every stage and aspects of employees are covered. Productive mainteannce refers to achievement of efficiency and effectiveness in maintenance works. All respondents stated similar meanings on, productive human resource is essential in achieving maintenance productivity and, good attitudes are essential to be a good human resource. Building Services are the main supportive from the building in order to achieve the needs of the occupants who work or live within the building premises (The Chartered Institution of Building Services Engineers, 2018).

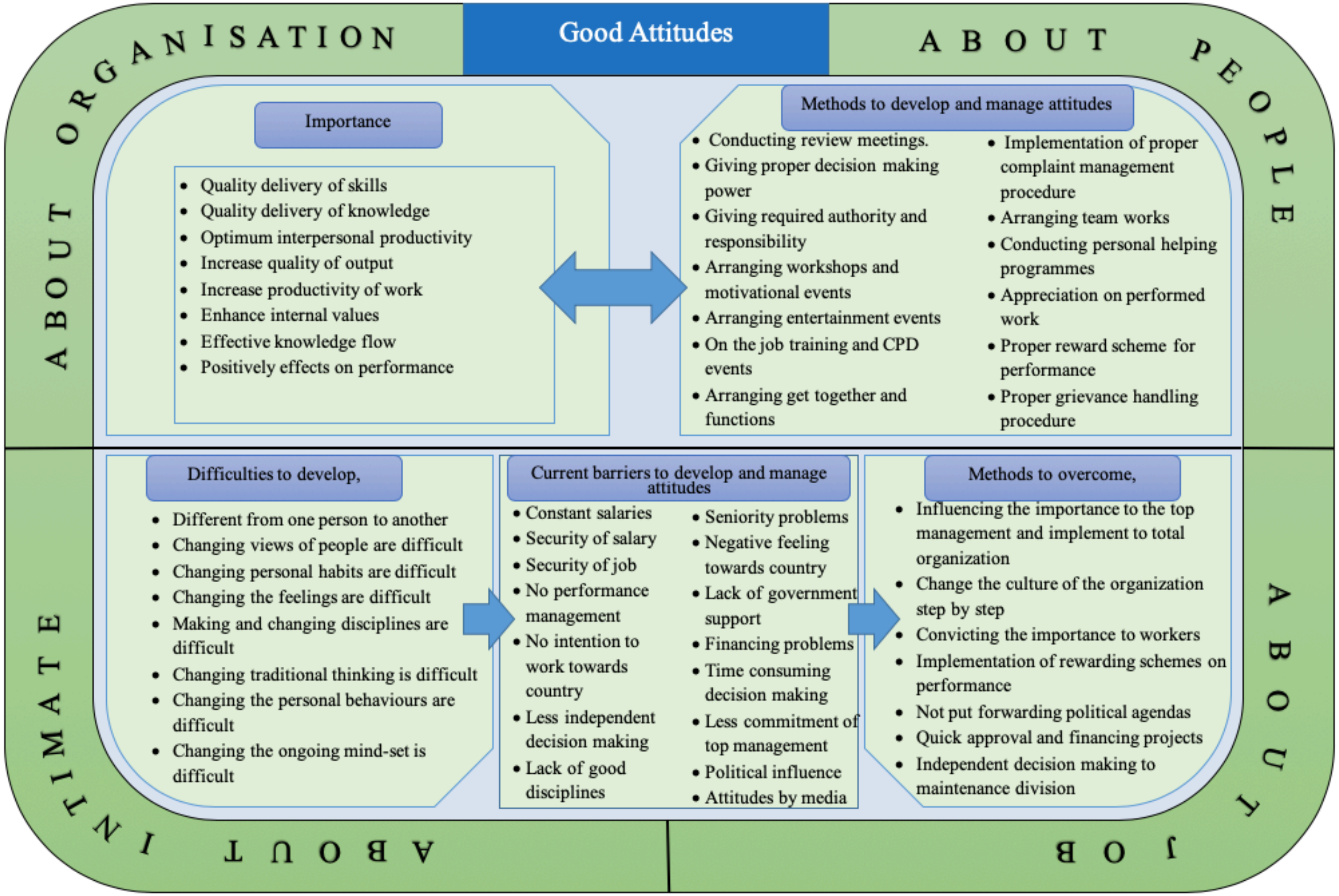

Figure 1: The framework to enhance productivity through human attitudes

All respondents asserted similar ideas on the importance of integrating good building services in each building and having a proper maintenance in order to have proper productivity out of the building. According to Velnampy (2008), currently there is no proper system or weight given to the field of attitude development and management in Sri Lanka even though it iss essential to develop and manage attitudes of maintenance staff of public sector in Sri Lanka. All respondents delivered similar ideas that the attitude development of maintenance staff is a must in public sector and it should start from department level.

6. CONCLUSIONS

Building service's maintenance costs are rising day by day. The need for productive maintenance has become a vital fact in order to increase the quality of maintenance and reduce the related costs on maintenance. Proper attitude development and management within the workers of maintenance department will enhance the maintenance productivity directly. In Sri Lankan public sector organizations, there are many inefficiencies in maintenance departments and most of them are due to the improper delivery of maintenance works. Enhancement of proper attitude development and management within the maintenance departments will reduce the improper delivery of maintenance works and thorough attitude development, people will motivate towards the proper delivery of their intended job roles. According to the research finding, it was identified that, attitude of maintenance workers must be managed well in government sector organizations in order to achieve productive maintenance. As found out by the literature and confirmed by data analysis, attitude development of maintenance staff of Sri Lankan public sector organisation can be accurately done under developing strategies for basic categorisation of human attitudes. Final output was given by developing a framework and identifying importance, difficulties, current barriers and strategies to develop attitudes in maintenance department of public sector organisations in Sri Lanka.

7. REFERENCES

Al- Najjar, B. and Alsyouf, I., 2000. Improving effectiveness of manufacturing systems using total quality maintenance. *Integrated Manufacturing Systems,* 11(4), pp.267-276.

Ajzen, I., 2005. *Attitudes, personality, and behavior*. McGraw-Hill Education (UK).

Allen, D., 1993. What Is Building Maintenance?. *Facilities,* 11(3), pp.7-12.

Almeanazel, O.T.R., 2010. Total productive maintenance review and overall equipment effectiveness measurement. *Jordan Journal of Mechanical and Industrial Engineering*, 4(*4*).

Atkin, B. and Brooks, A., 2015. *Total Facility Management.* 1st ed. United Kingdom: John Wiley and Sons.

Baartman, L. K. and de Bruijn, E., 2011. Integrating knowledge, skills and attitudes: Conceptualising learning processes towards vocational competence. *Educational Research Review,* 6(2), pp. 125-134.

Bandaranayake, J., 2012. *A-Level Business Studies Part-II.* Colombo: Tharangi Printers, Navinna.

Birdi, K., Clegg, C., Patterson, M., Robinson, A., Stride, C.B., Wall, T.D. and Wood, S.J., 2008. The impact of human resource and operational management practices on company productivity: A longitudinal study. *Personnel Psychology*, *61*(3), pp.467-501.

Carmeli, A. H., 2003. The relationship between emotional intelligence and work attitudes, behavior and outcomes. *Journal of Managerial Psychology,* 18(8), pp.788-813.

Chan, F.T.S., Lau, H.C.W., Ip, R.W.L., Chan, H.K. and Kong, S., 2005. Implementation of total productive maintenance: A case study. *International Journal of Production Economics*, *95*(1), pp.71-94.

Dhammika, K., 2013. Measuring Employees' Performance in the Public Sector in Sri Lanka: Testing of Two Models. *Kelaniya Journal of Human Resource Management,* 8(1), pp.1-20.

Fuentes, J., Gallego, E., García, A. and Ayuga, F., 2010. New uses for old traditional farm buildings: The case of the underground wine cellars in Spain. *Land Use Policy,* 27(3), pp.738-748.

Gagné, M., 2009. A model of knowledge-sharing motivation. *Human Resource Management,* 48(4), pp.571-589.

Hensen, J. L. and Lamberts, R., 2012. *Building performance simulation for design and operation.* 1st ed. Routledge.

Hoe, S. L., 2017. What makes a competent change manager? The importance of developing the "right" attitudes. *Development and Learning in Organizations: An International Journal,* 31(5), pp.14-16.

Inkson, K., 2008. Are humans resources. *Career Development International,* 13(3), pp.270-279.

Ismail, Z., 2014. System development toward effective maintenance management practices. *Built Environment Project and Asset Management,* 4(4), pp.406-422.

Keh, H. T., Chu, S. and Xu, J., 2006. Efficiency, effectiveness and productivity of marketing in services. *European Journal of Operational Research,* 170(1), pp.265-276.

Kelly, A., 2006. Total productive maintenance: its uses and limitations. *Plant Maintenance Management Set,* 8(1), pp.247-265.

Lind, H. and Muyingo, H., 2012. Building maintenance strategies: planning under uncertainty. *Property Management,* 30(1), pp.14-28.

Manzoor, Q., 2011. Impact of Employees Motivation on Organizational Effectiveness. *Business Management and Strategy,* 3(1), pp.1-12.

Mendes, N., Oliveira, G. H. and De Araújo, H. X., 2001. *Building thermal performance analysis by using matlab/simulink. In Seventh International IBPSA Conference.* Rio de Janeiro, Brazil, pp.473-480.

Michael, A., 2006. *A Handbook of Human Resource Management Practice.* London: Kogan Page Publishers.

Ministry of Finance (MOF) Sri Lanka, 2017. Available from: http://www.treasury.gov.lk [Accessed 15 September 2019]

Neale, K., Wu, S., Williamson,, M. and Hornby, M., 2010. Research opportunities in maintenance of office building services systems. *Journal of Quality in Maintenance Engineering,* 16(1), pp.22-33.

Ordóñez de Pablos, P. N. and Lytras, M. D., 2008. Competencies and human resource management: implications for organizational competitive advantage. *Journal of Knowledge Management,* 12(6), pp.48-55.

Pfeffer, J., 2010. Building Sustainable Organizations: The Human Factor. *Academy of Management Perspectives,* 24(1), pp.34-45.

Pidd, M., 2012. Measuring public sector performance. In Measuring the Performance of Public Services. *Principles of performance measurement : Principles and Practice,* 1(1), pp. pp.3-26.

Portland Energy Conservation Inc., 1997. *Operation and Maintenance Service Contracts.* Washington: s.n.

Prabaharan, T. and Panchanatham, N., 2016. Occupational Role Stress among Public Sector Banks Employees in Sri Lanka. *Wayamba Journal of Management,* 4(1), pp.22-25.

Quintana, R. and Ortiz, J. G., 2002. Increasing the effectiveness and cost-efficiency of corrective maintenance using relay-type assignment. *Journal of Quality in Maintenance Engineering,* 8(1), pp.40-61.

Redman, M., Taylor, E., Furlong, R., Carney, G. and Greenhill, B., 2012. Human rights training: impact on attitudes and knowledge. *Tizard Learning Disability Review*, *17*(2), pp.80-87.

Saari, L. M. and Judge, T. A., 2004. Employee attitudes and job satisfaction. *Human Resource Management,* 43(4).

Sheth, J. N. and Sisodia, R. S., 2002. Marketing productivity: issues and analysis. *Journal of Business Research,* 55(5), pp.349-362.

Tavitiyaman, P., Qu, H. and Zhang, H. Q., 2011. The impact of industry force factors on resource competitive strategies and hotel performance. *International Journal of Hospitality Management,* 30(3), pp.648-657.

The Chartered Institution of Building Services Engineers, 2018. *what-is-building-services.* [Online] Available at: https://www.cibse.org/building-services/what-is-building-services [Accessed April 2018].

Tsang, A. H., 2002. Strategic dimensions of maintenance management. *Journal of Quality in Maintenance Engineering,* 8(1), pp.7-39.

Velnampy, T., 2008. Job attitude and employees performance of public sector organizations in Jaffna district, Sri Lanka.". *GITAM Journal of Management,* 6(2), pp.66-73.

Wickramasinghe, V., 2007. Staffing practices in the private sector in Sri Lanka. *Career Development International,* 12(2), pp.108-128.

Wright, P. M., Gardner, T. M. and Moynihan, L. M., 2003. The impact of HR practices on the performance of business units. *Human Resource Management Journal,* 13(3), pp.21-36.

Ratnasabapathy, S., Perera, S. and Alashwal, A., 2019. A review of smart technology usage in construction and demolition waste management. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 45 -55. DOI: doi.org/10.31705/WCS.2019.5. Available at: https://2019.ciobwcs.com/papers

A REVIEW OF SMART TECHNOLOGY USAGE IN CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT

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ABSTRACT

The management of construction and demolition (C&D) waste, a major part of solid waste, is increasingly become a critical challenge in the quest of social, environmental, and economic sustainability. Innovative and smart technologies are emerging to provide inevitable benefits because of their capacity to enable digitisation, automation, and integration of Solid Waste Management (SWM) processes. Nevertheless, the application of such technologies in Construction and Demolition Waste Management (CDWM) has not gained the appropriate attention. This study aims to draw insights into the current and potential use of smart technologies in CDWM. A literature review-based approach surveyed both academic and applied publications to analyse the current and potential use of smart technologies in both SWM and CDWM. Altogether, 75 peer-reviewed articles and technical white papers were analysed. It was found that the usage of smart technologies is much advanced in SWM and the adoption is still at the prototype stage in CDWM. The results emphasise that the integration of smart technologies into multiple processes of CDWM would overcome many issues related to waste minimisation and management including waste estimation, waste reporting, and data management and waste diversion. The framework developed in this study contributes to the understanding of the potential role of each category of technologies in improving the waste management processes in the C&D sector. This review is useful to waste management practitioners, regulatory bodies and the government to understand the benefits of emerging technologies and to the development of effective strategies and future training programmes.

Keywords: *Blockchain; Construction and Demolition Waste Management; Information and Communication Technologies (ICTs); Smart Technologies; Solid Waste Management.*

1. INTRODUCTION

Solid waste generation is one of the most significant by-products of urban lifestyle (Hannan *et al*., 2015). Global municipal solid waste contributes to 2.01 billion metric tons/year and it is increasing rapidly due to the continuous growth in urbanisation and associated industrialisation. 3.40 billion metric tons/year is expected to be generated by 2050 (Kaza *et al*., 2018). Construction and Demolition (C&D) waste is one of the major parts of solid waste. C&D waste is a combination of different materials, including inert waste, non-inert non-hazardous waste and hazardous waste, generated from new construction, renovation and demolition activities and natural disasters (Chen and Lu,

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2017, Faleschini *et al*., 2017). The rapid growth of population associated urbanization and economic development call for increased demand for C&D activities which will significantly impulse the waste generation by the construction industry to rise across the globe. Globally, the construction industry is considered as the major waste generator which has led the industry to be the key contributor to environmental degradation and pollution (de Magalhães *et al*., 2017, Ding *et al*., 2018). The global construction sector contributes one-third of solid waste which is around 30-40 % of the total solid waste generation (Ajayi and Oyedele, 2017). This figure varies between countries subject to the factors related to the profile of the construction industry and the economy, legislation and cultural characteristics of the country (Duan *et al*., 2015). Failure to adopt effective management strategies will lead to detrimental environmental, socio-health, political and economic impact on both current and future generations.

Solid Waste Management (SWM) is a multidisciplinary activity, involving several processes related to planning, collection, logistics, monitoring, control, recycling, and disposal. As these processes involve sustainability in environmental, economic and social terms, they may create problems and hence need multi-criteria decisions at every stage of its life cycle (Melare *et al*., 2017). Managing solid waste would, therefore, be very costly (Lamichhane, 2017). While, Construction and Demolition Waste Management (CDWM) is considered as an inter-disciplinary area as it involves social, environmental, economic, institutional and political aspects while it faces challenges from the perspective of engineering, technology, management and policies and legislation (Arshad *et al*., 2017, Jin *et al*., 2019). Nonetheless, recent studies have focused on finding solutions with the use of advanced Information and Communication Technologies (ICTs) to face those challenges in waste management. Rapid improvement in the capacity of innovative technologies enables digitisation, automation, and integration of the construction process at all stages (Oesterreich and Teuteberg, 2016).

Several past studies have recognised the potential use of various ICTs brought by the revolution of industry 4.0 in improving waste management practices (Jin *et al*., 2019). These emerging ICTs are being adopted in different solid waste management processes to provide widespread solutions to achieve the goals of sustainability (Melare *et al*., 2017). However, limited attention is paid to the application of such technologies in the CDWM stream as compared to the SWM stream. This bounds understanding of their potential application, where the construction sector is ignorant hence is not yet ready to transmit and extract their real value in CDWM. In this context, the objectives of this study are twofold. The first is to evaluate the extent of current adoption and potential use of smart technologies and ICTs in SWM and the second is to outline the potential applications of such technologies in multiple processes of CDWM.

2. LITERATURE REVIEW

During the past few decades, several ICTs and other emerging smart technologies have been employed to improve the efficacy of SWM practices. Melare *et al*. (2017) observed a good distribution of the use of wide range of emerging smart and digital technologies such as Geo Technologies (e.g. GIS - Geographic Information System, GPS-Global Positioning System) Physical Computing and IoT (Internet of Things), RFID (Radio Frequency Identification), Cloud Computing, IP (Image Processing), CAD (Computer-Aided Design) and Databases in SWM during the past decade. The usage of these technologies varies depending on the application in different processes involved in SWM from waste generation to final destination. Melare *et al*. (2017) perceived that integration of ICTs in multiple processes of SWM could aid to achieve social, environmental and economic sustainability objectives while serving the community in a fast and efficient way with less impact to the environment (less pollution or greenhouse gas emissions) and at a lower cost. ICTs improve effective practices in terms of planning and management and help managers to make informed decisions on environmentally related issues (Melare *et al*., 2017).

In the context of the C&D sector, integration of embryonic digital technologies such as BIM (Building Information Modelling), Big data, GIS, GPS and RFID technologies in CDWM has been studied in some previous studies. However, the application of these technologies has not fully implemented in the sector (Jin *et al*., 2019). The construction industry is recognized as the second least industry in adopting the technologies and systems across the construction value chain (Agarwal *et al*., 2018). Some researchers have recognized that the lack of the use of advanced technologies in CDWM hinders the development of effective management practices in the construction sector. The issues identified with the lack of usage of advanced technologies in WM are lack of historical waste data, inconsistencies in waste data reporting, inaccuracy in waste estimation and lack of established platforms for promoting the circularity of recovered waste materials through reusing, repairing and recycling. In contrast, Melare *et al*. (2017) perceived that lack of historical data on waste collection management hinders the accurate planning and forecasting and hence directs to inaccurate decision making. Contributions of ICTs become substantial in handling the issues associated with increasing solid waste, which in turn has urged the need for the automation of waste data acquisition, identification, communication, storage, and analysis (Hannan *et al*., 2015).

The necessity for uniform historical waste data in implementing a successful WM system has been further emphasized by some researchers in the C&D waste stream. For instance, Zaman and Swapan (2016) highlighted the need for a uniform data capture platform to obtain more reliable and compatible data on waste estimation which could provide appropriate developmental directions for benchmarking of WM in the future. Wu *et al*. (2014) suggested that computer-aided technologies can be useful to record the C&D waste information for benchmarking and enhanced WM.

3. METHODOLOGY

A literature review-based approach surveyed both academic and applied publications to systematically review the adoption and potential use of ICTs and smart technologies in both SWM and CDWM. In the first stage, to limit the scope of the research, a keyword search in Scopus and Google Scholar were conducted. Several keywords were applied to find related publications. For example, for Scopus research engine, the following keywords were used: TITLE-ABS-KEY (ICTs) AND (Solid Waste AND Waste Management) AND (LIMIT-TO (DOC-TYPE, "Article")) AND LANGUAGE (English); TITLE-ABS-KEY (Construction AND Demolition Waste) AND (Waste Management AND ICTs) AND (LIMIT-TO (DOC-TYPE, "Article")) AND LANGUAGE (English). Besides, publicly available applied publications such as technical white papers, and other commercial web pages were reviewed to identify the use of ICTs and other smart technologies in commercial based SWM systems (online platforms) to which no peer-reviewed articles were found. Altogether 75 peer-reviewed articles, white papers, and commercial applications were reviewed to gain a broad understanding and evaluate the current and potential use of the ICTs and smart technologies in both SWM and CDWM streams. To understand and analyse the potential use of such technologies in CDWM, the current adoption of smart technologies in SWM was reviewed. Based on the existing adoption of smart technologies in SWM and CDWM, potential applications of such technologies were mapped out for CDWM which included the potential integration of ICTs and other smart technologies into the different processes of CDWM.

4. RESULTS AND DISCUSSION

In line with the review, a wide range of smart technologies have been adopted and proposed in SWM and the development of ICTs based WM systems are comparatively in the C&D sector. Table 1 presents a summary of the current status of the application of various types of spatial, identification, data communication and acquisition technologies in several processes of SWM and CDWM. In both streams, GIS has been the most widely used ICTs in combination with other technologies such as RFID, GPS among others.

Table 1: Different types of smart technologies applicable to SWM and CDWM

WM Process	Types of ICTs adopted		References
	SWM	CDWM	
Management of collection, route, and transportation	GPS, Imaging	GIS, GPS	Hannan *et al*. (2015); Li *et al*. (2005); Melare *et al*. (2017)
Site selection; planning; forecasting; management; estimation; optimisation	GIS, Remote Sensing, Imaging	Big data, BIM	Jin *et al*. (2019); Hannan *et al*. (2015); Melare *et al*. (2017)
Management and monitoring of containers	Sensors, Wireless network, Internet, RFID, GIS, GSM, GPRS		Melare *et al*. (2017)
Public administration and sustainable development	GIS	RFID, BIM	Melare *et al*. (2017); Iacovidou *et al*. (2018)
Determination of waste-disposal sites/illegal waste dumping sites	GIS, Remote Sensing, Image Processing	GIS	Melare *et al*. (2017); Hannan *et al*. (2015); Seror and Portnov (2018)
Waste Sorting	Robotics, RFID, Sensors, Imaging		Hannan *et al*. (2015)
Watch Matching	Artificial Intelligence		EME (2018)
Recycling of solid residues and management of electronic waste	GIS, RFID, Image Processing, IoT, Barcode		Hannan *et al*. (2015); Melare *et al*. (2017);
Waste material exchange	Resource Passport, Artificial Intelligence, Blockchain	PHP and Java Applet	EME (2018); Pun *et al*. (2007)

WM Process	Types of ICTs adopted		References
	SWM	CDWM	
Material information sharing	Blockchain		Licht *et al*. (2018)
Weight-based waste disposal payment	Blockchain, IoT		Lamichhane (2017)
Intelligent recycling; waste disposal; reduce landfill space; risk management	Barcode, RFID		Hannan *et al*. (2015)
Short and long-range communication	ZigBee, WI-FI, Bluetooth, VHFR, GSM/GPRS		Hannan *et al*. (2015)
Tracking and scheduling construction waste; stimulating reuse of construction components		RFID and Rule-based Reasoning	Zhang and Atkins (2015); Iacovidou *et al*. (2018)
Environmental impact assessment	Remote Sensing	GIS	Chen *et al*. (2018); Hannan *et al*. (2015);
Design review, 3D coordination, quantity take-off, and phase planning for managing waste		BIM	Kim *et al*. (2017); Chen *et al*. (2018); Won and Cheng (2017); Porwal and Hewage (2012); Cheng and Ma (2013)
Decision support in managing the waste generated from civil construction and demolition		GIS, Geo-referencing, Data input modules, and online analytical modules, Databases	Banias *et al*. (2011)
Demolition waste generation and performance comparison		GIS, Big data	Lu *et al*. (2015); Chen and Lu (2017); Chen *et al*. (2018)
Waste Estimating		Data input modules and online analytical modules	Paz and Lafayette (2016); Li and Zhang (2013); Pun *et al*. (2007)

GSM - Global System for Mobile Communication, GPRS - General Packet Radio Service, VHFR - Very High-Frequency Radio, EME -Excess Material Exchange

According to Akinade *et al*. (2018), existing CDWM tools such as waste management plan templates and guides, waste data collection and auditing tools, waste quantification tools, and environmental impact assessment tools have several issues. The identified issues associated with the above tools include insufficient and inconsistent data quality and waste reporting for waste management, inability to integrate with the design process and lack of interoperability with other software (Akinade *et al*., 2018). These problems have opened up the doors of opportunities to find solutions through the adoption of emerging spatial, identification, data communication, and acquisition technologies. Jin *et al*. (2019), recognised that more integrated approaches that adopt advanced technologies are useful to improve the C&D waste diversion and management practices. For example, Jin *et al*. (2019), have acknowledged that Big data and BIM are best-suited technologies by their inherent nature in facilitating to store and process a large amount of data that can be integrated to aid in the C&D waste quantification and waste control in overall project management. Therefore, it could be useful to review and understand the potential functions of smart technologies in the C&D sector. As such, the following sections briefly discuss the proposed applications and likely usage of some advanced technologies in different CDWM processes.

4.1 BIG DATA

The implementation of Big data in projects enables the collection of large amounts of exact data (from all data-generating devices or agents like BIM models or people), processes them at unprecedented speed and makes them accessible to all project participants thus saving substantial time and effort (McMalcolm, 2015). The issue of insufficient data quality has been addressed with the use of Big data in a study by Lu *et al*. (2015) in which Big data has been applied to compare the WM performance between the public and private sectors. Furthermore, Chen and Lu (2017) have used Big data analytics to examine the inter-relationships among waste generation and multiple factors such as demolition cost, demolition duration, and public-private nature of a building project by connecting several databases.

4.2 GIS AND GPS

GIS, alternatively, offers great benefits in data acquisition, storage, correlation, processing and analysis (Chen *et al*., 2018). In addition to the function which facilitates estimating the generated demolition waste, GIS can be used as an environmental impact assessment tool. For example, Mastrucci *et al*. (2017) applied GIS to build a bottom-up material stock model which integrates with the Life Cycle Assessment (LCA) to assess the environmental impact at the urban scale and integrates with GPS technology to provide real-time location of the material and its arrival time to the construction site (Li *et al*., 2005). In recent times, Seror and Portnov (2018) employed GIS to identify the dumping sites where C&D waste illegally dumped with potential risk.

4.3 RFID

RFID tags are another data collection technology that can be employed to track and trace construction materials and components, equipment, and tools as well as the construction workforce. RFID can stimulate the reuse of construction components and reduce their wastage (Iacovidou *et al*., 2018, Chen *et al*., 2018). According to Iacovidou *et al*. (2018), integrating RFID with BIM can help to develop sustainable resource management. While Zhang and Atkins (2015) proposed a framework that combines Rule-based Reasoning technology and RFID technology to track, schedule and intelligently handle incidents of waste movement.

4.4 BIM

BIM emerged from two technologies: space technology and data communication technology. It is commonly used in Architecture, Engineering and Construction (AEC) industries and can be effectively integrated with identification and data acquisition technologies such as GIS, RFID, GPS (Chen *et al*. 2018) and Big data (Bilal *et al*., 2015). The integration of these technologies with BIM offers many advantages in terms of facilitating location-based management, tracking of building materials and collecting remote data (Chen *et al*., 2018). BIM has been used in the building design stage to estimate the amount of demolition waste (Kim *et al*., 2017). According to Won and Cheng (2017), BIM offers great potential capacities in design review, 3D coordination, quantity take-off and phase planning for managing waste more efficiently throughout the project life cycle.

Cheng and Ma (2013) developed a BIM-based system for demolition and renovation waste estimation and planning. This developed model poses the capability to deal with the estimates of the detailed volume information of each element category and material type, total inert, and non-inert demolition and renovation waste volumes, demolition and renovation waste-disposal charging fees and the total number of pick-up trucks for demolition and renovation waste. Porwal and Hewage (2012) proposed a BIM-based analysis to minimise the waste rate of the structural reinforcement applicable for a two-storey reinforced concrete structure. Therefore, BIM-based systems/models and integration of other digital technologies with BIM can provide wide solutions to minimise waste generation and optimise materials use.

4.5 BLOCKCHAIN TECHNOLOGY

Blockchain is a decentralised transaction and data management technology (Wang *et al*., 2017). Blockchain technology creates a decentralised environment in which storage, operation, and control of the transactions do not rely on trusted third parties (Yli-Huumo *et al*., 2016) and hence, Blockchain can significantly reduce the transaction overhead (Ølnes *et al*., 2017). Though BIM and Big data can be used as data communication technologies, Blockchain is the only technology where decentralised databases of records allow participants in the network to directly interact via a peer-to-peer network for information sharing and transaction of payments (Turk and Klinc, 2017).

According to Wang *et al*. (2017), Blockchain can improve the records of onsite construction information such as construction logbooks, works performed and quantities of materials used with reliability and trustworthiness of the information recorded. Further, the distributed nature of blockchain and its distinct features including a high level of trust, transparency, immutability, and traceability could help to address the issues related to the quality of historical waste data, reporting, and data management. However, the application of Blockchain in the construction industry, in general, has been limited and lack of studies exploring the role of Blockchain found in the WM stream (Turk and Klinc, 2017). Blockchain can fundamentally change the traditional way of collecting, storing, replicating and tracing waste data at each movement of waste thus enabling the auditing of waste management performance while fulfilling waste-related compliances. As a transaction technology, it can facilitate the trading of C&D waste with improved operational efficiency, trust, and transparency by enabling the waste generators and waste consumers to connect without a trusted intermediary. The authors' ongoing research is aiming to develop a platform using Blockchain technology for C&D waste data management (to capture, report and trace) and trading of waste materials.

Having reviewed the potential features of identified technologies, Figure 1 provides a framework that outlines the possible applications of smart technologies, categorised under major four groups: Spatial, Identification, Data communication & Acquisition, and Data management & Transaction Technology. The framework contributes to the understanding of the potential capacities of each category of technologies in improving the process of WM in the construction sector.

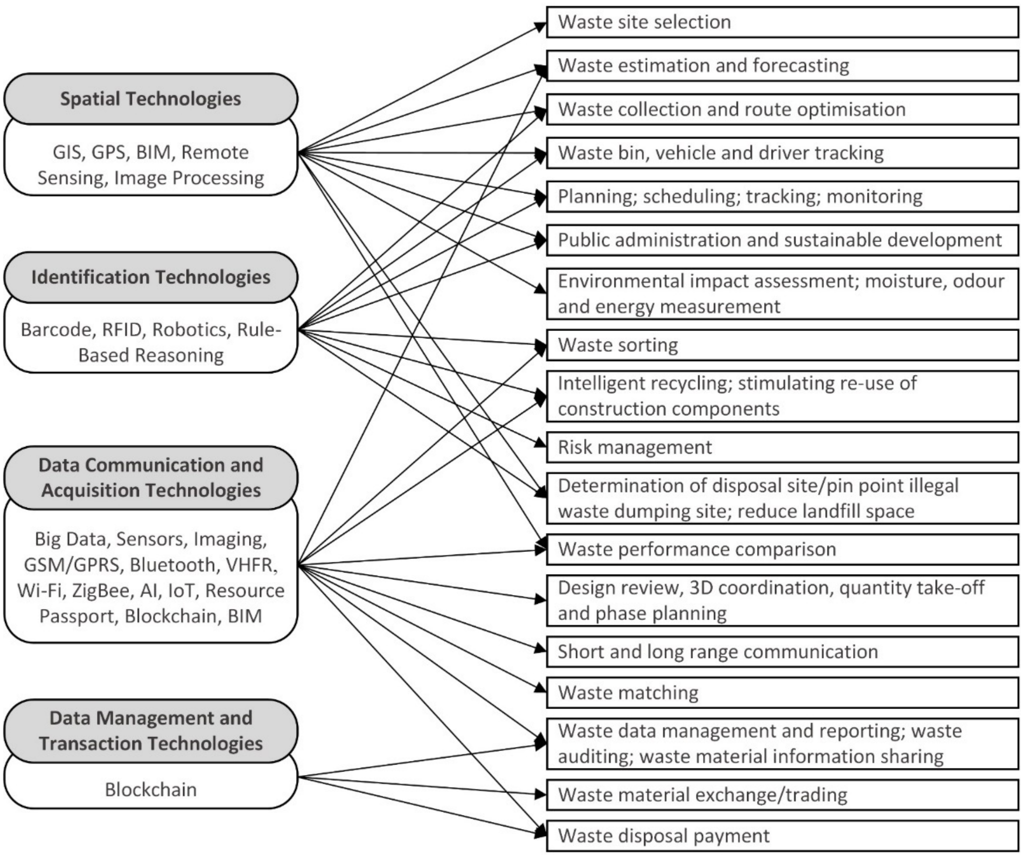

Figure 1: A framework for the potential use of different types of smart technologies in CDWM

This framework is useful to waste management practitioners/businesses, regulatory bodies and the government to understand the benefits of emerging technologies and to the development of effective strategies and future training programmes.

5. CONCLUSIONS

The integration of ICTs in various processes of WM has a positive impact on SWM and substantially contributes to sustainable development in emerging economies with economic benefits. This paper reviewed the current status and potential applications of innovative smart technologies in SWM and CDWM. A good distribution of a wide range of smart technologies and ICTs have been adopted in several processes of SWM while the adoption is still at the prototype stage with limitations in CDWM. However, it has been found that there is a lack of research on the integration of smart technologies to aid the waste data management, waste quantification, auditing and waste diversion in the

C&D sector. The framework which outlined the potential application of technologies contributes to the understanding of how smart technologies could play effective roles in improving waste management processes in the construction sector. More integrated approaches that adopt advanced technologies such as GIS, GPS, Big Data, BIM, RFID, IoT, and Blockchain could help to help to minimise the waste, reduce environmental impact, conserve resources and create new circular business models and global marketing opportunities in the C&D sector. This study also explored the features of Blockchain, as a viable data management and transaction technology which can facilitate waste data management and trading of waste with improved operational efficiency, trust, and transparency while enabling the waste generators and waste consumers to connect without a trusted intermediary. The authors' ongoing research is aiming to develop a C&D waste trading platform using Blockchain technology.

6. REFERENCES

Agarwal, R., Chandrasekaran, S. and Sridhar, M. 2018. Imagining construction's digital future. Available: https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future [Accessed 15/09/2019].

Ajayi, S.O. and Oyedele, L.O., 2017. Policy imperatives for diverting construction waste from landfill: Experts' recommendations for UK policy expansion. *Journal of Cleaner Production,* 147, pp.57-65.

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A. and Arawomo, O.O., 2018. Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. *Journal of Cleaner Production,* 180, pp.375-385.

Arshad, H., Qasim, M., Thaheem, M.J. and Gabriel, H.F., 2017. Quantification of Material Wastage in Construction Industry of Pakistan: An Analytical Relationship between Building Types and Waste Generation. *Journal of Construction in Developing Countries,* 22(2), pp.19-34.

Banias, G., Achillas, C., Vlachokostas, C., Moussiopoulos, N. and Papaioannou, I., 2011. A web-based Decision Support System for the optimal management of construction and demolition waste. *Waste Management,* 31 (12), pp.2497-2502.

Bilal, M., Oyedele, L.O., Qadir, J., Munir, K., Akinade, O.O., Ajayi, S.O., Alaka, H.A. and Owolabi, H.A., 2015. Analysis of critical features and evaluation of BIM software: towards a plug-in for construction waste minimization using big data. *International Journal of Sustainable Building Technology and Urban Development,* 6(4), pp.211-228.

Chen, J., Su, Y., Si, H. and Chen, J., 2018. Managerial Areas of Construction and Demolition Waste: A Scientometric Review. *International Journal of Environmental Research and Public Health,* 15 (2350).

Chen, X. and Lu, W., 2017. Identifying factors influencing demolition waste generation in Hong Kong. *Journal of Cleaner Production,* 141, pp.799-811.

Cheng, J.C.P. and Ma, L.Y.H., 2013. A BIM-based system for demolition and renovation waste estimation and planning. *Waste Management,* 33 (6), pp.1539-1551.

de Magalhães, R.F., Danilevicz, Â.d.M.F. and Saurin, T.A., 2017. Reducing construction waste: A study of urban infrastructure projects. *Waste Management,* 67, pp.265-277.

Ding, Z., Zhu, M., Tam, V.W.Y., Yi, G. and Tran, C.N.N., 2018. A system dynamics-based environmental benefit assessment model of construction waste reduction management at the design and construction stages. *Journal of Cleaner Production,* 176, pp.676-692.

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, pp.611-620.

EME. 2018. Excess Material Exchange: Turn your waste into wealth (White paper). [Accessed 5th March 2019].

Faleschini, F., Zanini, M.A., Hofer, L., Zampieri, P. and Pellegrino, C., 2017. Sustainable management of demolition waste in post-quake recovery processes: The Italian experience. *International Journal of Disaster Risk Reduction,* 24, pp.172-182.

Hannan, M.A., Abdulla Al Mamun, M., Hussain, A., Basri, H. and Begum, R.A., 2015. A review on technologies and their usage in solid waste monitoring and management systems: Issues and challenges. *Waste Management,* 43 (2015), pp.509-523.

Iacovidou, E., Purnell, P. and Lim, M.K., 2018. The use of smart technologies in enabling construction components reuse: A viable method or a problem creating solution? *Journal of Environmental Management,* 216 (2018), pp.214-223.

Jin, R., Yuan, H. and Chen, Q., 2019. Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018. *Resources, Conservation and Recycling,* 140, pp.175-188.

Kaza, S., Yao, L., Bhada-Tata, P. and Woerden, F.V. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050,* Washington World Bank Group.

Kim, Y.C., Hong, W.H., Park, J.W. and Cha, G.W., 2017. An estimation framework for building information modeling (BIM)-based demolition waste by type. *Waste Management & Research,* 35 (12), pp.1285-1295.

Lamichhane, M. 2017. *A Smart Waste Management System using IoT and Blockchain Technology.* PERCCOM Master Program Master, ITMO University.

Li, H., Chen, Z., Yong, L. and Kong, S.C.W., 2005. Application of integrated GPS and GIS technology for reducing construction waste and improving construction efficiency. *Automation in Construction,* 14 (3), pp.323-331.

Li, Y. and Zhang, X., 2013. Web-based construction waste estimation system for building construction projects. *Automation in Construction,* 35, pp.142-156.

Licht, J., de Jong, T., Oudshoorn, K. and Pasotti, P. 2018. Circularise (White Paper). 2.3.

Lu, W., Chen, X., Peng, Y. and Shen, L., 2015. Benchmarking construction waste management performance using big data. *Resources, Conservation and Recycling,* 105, pp.49-58.

Mastrucci, A., Marvuglia, A., Popovici, E., Leopold, U. and Benetto, E., 2017. Geospatial characterization of building material stocks for the life cycle assessment of end-of-life scenarios at the urban scale. *Resources, Conservation and Recycling,* 123, pp.54-66.

McMalcolm, J., 2015. How Big Data is transforming the construction industry. *Construction Global Weekly.*

Melare, A.V.d.S., Gonzalez, M.S., Faceli, K. and Casadei, V., 2017. Technologies and decision support systems to aid solid-waste management: a systematic review. *Waste Management,* 59, pp.567-584.

Oesterreich, T.D. and Teuteberg, F., 2016. Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry,* 83, pp.121-139.

Ølnes, S., Ubacht, J. and Janssen, M., 2017. Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Government Information Quarterly,* 34 (3), pp.355-364.

Porwal, A. and Hewage, K., 2012. Building Information Modelling-based analysis to minimise waste rate of structural reinforcement. *Journal of Construction Engineering and Management,* 138 (8), pp.943-54.

Pun, S.K., Liu, C., Langston, C. and Treloar, G., 2007. Electronic waste exchange for just-in-time building demolition. *The International Journal of Construction Management* 7(2), pp.65-77.

Seror, N. and Portnov, B.A., 2018. Identifying areas under potential risk of illegal construction and demolition waste dumping using GIS tools. *Waste Management,* 75, pp.22-29.

Turk, Ž. and Klinc, R., 2017. Potentials of Blockchain Technology for Construction Management. *Procedia Engineering,* 196, 638-645.

Wang, J., Wu, P., Wang, X. and Shou, W., 2017. The outlook of blockchain technology for construction engineering management. *Frontiers of Engineering Management,* 4 (1), pp.67-75.

Won, J. and Cheng, J.C.P., 2017. Identifying potential opportunities of building information modelling for construction and demolition waste management and minimization. *Automation in Construction,*79, pp.3-18.

Wu, Z., Yu, A.T.W., Shen, L. and Liu, G., 2014. Quantifying construction and demolition waste: An analytical review. *Waste Management,* 34 (9), 1683-1692.

Yli-Huumo, J., Ko, D., Choi, S., Park, S. and Smolander, K., 2016. Where Is Current Research on Blockchain Technology? -A Systematic Review. *PLoS One,* 11(10), e0163477.

Zaman, A.U. and Swapan, M.S.H., 2016. Performance evaluation and benchmarking of global waste management systems. *Resources, Conservation & Recycling,* pp.114, 32-41.

Zhang, L. and Atkins, A.S., 2015. A Decision Support Application in Tracking Construction Waste Using Rule-based Reasoning and RFID Technology. *International Journal of Computational Intelligence Systems,* 8 (1), pp.128-137.

Udawatta, C.S., Devapriya, K.A.K., Gowsiga, M. and Thatshayini, P., 2019. An investigation into value addition concept correlated to facilities management. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 56-65. DOI: doi.org/10.31705/WCS.2019.6. Available at: https://2019.ciobwcs.com/papers

AN INVESTIGATION INTO VALUE ADDITION CONCEPT CORRELATED TO FACILITIES MANAGEMENT

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ABSTRACT

The purpose of this research is to enable Facilities Management (FM) decision makers to identify key FM interventions that add value to the organisations and to manage a successful implementation and to measure the outputs. This study inaugurated with literature review, and then a preliminary survey was carried out to validate the data gathered from the literature review. To inform the findings reported in this paper data was collected through semi structured interviews with expert from different industrial backgrounds. Empirical finding shows that most industrial professions think they should apply the concept of Adding Value in daily practice but there are constraints such as resistance from top management, limitations within the hierarchy, workload factor etc. Many experts identified that identifying a particular added value and the part FM played in is extremely complex and momentarily difficult. And the most acceptable interventions which were identified through interviews are changing the physical environment, changing the facilities services and strategic advice and planning. All the interviewees agreed that they only use Key Performance Indicators (KPIs) to measure the performance of facility related activities.

Keywords: *Added Values; Facilities Management; Interventions; Key Performance Indicators.*

1. INTRODUCTION

Analysing what is 'value' has long been a challenge in research and practice in service industries and as a concept, it has numerous meanings and usages (Anderson and Narus, 1998). In a higher level of generalisation, it outlined as the trade-off among benefits ("what you get") and sacrifices ("what you give") in a market exchange (Zeithaml, 1988). Delivering a superior value requires maximising the benefits and minimizing the sacrifices for customers within their relationship with suppliers (Ulaga and Chacour, 2001). Along with that, nowadays value becoming an important aspect and specifically, in the FM field, value is commonly based on economic rules of thumb. Value is produced when monetary value is added like lesser expenses or higher incomes to client organisation (Jensen, 2005). It can be viewed as the keystone of FM due to its activities are used as inputs into the client's resource-integrating and value creating activities as

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clearly described in the value chain of (Porter and Advantage, 1985) where FM is part of the organisations' infrastructure. Recently, companies have paid more attention on performance measurement and performance is considered as a key competitive matter (Tranfield and Akhlaghi, 1995). There is a wide range of choices available to measure FM performance, reflecting the varied nature of the field. Hronec's (1993) emphasises establishing performance measures as a vital sign of an organisation, showing how well activities within a process or the outputs of a process achieve a specific goal. The structure of the paper begins with a review of literature related to key concepts of the study. Next it presents the method used in achieving the aim of the study and finally it presents the discussion on research findings together with conclusions and the recommendations.

2. LITERATURE REVIEW

2.1 THE FACILITIES MANAGEMENT VALUE MAP

Recently, there has been a growing interest in the value construct and its significance for business success (Woodside *et al.,* 2008). One of the first manifestations of the new focus on added value in FM was the establishment of a Nordic FM work group in 2006 to 'Highlight the added values for the core business provided by FM' (Jensen, *et al*., 2013). Value, to the customer, is benefits received for sacrifices given. Benefits refer to needs and wants and are what the customer seeks to buy, whereas sacrifices have both monetary and non-monetary components (Berry, 2009). Lindhom (2008) defines the added value as the value of the product reduced by the value of the resources used during the process, which leads to added exchange value by reducing cost and increasing efficiency. Furthermore, the FM Value Map can be used in general to provide a better understanding of the value and contributions of FM, for instance by FM organisations in the dialogue with their customers (Jensen, 2010). The generic version of the FM Value Map by Jensen (2010) is shown in Figure 1.

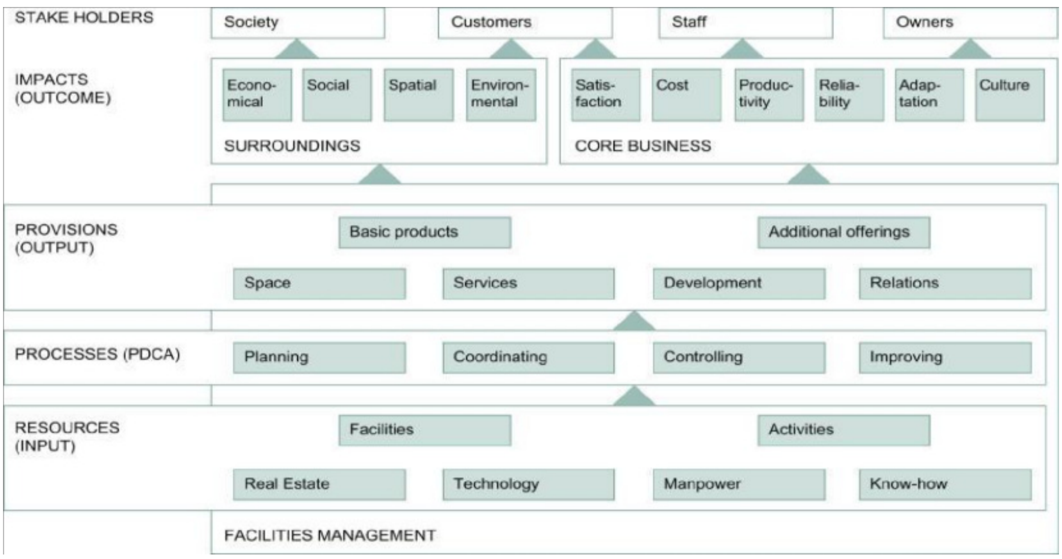

Figure 1: FM Value Map (Source: Jensen, 2010)

This is a conceptual framework to understand and explain the different methods in which FM can produce value to core business and to the surroundings for the benefits of multiple stakeholders together with owners, staff, customers and society. It maps the resources used by FM as inputs into the internal processes to produce outputs like space, services, development and relations, and the impacts the provisions from FM can have on core business in terms of satisfaction, cost, productivity, reliability, adaption, and culture, and on the surroundings in terms of economic, social, spatial and environmental aspects and uses a standard logic model (input-process-output) to specify the possible effects to different stakeholders (Jensen, 2010). Accordingly, the FM value map is for adopting a knowledge management approach, with a knowledge focus foundation, for FM that carefully considers how information can be utilised (gathered, captured, stored, retrieved and applied) to build capability and the knowledge of the individual, to add value to the organisation (Then and McEwan, 2004).

2.2 FACILITIES MANAGEMENT INTERVENTIONS

Coenen *et al*. (2012) developed a typology called "Interventions" or "Decisions on type of change", that can be applied to the FM context. The typology categories FM interventions to six types such as changing the physical environment, changing facilities services, changing the interface with core business, changing the supply chain, changing the internal processes and strategic advice and planning

2.2.1 Changing the Physical Environment

The physical environment is key to FM. It includes buildings, internal and external spaces, technical services (installations), indoor climate, fitting out, furniture, workplaces, technology, artwork and ambience. Typical examples of changing the physical environment include rebuilding, refurbishment or adaptive re-use, changing workplace layout, moving to another location and changing appearance.

2.2.2 Changing Facilities Services

Facilities services are the operational FM activities and few interventions related to the facilities are:

- Changing the maintenance approach from being mostly reactive to being more proactive by focusing on preventive maintenance to improve the facility condition.
- Changing the indoor climate monitoring to improve thermal and air comfort.
- Changing the monitoring and management of energy to reduce energy consumption.
- Changing the gardening of green areas to organic gardening without any use of pesticides to reduce the negative impact on environment
- Changing the workplaces with more flexible furniture to increase ergonomic quality and adaptability to individual work styles.
- Changing the facilities and providing the users with the opportunity to engage in sport and fitness activities in the corporate building
- Changing the monitoring of corporate facilities by installing CCTV surveillance to increase safety and security
- Changing the environmental management to engage the users more in reducing the negative environmental impact in relation to energy and waste.

2.2.3 Changing the Interface with Core Business

FM is normally established as a separate function, when organisations reach a certain size and complexity. The interface between the core business and FM is defined specifically in each organisation and is not static. If the FM function is successful, in many cases it will intensify its area of responsibility. This is often part of a centralization of the responsibility from several parts of the core business organisation to the FM function.

2.2.4 Changing the Supply Chain

In most cases FM is organized as an amalgamation of an in-house FM function and a number of external providers of facility services, which constitute a FM supply chain. Changes in the supply chain are principally changes in the delivery process. However, but they also often have consequences for the incentives for different parties and the management of the mutual relationships between the parties.

2.2.5 Changing the Internal Processes

This is about increasing the efficiency of operational processes within a specific organisation without necessarily changing either the product or the supply chain. The organisation can be in-house or an external FM provider. A lot of concepts aimed at increasing productivity and process efficiency, for instance Total Quality Management, Business Process Re-engineering, Benchmarking and Lean Management within management theory and practice. In such concepts, typical elements are eliminating waste, applying new technological solutions and optimising the workflow.

2.2.6 Strategic Advice and Planning

Strategic advice and planning are indispensable elements in the strategic and tactical activities of FM. The FM taxonomy of Jensen *et al*. (2008), includes some products at a strategic and tactical level, including a number of central functions with sub-products mentioned in parentheses such as sustainability, quality, risk and identity. A typical area of strategic advice from FM to top management relates to the development of a long-term strategy for the corporate property portfolio. This requires a profound and up-to-date understanding of the overall corporate strategy to determine the future demand for property, and close dialogue with the evaluation of options, scenarios and proposals concerning the future supply of property.

2.3 Performance Measurement Models Used in Facilities Management

Various models were developed to measure the performance of organisations, which could include Balanced Scorecard (BSC), Business Excellence Model (BEM), Capability Maturity Model (CMM), KPIs and etc. While these models come from various backgrounds, all of them have achieved significant success for the improvement of organisations' performance (Hamel and Prahalad, 1994). According to Bassioni *et al*., (2005) and Pitt and Tucker (2008) the revolution of performance measurement has spread into many disciplines, including FM. In contrast, Bassioni *et al*. (2005) have matched the application of various performance models and acknowledged a gap among knowledge and practice. Even though performance measurement is fresh to FM, certain researches have emerged in last years for the purpose of individual models in particular areas. For example, Shohet (2006) inspected the key indicators for the performance of maintenance management in healthcare facilities. In the following, four main performance models are introduced and discussed.

2.3.1 Balanced Scorecard (BSC)

Conventional investment evaluation methods focus on financial quantity (Marsh and Flanagan, 2000). Contrasting traditional methods, Kaplan and Norton (2000) introduced the BSC to appraise whether a business is moving towards its strategic goal from four different perspectives such as financial, customer, internal business process, and learning and growth. In latest years the BSC has been slowly acknowledged by FM academics and specialists. For example, (Amaratunga and Baldry, 2000) used BSC to develop a conceptual framework for FM performance measurement in higher education assets. It has its defects like insufficiency of four perspectives while has gradually grownup popularity (Bassioni *et al*., 2005). Due to that, certain BSC models have gone beyond four perspectives.

2.3.2 Business Excellence Model (BEM)

European Foundation of Quality Management developed BEM in 1990 (Conti, 2007), BEM presents a cause-and-effect connection among enablers and results of business processes in an organisation based on nine criteria (Turner, 2008): results such as financial, customer satisfaction, people satisfaction, and impact on society, are achieved through acting on enablers such as leadership, policy and strategy, people management, resources, and processes management. This has progressively grown from the typical total quality management concept (Adebanjo, 2001). Accordance with this concept, several similar types of models were developed in other fields: e.g. Bassioni *et al.* (2005)'s conceptual framework for appraising business performance in construction.

2.3.3 Capability Maturity Model (CMM)

The Software Engineering Institute of Carnegie Mellon University recommended CMM as a software development evaluation standard in 1991 (Chrissis *et al*., 2003). CMM assists to pinpoint best exercises of an organisation which they presently reveal and in which they have to improve. A vital process zone mentions to a collection of linked actions to attain a set of goals that are regarded as important (Punch, 2005). In current years, the continuous representation was also included as one more path of assessment and enhancement. It enables an organisation to progressively improve processes corresponding to an individual process area(s). CMM has been initiated for several other disciplines along with the success in software sector. Compared to the wide acceptance of the BSC, BEM and KPI in construction, there are no explicit signs of the CMM-related models in the findings of Bassioni *et al*. (2005).

2.3.4 Key Performance Indicators (KPIs)

A performance indicator is a measure of performance (Fitz-Gibbon, 1990). KPIs are general indicators of performance that focus on critical aspects of outputs or outcomes (Chan and Chan, 2004). The KPI has been increasingly recognized by different industry sectors as a performance measurement system. Present days, some research works have been built on the KPI model for the FM discipline as an introduction. As sample, developed 11 performance indicators were developed by Shohet (2006) for planned maintenance of healthcare facilities, Hinks and McNay (1999) identified 23 performance indicators for managing various facilities. The usage of KPIs in a FM background can generate abundant benefits. It can assist to focus on managerial works regarding performance and can be used for FM service provider selection, communicating clear picture of required results and how which will be monitored and controlled (Loosemore and Hsin, 2001).

3. RESEARCH METHODOLOGY

The research aims to enable FM decision makers to identify key FM interventions that add value to the organisation and to manage a successful implementation and to measure the outputs through achieving the following objectives of the study. Research approach coordinates research activities and organises the data collection in order to achieve research aims (Thurairajah *et al*., 2006). Qualitative approach was used in this study in order to identify the most feasible performance measurement models applicable to FM. Additionally, actions were taken to develop a list FM interventions and performance measures to extract the interviewers' practices and opinion. The performance measurement and FM interventions were identified through the literature review. Prime data was gathered through the literature survey and then a preliminary interview was done to validate those collected data. Preliminary interviews were conducted with three industry experts who are currently engaged in industry high ranks using semi-structured questions. Table 1 reflects the summary of each interviewee with related to the practice, experience and the awareness of the concepts. the preliminary interview was performed by personal face to face interviews in order to increase the reliability of the data. Data collection was limited with the availability of seven industry experts related to the concept. Content analysis was used to analyse the collected data by using the NVivo 11.0 software. Interviewers' details are illustrated in Table 1.

Table 1: Details of the interviewers

Interviewee	Sector	Designation	Experience
IA	Goods Manufacturing	Premises Manager	> 20 years
IB	FM Service Provider	Senior Facilities Executive	>10 years
IC	Apparel Sector	Senior Manager - Maintenance	07 years

4. RESEARCH FINDINGS AND ANALYSIS

4.1 PERCEPTIONS ON VALUE AND ADDED VALUE

All the respondents believe that value subject in FM should be given more professional consideration. Particularly in the FM field, value is commonly established on economic rules of thumb. Value is formed when financial value is added, i.e. fewer costs and more revenue for the organisation. Since, typically cost is prioritised and the technical approaches of FM, as per the interviewees, the profession still appears to be focused on a counting mind-set. But they all principally agreed that it is important a change of focus should happen from financial value in the direction of a holistic value of FM while formerly shareholder interests were the main perspective of value in the core functions of an organisation. IB believes that the Adding Value concept can be interpreted in large number of ways and associated with great diversity in different areas. He said that prioritizing different sorts of values tend to be extremely subjective and can be differ from organisation to organisation. He insisted that the value in FM rest on who get benefits from that particular added value and who bares the risks. Hence, it is vital to allow for the perceptions and curiosities of various stakeholders: organisation itself, suppliers, shareholders, customers and society. IA stated that to convince the top corporate levels about opportunities for added value, mainly, can be achieved by using strategic analysis and practical examples. IA and IB believes that adding value should mostly be considered at the strategic level, e.g. with the department or regional heads, not at the operational levels which comes under. IA went deeply and identified that FM is currently not a strategic matter in almost all of the organisations, He said top managements is not attentive to look in that way. The perception still going around is that FM is largely considered a tactical concern coming up from the organisational policies and strategies. He firmly believes FM should be a strategic concern that should work out by all the organisations themselves. FM is subject to the circumstances the organisation is going through under. IC mentioned that adding value is often considered at the strategic level with a focus largely on the cost as a value. But he believes that although all the planning and strategic directions have to be formulated at a strategic level (top managerial level), all the implementations should affect from a tactical level. According to IA different people have different perceptions on added value hence should be carefully discussed with people who are thorough in knowledge about added value which means the top-to-bottom approach is necessary when formulating the value adding strategies for a successful implementation. IC had a different spectrum on this. He believes that this concept should be treated similarly in the all levels but in different methods:

1. Strategic level: primarily focuses on long term decisions, avoiding risks, satisfaction of shareholders and customers
2. Tactical level: focuses on budget alignments, satisfaction of employees and strategies to reduce costs.
3. Operational level: this level largely focuses on timely delivery of what is asked of them.

4.2 BENEFITS AND LIMITATIONS OF ADDED VALUE (AV)

As per the interviewees concentrating on added value helps the organisation to focus on the impacts of FM and the expectations of strategic management. As all the interviewees believe speaking strategically is the language that top managements understand. It’s significant to know the values which are important for the organisation and to ask the correct and measurable questions to recognize what the top management really need. He said that in a long-term view more often than not this can be not just simply resolving a current problem, which is the current practice in Sri Lankan FM context. IA said that it makes those who are responsible in making facilities-related decisions focus more on the strategic characteristics of FM and gives space for a more constructive discussion than focusing solely or more on cost. All of the respondents believed that there are definitely limitations, but few downsides compared with benefits. Considering about the limitations, they had different perspectives from each. IA said that added value is perceived differently by each people hence coming to a trade-off would be the major barrier going forward. According to him defining what value adding is proven to be difficult at times. For example, satisfaction can come up as financial satisfaction, customer satisfaction, employee satisfaction. As per him this is a major aspect that hinders the rise of FM in Sri Lankan context. IC mentioned that the main problem is that even though all the aspects with regard to the added value are identified by the top management, there is absolutely no or very less correlation between the departments which are responsible for preserving those added values. For an example in Sri Lankan context there is a myth the all the employee related aspects have to be handled under a Human Resources Department, even though to a certain extend it is true there are measures that comes under the other departments of an organisation which have direct impacts on employee satisfaction. So, without proper coordination a true success cannot be achieved specially because of the Sri Lankan organisation cultures. Another thing he noticed was that the added value is challenging to document. The things related with added value concept mostly cannot be measured immediately, for example in financial terms. Added value largely involves with feelings and subjective perceptions hence this can be subjective to a certain degree and it can be extremely difficult to document.

4.3 FACILITIES MANAGEMENT INTERVENTIONS

As per the interviewees, after classifying the interventions according the findings of the literature review regarding the FM interventions, all were agreeable and all can be categorized into the six factors identified. The results are briefly presented in Figure 2. The most mentioned interventions are changing the physical environment, changing the facilities services and strategic advice and planning. Findings were entered to the NVivo 11.0 software and analysis was done using generated nodes and cognitive maps.

Name	Sources	References
Facilities Management Interventions	0	0
Facilities Management intervention types	3	3
Changing the physical environment	3	3
Changing facilities services	2	2
Strategic advice and planning	2	2
Changing the internal processes	1	1
Changing the interface with core business	1	1
Changing the supply chain	1	1

Figure 2: Coding structure for facility management interventions

4.4 PERFORMANCE MEASUREMENT

Surprisingly all the interviewees agreed that they only use KPIs to measure the performance of facility related activities. IA mentioned that performance measurement is new to FM context in Sri Lanka hence there is a gap between knowledge and actual practice. All agreed that even KPIs are used to set benchmarks for relatively few of the functions coming under their respective departments, largely maintenance and health & safety. As shown in Figure 3 findings were inserted to the NVivo 11.0 software and analysis was done based on the generated nodes and cognitive maps.

Name	Sources	References
Performance Measurement Models	0	0
Performance measurement models in practice	3	3
Key Performance Indicators	3	3

Figure 3: Coding structure for performance measurement models

5. CONCLUSIONS AND RECOMMENDATIONS

At the end of the empirical findings, it is clear that that concept of adding value is emerging in Sri Lankan business context as more people become aware of it, more people tend to seek added value to optimize the processed within their organisations could be identified through in-depth discussions with respondents. The interviews with experts showed that most practitioners think they should apply the concept of Adding Value in daily practice but there are constraints such as resistance from top management, limitations within the hierarchy, workload factor, etc. Many experts identified that identifying a particular added value and the part FM played in is extremely complex and momentarily difficult. And the most acceptable interventions which were identified through interviews are changing the physical environment, changing the facilities services and strategic advice and planning. All the interviewees agreed that they only use KPIs to measure the performance of facility related activities. This suggested value map helps the FM decision makers to where they can improve and work on by proving a framework on value adding management. It enables the decision makers to appropriately consider and implement FM interventions and they can use the identified tools using the PDCA cycle to ensure the value adding management model is a successful one. Also, this enables the FM decision makers to convince the top managements to give a strategic perspective to FM and to convince them to use this as a more strategic-centred profession rather than a cost-centred one. The developed FM value adding framework can use as a step by step process to implement appropriate interventions and add value to the organizations. The introduced tools to support successful implementation of the interventions throughout the PDCA cycle can use by the practitioners as they are easy to work with will give maximum possible outcomes as expected to enhance the organizational performance.

6. REFERENCES

Adebanjo, D., 2001. TQM and business excellence: is there really a conflict?. *Measuring Business Excellence*, *5*(3), pp.37-40.

Amaratunga, D. and Baldry, D., 2000. Assessment of facilities management performance in higher education properties. *Facilities*, 18(7/8), pp.293–301.

Anderson, J.C. and Narus, J.A., 1998. Business marketing: understand what customers value. *Harvard Business Review*, *76*, pp.53-67.

Bassioni, H., 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), pp.495–507.

Berry, L., 2009. Competing with quality service in good times and bad. *Business Horizons*. 52(4), pp.309–317.

Brackertz, N., 2006. Relating physical and service performance in local government community facilities. *Facilities*, 24(7/8), pp.280–291.

Chan, A. P. C. and Chan, A. P. L., 2004. Key performance indicators for measuring construction success, *Benchmarking. An International Journal*, 11(2), pp.203–221.

Chrissis, M.B., Konrad, M. and Shrum, S., 2003. *CMMI guidlines for process integration and product improvement*. Addison-Wesley Longman Publishing Co., Inc.

Coenen, C., Alexander, K., Kok, H. and Jensen, P., 2012. FM as a value network: exploring relationships amongst key FM stakeholders. *The added value of facilities management: concepts, findings and perspectives. Lyngby: Polyteknisk Forlag*.

Conti, T. A., 2007. A history and review of the European Quality Award Model. *The TQM Magazine,* 19(2), pp.112–128.

Fitz-Gibbon, C.T. ed., 1990. *Performance indicators* (Vol. 2). Multilingual Matters.

Hamel, G. and Prahalad, C. K., 1994. *Competing for the Future Harvard Business*. Boston: School Press.

Hinks, J. and McNay, P., 1999. The creation of a management-by-variance tool for facilities management performance assessment. *Facilities*, 17(1/2), pp.31–53.

Hronec, S., 1993. *Vital Signs: Using Quality. Time and Cost Performance Measurements to Chart Your Company's Future.* New York: Amacom.

Jensen , P., Nielsen, K. and Nielsen , S. B., 2008. Facilities Management Best Practice in the Nordic Countries – 36 cases, *Centre for Facilities Management – Realdania Research, DTU Management Engineering: Technical University of Denmark.*

Jensen, P.A., 2005. Value concepts and value based collaboration in building projects. In *Designing Value: New directions in architectural management*. Technical University of Denmark (DTU).

Jensen, P., 2010. The Facilities Management Value Map: a conceptual framework. *Facilities*, 28(3/4), pp.175–188.

Jensen, P.A., Sarasoja, A.L., Van der Voordt, D.J.M. and Coenen, C., 2013. How can facilities management add value to organisations as well as to society?. In *Proceedings of the 19th CIB World Building Congress 2013 "Construction and Society", Brisbane, Australia, 5-9 May 2013*. International Council for Building (CIB).

Kaplan, R. and Norton, D., 2000. Having trouble with your strategy? Then map it. *Focusing Your Organization on Strategy—with the Balanced Scorecard, 49.*

Lindholm, A., 2008. *Identifying and measuring the success of corporate real estate management*. Teknillinen korkeakoulu.

Loosemore, M. and Hsin, Y. Y., 2001. Customer-focused benchmarking for facilities management. *Facilities*, 19(13/14), pp.464–476.

Marsh, L. and Flanagan, R., 2000. Measuring the costs and benefits of information technology in construction. *Engineering Construction and Architectural Management*, 7(4), pp.423–435.

Pitt, M. and Tucker, M., 2008. Performance measurement in facilities management: driving innovation?. *Property Management*, 26(4), pp.241–254.

Porter, M. and Advantage, C., 1985. *Creating and Sustaining Superior Performance.* New York: Free press.

Punch, K. F., 2005. *Introduction to social research: Quantitative and qualitative approach*. 2nd ed. SAGE Publications.

Shohet, I., 2006. Key performance indicators for strategic healthcare facilities maintenance. *Journal of Construction Engineering and Management*, 132(4), pp.345–352.

Then, D.S.S. and McEwan, A., 2004. Capturing knowledge from facilities management practices–Issues and Possibilities. *Facilities Management and Maintenance*, pp.251-263.

Thurairajah, N., Haigh, R. and Amaratunga, D., 2006. Leadership in construction partnering projects: Research methodological perspective., In *ARCOM Doctoral Workshop on Public Private Partnerships/Private Finance Initiatives (PPP/PFI), Glasgow Caledonian University, UK.*

Tranfield, D. and Akhlaghi, F., 1995. Performance measures: relating facilities to business indicators. *Facilities*, 13(3), pp.6–14.

Ulaga, W. and Chacour, S., 2001. Measuring customer-perceived value in business markets: a prerequisite for marketing strategy development and implementation. *Industrial Marketing Management,* 30(6), pp.525–540.

Woodside, A., Golfette, F. and Gibbert, M., 2008. *Creating and managing superior customer value*. Emerald Group Publishing.

Zeithaml, V.A., 1988. Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. *Journal of Marketing*, *52*(3), pp.2-22.

Misbah, A.S.M., Disaratna, V., Ganeshu, P. and Nazeer, F.S., 2019. Analysis of survival factors of subcontractors in economic recession. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 66 -76. DOI: doi.org/10.31705/WCS.2019.7. Available at: https://2019.ciobwcs.com/papers

ANALYSIS OF SURVIVAL FACTORS OF SUBCONTRACTORS IN ECONOMIC RECESSION

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ABSTRACT

Subcontracting is a term which means giving a portion of the work or obligations to another party called as subcontractor (SC) under a contract. This was used in several industries but in the construction industry, it plays a vital role to complete the project with a higher quality of output. In gross domestic product (GDP) calculation of the national economy, the significance of the construction industry is very high. When a country faces an economic recession, it has a direct impact on the construction industry and the stakeholders of that industry. A small number of researches was available regarding how the construction firms handle the external changes like economic recession. In this respect, this research analyses the key strategies used by the SCs when they face an economic recession. Purposive sampling method was used for data collection and a questionnaire survey was selected as the basic technique to collect data. The respondents were first asked about their profile and then about the effect of recession and survival strategies in economic recession. Relative Importance Index (RII) method was used to rank the effects and the strategies according to its importance given by the respondents. Findings of the research were that there are various strategies which are most important to the survival of subcontracting firms "Increasing the focus on forming relationship with main contractors", "maintain goodwill to get additional financial support from bank", "Implementing stricter site management to reduce material and time wastage", "Implementing stricter financial management on company cash flow", and "bidding for more projects that are within the firm's resources and capabilities". Finally, practicable suggestions were identified for SCs to survive in the construction industry during the economic recession period.

***Keywords**: Economic Recession; Key Strategies; Subcontractors (SC); Survival Factors.*

1. INTRODUCTION

The most changing and challenging industry is the construction industry facing more risk and uncertainty compared to other industries. Furthermore, according to Thevendran and Mawdesley (2004) construction industry has risks and obviously, it is felt in construction projects. According to Poh and Tah (2006), various types of risks are experienced by the construction projects regularly and moreover, Kangari (1995) stated that it affects the productivity, performance, quality, and budget of a construction project. However, risks are inevitable (Zou *et al*., 2007). As reported by Kangari (1995) risk can be minimized or

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transferred from one stakeholder to other stakeholders in the construction process. Thus, to manage all types of risks there should be a risk management process in construction projects (El-Sayegh, 2008).

According to Baynes (2008), Gross Domestic Product (GDP), which is the market value of all final goods and services produced within an economy at a given period of time, is considered the broadest indicator of economic output. The construction industry contributes more than 6.4% to the GDP in Sir Lanka (Central Bank of Sri Lanka, 2008). People involved in the construction project are owners, designers, construction main contractors (MC), subcontractors (SC), maintenance contractors, and material suppliers, etc. (Moore *et al*., 1992). Nature of the modern construction technology, size and scale are moving towards more specific and complex. Therefore, the MC is willing to subcontract the work due to their lack of skill and knowledge and resources (Chamara, 2011). Subcontracting is defined as the arranging and applying of the tasks that differ from the main activity of the contractor, supply materials, equipment, and manpower are few tasks of SC's (Gonzalez-Diaz *et al*., 2000). Piyasoma (1994) had found that more than 80% of specialized works were done by the SCs in Sri Lanka.

Therefore, subcontractors are very important to consider in the Sri Lankan economy. Sub-contractor's survival in an economic recession is very important to the construction industry. There was no existing study focus on the surviving strategy of subcontractors in the economic recession. This study focuses on this gap. This paper initially provides a comprehensive literature review in order to identify the strategies taken by the SCs to survive in economic recession times. Then the findings of the questionnaire surveys are presented and further subjected to a discussion. Finally, conclusions are drawn from the findings.

2. IMPORTANCE OF THE CONSTRUCTION INDUSTRY

A country has several sectors that contribute to the economy and depending on the resources distribution; these sectors might change from country to country. The construction sector can be identified as a contributor to the economy in almost every country in the world. Gross Domestic Product (GDP) of a country is considered one of the most successful macro-economic indicators. By determining the contribution of every sector to the GDP we can understand its contribution to the economy.

2.1 DEFINITION FOR SUBCONTRACTOR

Most of the construction projects undertaken are more complex in nature, demanding greater skill and technologies, fast track and concurrent works practices. Further, they are very competitive in terms of price, demanding end product quality and good decision-making skills, capabilities in utilizing knowledge management and very critical in dealing with contractual issues than ever before (Manoharan, 2005). As a result, it requires many specialist consultants and contractors to be employed in projects. In a situation like this, a single main contractor cannot possibly handle all related project tasks. As Manoharan (2005) further mentioned the client awarded the works to the contractor, and then the contractor will have engaged a few companies called "SC" to carry out the works according to the work assigned. It has created a circumstance for SCs to involve in construction projects. Arditi and Chotibhongs (2005) indicated that SC is a construction firm that contracts with the main contractor to perform some aspects or special aspects of the main contractor's work. Unlike main contractors, an SC is an individual or in many cases a business that signs a contract to perform a special part or all of the obligations of another's contract. SC can also sublet the projects within other contractors.

2.2 RISK IN CONSTRUCTION INDUSTRY

Construction projects have more inherent risks due to the involvement of many contracting parties such as owners, designers, contractors, SCs, suppliers, etc. Construction projects are unique and built only once. It also involves a temporary project team that is assembled from different companies, countries, cultures, etc. Moreover, the size and complexity of construction projects are increasing which adds to the risks.

Risks may come from various sources in the construction project which is always unique (Oyegoke, 2006). Construction industries do always have more and more Risks and uncertainties when compared to other industries. It has the complex and time-consuming process of planning, executing and maintaining. Many main contractors are forced to rely heavily on subcontracting to minimize their risks due to the unpredictable workloads and a need for a multitude of specialized skills Beardsworth *et al*. (1988). According to Richter and Mitchell (1982) subcontracting the work to those who have the necessary resources to perform the work done efficiently and economically does help the main contractors in obtaining a higher profit margin by reducing their workload.

2.3 DEMAND FOR SUBCONTRACTOR'S WORK

SCs practice an important segment of the construction industry work in the current construction market. Main contractors are provided with the chance of minimizing the required resources, with the help of SCs, and they are provided with specialized expertise in construction projects. This makes the main contractors to rely on SCs to carry out the construction work, and it helps to increase the demand for subcontracting organizations (Mbachu, 2008). As per Hartmann and Caerteling (2010) in the Netherlands context up to 90% of the total value of a construction project, SCs supply labor, and material facility. The performance of the SCs determines the ability of the main contractor and consultants to deliver the project within time, quality and cost targets. Further, Mbachu (2008) explained expectable reasons for subcontracting as below.

- Expected high quality of works, since SCs are seen as 'specialists' in their own fields
- The main contractor's margin and costs are known from the commencement of the contract through the SCs' quotations
- The main contractor passes on the risks and responsibilities of redeployment, hiring and firing of subcontracting workers on to the SCs
- Cash flow problems and the challenge of financing the project are all eased by the use of SCs
- The main contractor's overheads commitment in the form of supervision, office staff, accommodation, etc., can be reduced significantly when working with reliable SCs

2.4 STRATEGIES TAKEN BY SUBCONTRACTORS TO SURVIVE DURING RECESSION

For the survival of economic downtrend, construction firms can be able to use various kinds of schemes to help them.

- Financial capital

There are some situations that indicates the importance of having own finance. Having finance for paying to the material in advance, manpower, and tools sent to the building site (Palaneeswaran *et al*., 2009). The payment period is much shorter than their regaining period. Especially the wages of workers are paid within 30 days (Arditi *et al*., 2000). In conclusion, the extra financial costs, additional financial support is needed by the subcontractors (Arditi and Chotibhongs, 2005).

- Demand

From the demand side, there is a clear downward pressure on costs in a crisis scenario. In the long run, there is no sustainability in the downstroke of the price. Selling products at lower costs will cause a difficult situation in more professionalized companies (Schleifer, 1990), with or without knowing. This can be broken to get the mutual interest of parties because the client always wants the cheapest.

- Geographic scope

The subcontractors performing best according to their geographical scope even in the crisis scenario. Internationalization is the word mostly pronounced in trend. Generally, a consideration to extending the scope has been taken by the stakeholders such as developers, engineers, subcontractors and suppliers (Martin and Gonzalez, 2010). The scope of the local companies extended along with the whole country and the larger ones have become international (Schleifer, 1990).

- Managerial assets

The systematic management process is not followed by the subcontractors usually in their construction sites. Furthermore, the main competitive advantages in business management is the flexibility which is deliberated by the subcontractors. These actions are practicable because SCs are smaller in business with an organization and the powers are centralized with the owner or CEO (Arditi *et al*., 2000).

- Relationship assets

There are main factors to get a project which are, the establishment of the relationships of trust in the part of the subcontractor's corporate image (Kumaraswamy and Mathews, 2000), and relationship with the main contractor in past projects (Palaneeswaran *et al*., 2009). In the project-delivery-method category it is partly contrary that when awarding subcontract, the price is the key factor (Ling *et al*., 2010). Therefore, to bid a contract and qualify, these "trusting relationships" can be considered as a qualification.

3. RESEARCH METHOD

The research initiated with a literature synthesis to identify the strategies taken by SCs during economic recession times. The research approach for this study was mainly a quantitative approach. The selection of the research approach for this study was justified through the following reasons such as the research is to identify and establish a generalized opinion of a society, in an objective manner without any in-depth investigation; a large number of possible respondents and the research question which attempts to identify "What are the factors that help to survive the subcontractors in recession?". By considering the circumstances of this particular research, especially neediness of the identification and perceptions of construction industry practitioners about the survival factors among subcontract parties, a questionnaire survey was selected as the basic technique to collect data and convenience non-probability sampling was used as a method of sampling.

Data obtained through the detailed questionnaire survey was analyzed using the Relative Importance Index (RII). RII is identified as a data analysis technique used to rank the factors and identify the most significant factors by many researchers (El-Sayeh, 2008). Furthermore, the selection of RII is justified as this study intends to rank the survival factors.

4. DATA ANALYSIS AND FINDINGS

During the data collection stage, a purposive sampling technique was used as this study need to focus on special groups such as subcontracting firms and few main contracting firms. The questionnaires were filled by thirty-eight responders. There were a total of thirty-one strategies identified to analyze in the questionnaire and those strategies were categorized as per project size, forward agreements with suppliers and SCs, bid margin strategies, specialization, relationship, marketing, and new work sources, diversification, cost reduction, employment, financial resources and fulfillment with training.

4.1 PROJECT SIZE

The first three strategies of the questionnaire asked for responses to project size. Of those strategies, fifteen respondents filled "Bidding for more projects that are within the firm's resources and capabilities" as very important and most important and seventeen respondents filled as important. As shown in Table 1, the mean of the strategy was 3.29 and RII was 65.79%. The respondents described that their "strike rate", the secured project which had relation with their priced was reduced dramatically during the economic recession period. Because of that, they thought this strategy was important.

Table 1: Results for project size strategies

Strategy	Mean	RII (%)
Bidding for more projects that are within the firm's resources and capabilities	3.29	65.79
Targeting smaller than usual contracts.	2.66	53.16
Setting limits on project size so that any failure of one project would not harm the firm's operation.	2.39	47.89

4.2 FORWARD AGREEMENTS WITH SUPPLIERS AND SCS

In this category, the fourth strategy of the questionnaire was asked to fill from the respondents who were "Entering into forward contracts with suppliers and subcontractors to protect the firm against cost escalation". This strategy had a mean rating of 2.82 and the RII of 56.38%. eleven respondents had identified this strategy as not important or slightly important because most SC's works are tendered and it makes difficult to predict their upcoming resource requirements. But nine respondents identified this as very important or most important (refer Table 2).

Table 2: Results for forward agreements with suppliers and SCs strategies

Strategy	Mean	RII (%)
Entering forward contracts with suppliers and subcontractors to protect the firm against cost escalation	2.82	56.38

4.3 SPECIALISATION

In this category, the seventh and eighth strategies of the questionnaire were asked to fill from the respondents which were regarding fast track projects and specializing in expertise. Those strategies had a mean rating with 2.79, 3.21 and with RII of 55.79, 64.29 respectively (refer Table 3). Furthermore, twelve respondents replied as very important or most important and ten respondents replied as important to the short term and fast track project strategy. Moreover, thirty-four respondents replied as important or very important.

Per a few respondent's views, if an SC specialized in a specified work when the MC could have the work, MC can be picking up those specialized SCs to the projects the SC specialized in.

Table 3: Results for specialization strategies

Strategy	Mean	RII (%)
Undertaking short-term and fast track projects	2.79	55.79
Specializing in a particular expertise	3.21	64.29

4.4 RELATIONSHIP

In this category, from ninth to fourteenth strategies asked for response from respondents which had a relationship with both other SCs and clients of SCs. Table 4 shows the mean rating of each relationship strategy and the RII of each relationship strategy.

Table 4: Results for relationship strategies

Strategy	Mean	RII (%)
Subcontracting work from other SCs	1.79	35.79
Acquiring projects from defunct companies	1.39	27.89
Forming joint ventures with other SCs	2.24	44.74
Forming partnership with MC	2.84	56.84
Forming partnership with construction clients	3.05	61.05
Increasing the focus on forming relationships with MC	3.84	76.84

"Forming partnership with main contractor" had a mean rating of 2.84 and with the RII of 56.84. Ten respondents identified this strategy as not important or slightly important and ten respondents identified as very important or most important. So, the respondents had mixed feelings for this strategy. Some respondents mentioned that this strategy was good for SCs to secure the works before pricing and both parties, MC and SC will feel better by working together as they wanted out of the partnership.

Dainty *et al*. (2001) mentioned that, on supply chain alliances between SC and MC, the response from SCs was that MC's didn't fully comprehend the idea of partnering and the reasons MCs undertook the practice was for their own good only. In this respect, few respondents said, the MCs may accept the lowest price or try to make partnership to their advantage at the expense of the SC.

The fourteenth strategy of the questionnaire "Increasing the focus on forming relationships with MCs" had the highest mean rating and the RII of 3.84, 76.84 respectively. Most of the respondents rated this strategy as either very important or most important in the scale of the questionnaire. The respondents mentioned in order to ensure the survival of SC's business', they should maintain a good relationship with others. This relationship will give the information about the new work and if once established the relationship with MC, they know each other's business works and they work better together with fewer problems regarding money or payments.

4.5 Marketing and New Work Sources

The fifteenth and sixteenth strategy of the questionnaire asked for responses which were "increasing time/ expenditure on marketing" and "Trying to break into new sources of work" (refer Table 5).

Table 5: Results for marketing and new work sources strategies

Strategy	Mean	RII (%)
Increasing time/ expenditure on marketing	2.84	56.84
Trying to break into new sources of work	2.74	54.74

The "increasing time/ expenditure on marketing" had a mean of 2.84 and the RII was 56.84. The respondents stated that during the recession period SCs will increase their time and expenditure on marketing like giving radio advertisements. It will be very effective to increase their brand awareness in the business market. However, this marketing strategy was not rated as great. Because most of the respondent's points of view, the money spent on marketing their business would be better to spend on strengthening their relationships.

The remaining strategy in this category, "Trying to break into new sources of work" had a mean rating of 2.74 and the RII was 54.74. This strategy had a low mean rating because when considering this strategy, the SCs can lowering their price to a large amount of work to break into new sources of work to work under another MC. If they did as like that they could win. However, that MC already dominated by strong relationship with their own SC who is completely competitor to the new SC, even though the new SC had a chance to win, the works would be given to their opposition or MC's own SC.

4.6 Cost Reduction

In this category, the twentieth and twenty-first strategies of the questionnaire were asked to fill from the respondents (refer Table 6).

Both the strategies in this category had a relatively high mean rating and RII. "Implementing stricter site management to reduce material and time wastage" had a mean rating of 3.53 and the RII of 70.53 which was third higher rank. Most of the respondents said that their companies always try to achieve this strategy. During the recession period without implementing stricter site management to reduce the wastages will harm the firm's operation and it should become a more pressing issue. No matter how much work is on for a day but the firm should control day to day work themselves.

Table 6: Results for cost reduction strategies

Strategy	Mean	RII (%)
Implementing stricter site management to reduce material and time wastage	3.53	70.53
Implementing stricter financial management on company cash flow	3.42	68.42

When it came to "Implementing stricter financial management on company cash flow" it had a fourth higher ranking of mean rating and RII of 3.42, 68.42 respectively. As per some respondent's point of view, the SCs should change their rules related to purchasing and the subcontracting firms should allow only senior staff to purchase goods for a certain value or the proper approval should be made before purchasing goods by anyone. Lack of controlling financial aspects causes the construction firm's failure (Mutti and Hughes, 2002).

4.7 Financial Resources

In this category, the twenty-ninth and thirty-first strategy of the questionnaire were analyzed.

As shown in Table 7, "maintain goodwill to get additional financial support from banks" had the second-highest mean rating and RII of 3.61, 72.11 respectively. More than thirty respondents responded as very important or most important to this strategy.

Table 7: Results for financial resources strategies

Strategy	Mean	RII (%)
Find a minor financial consulting firm to do financial management and accounting services as outsourcing	2.47	49.47
Maintain goodwill to get additional financial support from banks	3.61	72.11

As per most of the respondent's point of view, maintaining good behaviour and reliable transactions are not only helping to get additional financial supports from banks, it is important to increase the customer base and to retain their old clients and new opportunities will be formed if the firm has longstanding business goodwill. Furthermore, if the firm's representative made any trouble, the MC or client was giving forgiveness because of their trust through SC's previous experience.

4.8 Fulfilment with Training

In this category, the remaining strategy was discussed which was "get adequate skilled persons with appropriate training". This strategy had a mean of 2.82 and the RII was 56.32 as shown in Table 8.

Table 8: Results for fulfillment with training strategies

Strategy	Mean	RII (%)
Get adequate skilled persons with appropriate training	2.82	56.32

This strategy was a bit important because some respondents said that business improvement is made by the training and it helps to increase the profit and staff morale. But few respondents said that it may be difficult to find skilled persons because their existing firm will not lose them. Nevertheless, the firm should give additional allowances to get them from their existing firm.

4.9 IMPORTANT SURVIVAL STRATEGIES

As per the RII analysis, the following strategies (refer Table 9) are filtered as important strategies for SC to survive during economic recession times.

Table 9: Filtered strategies

Nr.	Strategy	RII	Ranking
01	Increasing the focus on forming relationships with main contractors	76.84	01
02	Maintain goodwill to get additional financial support from banks	72.11	02
03	Implementing stricter site management to reduce material and time wastage	70.53	03
04	Implementing stricter financial management on company cash flow	68.42	04
05	Bidding for more projects that are within the firm's resources and capabilities	65.79	05
06	Specializing in a particular expertise	64.29	06
07	Forming partnership with construction clients	61.05	07
08	Increasing time/ expenditure on marketing	56.84	08
09	Forming partnerships with main contractor	56.84	08
10	Entering into forward contracts with suppliers and subcontractors to protect the firm against cost escalation	56.32	10
11	Get adequate skilled persons with appropriate training	56.32	10
12	Undertaking short-term and fast track projects	55.79	12
13	Trying to break into new sources of work	54.74	13
14	Targeting smaller than usual contracts	53.16	14
15	Employing on contract basis	50.53	15

The above strategies can be used as strategies to survive while economic recession. All of them can be implemented practically in the current construction industry without any limitations. As these have easy implementation features all kin of subcontractors can follow these without any hesitation.

5. CONCLUSIONS

The economic recession of the country is one of the major risks to the construction industry and it has a direct effect on the construction industry as exposed in the literature review. To survive from that risk, construction firms should handle alterations and strategies. There is no research found on the analysis of survival factors during the recession period for the construction firms in the Sri Lankan construction industry.

Therefore, this research focused on subcontracting firms due to the wideness of the area. The study was fulfilled with the questionnaire which was to identify the strategies that can be taken by the Subcontractors to survive during the recession period. All of these findings are practicable and very easy to implement. All kinds of subcontractors with different grades also can be implemented these things. Increasing the focus on forming relationships with main contractors, maintaining goodwill to get additional financial support from banks, implementing stricter site management to reduce material and time wastage are the most important strategies to follow in the economic recession.

6. REFERENCE

Arditi, D., and Chotibhongs, R., 2005. Issues in subcontracting practices. *Journal of Construction Engineering and Management, 131*(8), pp.866-876.

Arditi, D., Koksal, A., and Kale, S., 2000. Business failures in the construction industry. *Engineering Construction and Architectural Management, 7*(2), pp.120-132.

Baynes, R., 2008. *Economic indicators: Gross Domestic Product (GDP)* [online]. http://www.investopedia.com/contributors [Accessed 03 March 2019].

Beardsworth, A., Keil, E., Bresnen, M., and Bryman, A., 1988. Management transience and subcontracting: The case of the construction site. *Journal of Management Studies, 25*(6), pp.603-625.

Central Bank of Sri Lanka., 2008. *Annual Report.* Central Bank of Sri Lanka.

Chamara., 2011. *Evaluating subcontractor's approach in construction project.* Thesis (B.Sc). University of Moratuwa.

Dainty, A.R., Briscoe, G.H., and Millett, S.J., 2001. Subcontractor perspectives on supply chain alliances. *Construction Management and Economics*, *19*(8), pp.841-848.

El-Sayegh, S., 2008. Risk assesment and allocation in the UAE construction industry. *International Journal of Project Management, 26*(4), pp.431-438.

Gonzalez-Diaz, M., Arrunada, B., and Fernandez, A., 2000. Causes of subcontracting: Evidence from panel data on construction firm. *Journal of Economic Behavior & Organization*, pp.167-187.

Hartmann, A., and Caerteling, J., 2010. Subcontractor procurement in construction: The interplay of price and trust. *Supply Chain Management: An International Journal, 15*(5), pp.354-362.

Iqbal, A., and Vitner, M., 2011. The deeper the recession, the stronger the recovery: Is it really that simple? *Bus Econ, 46*(1), pp.22-31.

Kangari, R., 1995. Risk Management Perceptions and Trends of U.S. Construction. *Journal of Construction Engineering and Management, 121*(4), pp.422-429.

Kumaraswamy, M., and Mathews, J., 2000. Improved subcontractor selection employing partnering principles. *Journal of Management in Engineering, 16*(3), pp.47-57.

Teck Heng Lim, B., Lan Oo, B., and Ling, F., 2010. The survival strategies of Singapore contractors in prolonged recession. *Engineering, Construction and Architectural Management*, *17*(4), pp.387-403.

Manoharan, R., 2005. *Subcontractor selection method using analytic hierachy process.* Thesis (M.Sc), Universiti Teknologi, Malaysia.

Martin, R., and Gonzalez, J., 2010. The strategic repositioning of Spanish construction companies. *Construction Reports, 62*(520), pp.67-84.

Mbachu, J., 2008. Conceptual framework for the assessment of subcontractors' eligibility and performance in the construction industry. *Construction Management and Economics, 26*(5), pp.471-484.

Moore, C., Mosley, D., and Slagle, M., 1992. Partnering guidelines for win-win project management. *Project Management Journal, 22* (1), pp.18-21.

Mutti, N., and Hughes, W., 2002. Cash flow management in construction firms. In: Greenwood, D. (ed.). 18th annual ARCOM conference. Northumbria: Association of Researchers in Construction Management, pp.23-32.

Oyegoke, A., 2006. Construction industry overview in the UK, US, Japan and Finland: A comparative analysis. *Journal of Construction Research, 7*(1&2), pp.13-31.

Palaneeswaran, E., Tang, Z., and Thomas , N., 2009. Factors contributing to the success of equipment-intensive subcontractors in construction. *International Journal of Project Management, 27*(7), pp.736-744.

Piyasoma, W., 1994. *Interaction between main contractor and subcontractor in construction project.* Thesis (B.Sc), University of Moratuwa.

Poh, Y., and Tah, J., 2006. Integrated duration–cost influence network for modelling risk impacts on construction tasks. *Construction Management and Economics,, 24*(8), pp.861-868.

Richter, I., and Mitchell, R., 1982. *Handbook of construction law and claims.* Reston, Virginia: Reston Pub. Co.

Schleifer, T., 1990. *Construction contractors' survival guide.* New York: Wiley.

Thevendran, V., and Mawdesley, M., 2004. Perception of human risk factors in construction projects: An exploratory study. *International Journal of Project Management, 22*(2), pp.131-137.

Zou, P., Zhang, G., and Wang, J., 2007. Understanding the key risks in construction projects in China. *International Journal of Project Mangement, 25*(6), pp.601-614.

Bandara, K.T.W., Abeynayake, M.D.T.E. and Pandithawatta, T.P.W.S.I., 2019. Applicability of smart building concept to enhance sustainable building practice in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 77-87. DOI: doi.org/10.31705/WCS.2019.8. Available at: https://2019.ciobwcs.com/papers

APPLICABILITY OF SMART BUILDING CONCEPT TO ENHANCE SUSTAINABLE BUILDING PRACTICE IN SRI LANKA

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ABSTRACT

With the expansion of economic activities, sustainable development in construction industry got more attention worldwide. Hence, industry practitioners are more concerned on achieving sustainable construction goals to make more effective and efficient services. The Smart Building concept can be implemented with advanced building technologies to achieve clients' requirements with in the economic, environmental and social parameters while enhancing building performances efficiently. To explore the applicability of Smart Building concept to enhance sustainable building practices in Sri Lanka, the qualitative research approach was used in this research. The opinions of the smart and sustainable construction experts were obtained through semi-structured interviews. Smart Building concept is novel to the Sri Lankan construction industry and the implementation is still in the initial stage. However, the perception of the construction industry on the Smart Building concept is focused on a strong and positive direction. The recognised sustainable benefits of Smart Building concept implementation can be used as a promoting tool to make interest on Smart Buildings. Most of these benefits are long term and most of the clients do not recognise the value of Smart Buildings in terms of sustainability. Therefore, improving the knowledge and awareness of the developers is vital during the implementation process within the local context. Lack of financial resources, complex technology requirement, reluctant to commence new technologies and lack of knowledge of developers and owners are the main barriers that are existing within the local context. Mitigating these barriers will expedite the implementation process of Smart Building concept and will upgrade the performance of the local construction industry dramatically.

Keywords: *Applicability; Smart Buildings; Sustainable Development.*

1. INTRODUCTION

In the building sector, achieving sustainability is a key challenge due to its unlimited resource consumption (Kumara *et al*., 2016). Having sustainable construction goals is important to achieve economic, social and environmental parameters of the sustainable development (Adetunji *et al*., 2003). Instead of using a balanced approach of environmental, economic and social sustainable features, most of the stakeholders are concerned only on economic parameter. This has happened mainly because of the wide gap of awareness and knowledge on sustainable building practices (Shari and Soebarto,

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2013). Developing smart solutions for sustainability has been enhanced through the maximum efficiency in urban systems with the quality living standards (Elias and Krogstie, 2017). Smart Buildings (SB) integrate intelligence, enterprise, control, materials and construction to the entire building system, to achieve building progression, energy efficiency, comfort and satisfaction (Buckman *et al*., 2014).

The concept of smart receives a great amount of worldwide attention for solving sustainability issues (Ghaffarianhoseini *et al*., 2013). A SB is one that is responsive to the requirements of occupants, different organisations and the society. It is sustainable in terms of energy and water consumptions besides being lowly polluting in terms of emissions and waste: healthy in terms of well-being for the people within it; and functional according to the occupants' needs (Clements-Croome, 2009). Thereby smart solutions are much promoted worldwide for sustainability issue, makes use of interconnected technologies which generates a high level of occupant's comfort (Ghaffarianhoseini *et al*., 2013). However, SB concept is still novel to the Sri Lankan context and the practice is still in the primary stage. Therefore, Sri Lankan buildings are not in a stage to fully acquire the sustainable features delivered by the SBs (Shabha, 2006). Since, the adaptation of SB concept brings the occupant's satisfaction and effective performance of buildings in a sustainable way it is a timely need to carry out a study in Sri Lanka to explore the applicability of SB concept to enhance sustainable building practices.

2. LITERATURE FINDINGS

2.1 CONCEPT OF SUSTAINABILITY

The concept of sustainability increases the demand for sustainable construction which will bring benefits from the environment, economic and social factors (Pitt *et al*., 2009). However, various definitions of 'sustainable construction' clearly explains the responsibilities that the construction industry should be undertaken to achieve sustainability (Zhou and Lowe, 2003). Further, the three pillars of sustainability mainly connected with the selections made in the design stage and with the building and outdoor living space construction. These pillars are reflecting the responsible development of natural, human, and economic capital towards balancing the planet, people, and profits (Kajikawa, 2008; Schoolman *et al*., 2012).

Construction can be considered as a major sector which create a greater impact on the country's economy and at the same time, it also creates a massive impact on the natural resources (Pitt *et al*., 2009). Sfakianaki (2015) identified the construction industry as one of the largest end users of environmental resources and a polluter of the environment. Miyatake (1996), proposed 6 principles to provide a comprehensive perspective to the sustainable construction. They are resource consumption minimization, maximization of resource reuse, use renewable and recyclable resources, natural environment protection, healthy and non-toxic environment creation and pursuit of the quality build environment. When it comes to the buildings, there are number of environmental problems in its life cycle with the consumption of huge amount of energy and natural resource which can create negative influences on climate change by affecting the quality of air and water (Vyas *et al*., 2014). The necessity of sustainability for the building sector is identified with the view of protecting the natural resources while reducing environmental impact, resource consumption and waste production (Bastianoni *et al*., 2007).

2.2 CONCEPT OF SMART BUILDING

Implementation of SB systems to buildings was increased with the owner's awareness with the built environment and human productivity, which will achieve the energy efficient environment with maximum occupants' efficiency (Wong *et al*., 2008). Recent evidence suggests that SBs are developed upon Intelligent Building concepts (Wong and Li, 2009; Agarwal *et al*., 2010). According to Buckman *et al*. (2014), SBs have additional features than the Intelligent Buildings like a control mechanism, enterprise, material and construction. Sinopoli (2010) explained SBs as a concept which integrated with advanced technologies like building automation, life safety, user system, telecommunication and facility management systems. The Climate Group identified SB as "a suite of technologies used to make the design, construction and operation of buildings more efficient, applicable to both existing and new-build properties" (The Climate Group, 2008). As per Buckman *et al*. (2014), SBs are buildings which integrate and account for intelligence, enterprise, control, and materials and construction as an entire building system, with adaptability, not reactivity, at the core, in order to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction.

2.3 CONTRIBUTION OF SMART BUILDINGS TOWARDS SUSTAINABLE DEVELOPMENT

The main objectives of SBs are considered as efficient and effective use of the environment and maximising return on investment (Darwish, 2016). In the process of achieving these objectives, SBs will deliver multiple economic, social and environmental benefits. The identified benefits from various literatures are presented in Table 1.

Table 1: Contribution of smart buildings towards sustainable development

Benefits of smart buildings	Citations
Economic Benefits	
• Energy Savings - Reduce energy consumption	Wolfgang (2002); Yang (2013); Zhang *et al*. (2013)
• Time Saving- Save time with automating daily routines	Fujie and Mikami (1991)
• Reduce redesign cost by detecting faulty situation-fire, gas leaks and water	Darwish (2016)
• Minimum life cycle costs	Yang (2013)
• Minimising operations and maintenance expenses	Zhang *et al*. (2013)
• Maximize technical performance	Kaya and Kahraman (2014)
• Operation efficiency	Ghaffarianhoseini *et al*. (2016)
Environmental Benefits	
• Adapting to climatic changes	Kiliccote *et al*. (2011)
• Energy efficiency - protect natural resources	Wolfgang (2002); Yang (2013)
• Expert Systems - Contain information about requirements	Batov (2015)
• Optimising asset utilisation	Zhang *et al*. (2013)
• Less environmental pollution in operation stage	Morelli (2013)

Benefits of smart buildings	Citations
Social Benefits	
• Occupants comfort - Learn occupants' performance and attempts to increase comfort	Yang (2013); Brad and Murar, (2014)
• Capable of learning and adjusting performance from its occupancy and the environment	Kaya and Kahraman (2014)
• Maximise flexibility	Kaya and Kahraman (2014)
• Time saving	Fujie and Mikami (1991)
• Operation efficiency	Ghaffarianhoseini *et al*. (2016)
• Health and care - Revealed unsuitable temperature, air condition and light intensity parameters	Derek and Clements-croome (1997)
• Assistive domestics - Support in daily routines, warns in an emergency, reduce a sense of isolation	Batov (2015)

3. RESEARCH METHODOLOGY

The research was aimed at exploring the applicability of SB concept to enhance sustainable building practice in Sri Lanka. At the outset, a literature survey was carried out to identify the key features and principles of sustainability and SB concepts to recognise the relationships between the two concepts. Since the smart and sustainable concepts are new to the Sri Lankan construction industry there were only few numbers of respondents who were capable of being experts of this research study. Moreover, to fulfil the aim of this research, it was required to investigate the perception of the construction stakeholders and expert's opinions, experiences and knowledge. Since, expert interviewing is a useful data collection technique to assess attitudes, perceptions and values (Oswald *et al*., 2018), qualitative research approach was undertaken.

The purposive sampling method was used to select professionals in SB and Sustainable concepts. As a result of that, eight number of industry professionals who are actively and passionately involved in designing and managing SBs and sustainable building were selected. These professionals were selected from different fields which related to smart and sustainable practices such as MEP, civil engineering, facilities management and building automation. Semi-structured interviews were conducted with open-ended questions. Manual content analysis was carried out to facilitate clear outcome for establish the ideas gathered from the interviews. The experience and exposure of the interviewees with related to the SB and Sustainable concepts were given in the Table 2.

Table 2: Composition of respondents

Respondent	Profession/ Designation	Industry Experience	Level of awareness	Level of Experience in practice
R1	Managing director/ Senior MEP engineer	Above 20 years	High	High
R2	Managing engineer	Above 15 years	High	High
R3	Professor/Civil engineer	Above 15 years	High	Moderate
R4	Manager-Building Automation	Above 15 years	High	High
R5	Managing director	Above 25 years	High	High

Respondent	Profession/ Designation	Industry Experience	Level of awareness	Level of Experience in practice
R6	Chief operating officer	Above 15 years	High	Moderate
R7	Maintenance Engineer	Above 10 years	High	Moderate
R8	Project Engineer (BMS)	Above 10 years	High	Moderate

4. RESEARCH FINDINGS AND DATA ANALYSIS

4.1 SRI LANKAN STAKEHOLDERS' PERCEPTION TOWARDS SMART BUILDINGS

In order to explore the applicability of SB concept to enhance sustainable building practices, the perceptions of the Sri Lankan construction stakeholders' needs to be examined. If their perceptions are positive it could be concluded that the basis is there in the Sri Lankan context to obtain sustainable benefits through SBs. As per R1, Sri Lankan construction industry is still adopting conventional methodologies and technologies and the change to adopt new innovations is happening in a sluggish manner. Moreover, R6 identified the low level of technological knowledge of clients as the main obstacle in implementing SB concept in Sri Lanka. R4 mentioned that, with the weak legal enforcements for sustainable construction, Sri Lankan property developers are only considering about minimising the initial cost of construction and they are not concerning about the running cost of buildings. Furthermore, this has created a situation where building sector is responsible for a massive proportion of energy waste in Sri Lanka. Therefore, the R4 emphasised the importance of having a strong legal background for sustainable construction within Sri Lankan context. As per R7, building automation can be resulted in loss of job opportunities for employees in the fields of building security, maintenance and facilities management. Further, he explained that, "since the Sri Lankan labour policy is directed on creating more job opportunities SB concept may be against this policy and also against the social parameter of the sustainable development". However, opposing to his argument R8 stated that SB increases the job opportunities of the facilities managers by enabling them to focus on strategic problems, software and automation leading to overall growth in the number of professionals. By considering all of these arguments it can be concluded that the Sri Lankan construction industry stakeholder's perception on using SBs for improving sustainable construction is directed on a positive way.

4.1.1 Current Status of Smart Building Implementation in Sri Lanka

To gain the advantages of SB concept it needs to be practiced well in the industry. Therefore, it is important to recognise the current level of application of SB concept. All the respondents mentioned that current adoption of the SB has been at a marginal level in Sri Lanka. As per the respondents there are number of projects that have fully completed and quite a few numbers of projects will be completed in near future. As per R3, the levels of smartness of these buildings are not identical to each other as it varies within a huge range which depends on various factors such as availability of funds, client requirement and knowledge level. As per R1, the practicing level of the smart concept in Sri Lanka has been gone up to 60% - 70% and not fully adopt within the facilities. According to R7, SB concept is mainly implementing in Sri Lanka within hotel sector projects which demand guest room management systems and building projects which demand Building

Management Systems (BMS). All respondents without any contradictory opinions stated that, the lack of knowledge as the major problem that needs to be addressed immediately in order to increase the current level of application of SB concept. Moreover, findings disclosed lack of technology, lack of material, misconceptions, resistance to change and insufficient management support as the reasons behind slow progression of SBs. Further, R3 expressed that proper implementation, under a proper procedure, will upgrade the implementation of SB concept in the local construction industry dramatically.

4.1.2 Contribution of Smart Buildings towards Sustainable Development

The experts' ideas on the sustainability of SB revealed different opinions. According to R4, SBs usually blend with useful building services which enhance overall effectiveness of systems and make occupants productive and comfort. As per R6, it further enhances illumination, thermal comfort, air quality, security, and many more at a lower cost with minimum impacts to the environment. R1 stated that SB concept mainly address the active side of the sustainability which concerned on the building operation stage rather than the passive side which concerned with building design stage. In addition, R8 identified BMS as the main system that impacts on building automation and its sustainability. Further, R3 stated that the sustainable features of SB will bring long term benefits rather than short term benefits. Therefore, lot of people do not recognise the value of SB in terms of sustainability. The number of identified sustainable factors of SBs are less than the main factors identified from the literature review. This demonstrates the Sri Lankan construction experts' lack of awareness in smart and sustainability concepts. By confirming this fact, R6 explained that, *"When it compared the Sri Lankan smart and sustainable practice with the global content, it is in a lower level, due to the lack of education and training."* Further, R8 demonstrated that *"The smart concept is still new to the Sri Lankan construction industry than the sustainability. We have a limited number of professionals for both the concept to assign in projects. This has reduced the level of performance that could be achieved otherwise."* Therefore, when considering both opinions, SBs and its sustainable impacts will constructively change with the education and training to the professionals in the construction industry.

4.2 BENEFITS OF SMART BUILDINGS TOWARDS SUSTAINABLE CONSTRUCTION

Table 3 presents the identified benefits of smart buildings towards achieving sustainable construction.

Table 3: Benefits of smart buildings towards sustainable construction

Benefits	Applicability to Sri Lanka							
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Economic Benefits								
Energy Savings - Reduce energy consumption	√	√	√	√	√	√	√	√
Time Saving- Save time with automating daily routines	√	√	√	√	√	√	√	√
Reduce redesign cost by detecting faulty situation	√	√	√	√	√	√	√	√
Minimum life time costs	√	√	√	√	√	√	√	√
Minimising operations and maintenance expenses	√	√		√	√	√	√	√
Maximize technical performance,	√	√	√	√	√	√	√	√

Operation efficiency	√	√	√	√	√	√	√	√
Increase property value after construct	-	-	√	-	√	√	√	√
Environmental Benefits								
Adapting to climatic changes	√	√	-	√	√	√	√	√
Energy efficiency – protect natural resources	√	√	√	√	√	√	√	√
Expert Systems - Contain information about requirements	√	√	√	√	√	√	√	√
Optimising asset utilisation	√	√	√	√	√	√	√	√
Less environmental pollution in operation stage	√	√	√	√	√	√	√	√
Operation efficiency	√	√	√	-	√	-	√	√
Less embodied energy use	√	√	√	-	-	-	√	-
Good appearance and cleanliness to the city	√	√	-	√	√	√	-	√
Healthy and non-toxic environment creation	√	-	√	√	√	-	√	-
Use renewable and recyclable resources	√	√	√	√	√	√	-	√
Social Benefits								
Occupants Comfort	√	√	√	√	√	√	√	√
Capable of learning and adjusting performance from its occupancy and environment	√	√	√	√	√	√	√	√
Maximise flexibility	√	√	√	√	√	√	√	√
Time Saving	√	√	√	√	√	√	√	√
Operation efficiency	√	√	√	√	√	√	√	√
Maximise Health and Care	√	√	-	-	√	√	√	√
Assistive Domestics - Support in daily routines, warns in an emergency, reduce a sense of isolation	√	√	√	√	√	√	√	√
Quick respond to the occupants	√	√	-	√	-	-	√	√

For many developing countries like Sri Lanka, economic benefit is the main concerned factor in SB projects, rather than expecting environmental or social benefits. All the respondents recognised energy savings under environmental benefits and economic benefits. By explaining this fact, R3 mentioned that, *"Energy saving reduce the total CO_2 emission and reduce the purchasing cost of energy resources."* Moreover, R2 stated that detecting failures in systems like fire, gas and water is important since it minimise the redesign cost. All eight experts agreed that if the developer willing to pay a high cost during the initial stage of the SB construction, long term life cycle cost can be reduced. When it comes to the social category, two of eight respondents did not identify maximize health and care as a benefit due to the negative impacts on human health from the mechanized systems. R1 highlighted that, *"SB can automatically control the accurate percentage of carbon dioxide and the quality of fresh air by providing occupancy comfort while increasing its social value."* By considering all these benefits it can be concluded that the SBs can bring sustainable benefits to the Sri Lankan context.

4.3 BARRIERS IN IMPLEMENTING SMART BUILDINGS IN SRI LANKA

Table 4 presents the identified barriers to implementing smart buildings in Sri Lanka.

Table 4: Barriers of smart building implementation

Barriers	Applicability to Sri Lanka							
	R1	R2	R3	R4	R5	R6	R7	R8
Economic Barriers								
Less financial resources	√	√	√	√	√	√	√	√
Necessity of complex design and construction technologies	√	√	√	√	√	√	√	√
The cost in procurement practices	√	-	-	√	-	√	-	√
Risk of investment	√	√	√	√	√	√	-	√
Opportunity cost	-	√	-	√	√	√	-	√
Environment Barriers								
Insufficient response to sustainability	√	-	-	√	-	√	-	√
Environmental damages in construction by the design	-	√	-	-	√	√	-	√
Social Barriers								
Lack of knowledge of developers and owners	√	√	√	√	√	√	√	√
Reluctant to commence new technologies	√	√	√	√	√	√	√	√
Lack of knowledge on the environmental impact by inefficient buildings to the developers and owners	-	-	-	-	-	-	-	-
Less information on opportunities offered by intelligent technologies	√	√	-	√	√	√	-	√
Less cooperation and networking	√	√	√	-	√	√	√	√
Less motivation to professionals	√	-	√	√	√	-	√	√
Regulatory, Technical and Other Barriers								
Client opinions of essential services delivered.	√	√	√	√		√	√	√
Lack of support and inspire by Institutional structures	√	√	-	√	√	√	-	√
No evaluation system to assess the level of intelligence of smartness of a system	√	√	√	√	√	√	√	√
Not much practically used building codes, mandatory labelling, certificate schemes	√	√	√	√	√	√	√	√
Health and safety requirements by authorities	-	√	-	√		√	-	-
The scarcity of required material and skill tradesmen	√	√	√	√	√	√	√	√
Less political sense	√	√	√	√	√	√	√	√

As a developing country, economic barriers are the main obstacles by Sri Lankan developers in SB projects construction. Less financial resources for this type of projects can be considered a common issue. As per R1, R4, R6 and R8, other than the cost of complex technologies involved during the design, construction and operation phases, there is a cost occurred during procurement practice in terms of tendering and risk mitigation. According to the R3, social barriers mainly come from the users and the workers inside the building who concerned on comfort, human health protection and wellbeing. As per R6, there is reluctant to commence new technologies, because of fear of failure. R2 mentioned that, *"SBs required a close collaboration between professionals, users and suppliers since it require a high level of compatibility among design,* *construction and operation stages. However, Sri Lankan construction industry is a customer base industry, where others have very less control over the processes."* Further, majority of interviewees argued that there are no adequate institutional structures to inspire and support the SBs. There were instances where special technologies and experts were imported specifically for SB projects. The scarcity of required material and skill tradesmen is a significant barrier when implementing SB concept.

5. CONCLUSIONS

Smart Building concept is undertaken all over the world with the aim of improving the performance of the buildings with the use of advanced technologies like building automation, life safety, user systems, telecommunication and facility management. Even though the concept has been rapidly grown in the developed countries with appropriate knowledge and sense, the situation in developing countries is far too different. The findings of the study disclosed that, sustainable and smart concepts have different aims while targeting on developing different aspects of a project. However, both the concepts are inline while providing the benefits to the construction projects. Sri Lankan construction industry has recognized the involvement of SB towards the sustainable project delivery. Mainly, the stakeholders' perception towards the implementation of SB concept is focused on a favourable direction with the massive number of sustainable features it brings in to the building. However, implementation of SB concept needs to expedite and expand in order to obtain the numerous sustainable opportunities that are available. The implementation of SB concept is associated with numerous benefits and barriers where the barriers can be mitigated with a suitable set of strategies. The proper implementation process of SB concept, under a proper procedure, will upgrade the implementation of SB concept in the local construction industry and will expand the performance dramatically.

6. REFERENCES

Adetunji, I., Price, A., Fleming, P., and Kemp, P., 2003. Sustainability and The UK Construction Industry - A Review. *Proceeding of Institution of Civil Engineers - Engineering Sustainability,* 156, pp.185–199.

Agarwal, Y., Balaji, B., Gupta, R., Lyles, J., Wei, M., and Weng, T., 2010. Occupancy-Driven Energy Management for Smart Building Automation. *The 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building,* pp.1–6.

Bastianoni, S., Galli, A., Pulselli, R. M., and Niccolucci, V., 2007. Environmental and Economic Evaluation of Natural Capital Appropriation Through Building Construction: Practical Case Study in The Italian Context. *A Journal of the Human Environment*, 36(7), pp.559–565.

Batov, E. I., 2015. The Distinctive Features of " Smart " Buildings. *Procedia Engineering*, 111, pp.103–107.

Brad, B. S., and Murar, M. M., 2014. Smart Buildings Using IoT Technologies. *Construction of Unique Building Structures*, 5(20), pp.15-27.

Buckman, A. H., Mayfield, M., Beck, B. M., and Stephen., 2014. What is a Smart Building? *Smart and Sustainable Built Environment,* 3, pp.92–109.

Clements-Croome, D., 2011. Sustainable Intelligent Buildings for People: A Review. *Intelligent Buildings International*, 3(2), 67-86.

Darwish, A. S., 2016. Sustainable Green Smart Buildings: Future Energy Survivor. *ISESCO Journal of Science and Technology*, 12(21), pp.35–42.

Derek, J., and Clements-Croome, D., 1997. What Do We Mean by Intelligent Buildings? *Automation in Construction*, 6(5), pp.395–400.

Elias, S., and Krogstie, J., 2017. Smart Sustainable Cities of The Future: An Extensive Interdisciplinary Literature Review. *Sustainable Cities and Society*, 31, pp.183–212.

Fujie, S., and Mikami, Y., 1991. Construction Aspects of Intelligent Buildings*. IEEE Communications Magazine*, 29(4), pp.50–57.

Ghaffarianhoseini, A., Berardi, U., Alwaer, H., Halawa, E., Ghaffarianhoseini, A., and Clements-Croome, D., 2016. What Is an Intelligent Building? Analysis of Recent Interpretations from an International Perspective. *Architectural Science Review,* 59(5), pp.338–357.

GhaffarianHoseini, A. H., Dahlan, N. D., Berardi, U., GhaffarianHoseini, A., and Makaremi, N., 2013. The Essence of Future Smart Houses: From Embedding ICT To Adapting to Sustainability Principles. *Renewable and Sustainable Energy Reviews,* 24, pp.593–607.

Kajikawa, Y., 2008. Research Core and Framework of Sustainability Science. *Sustainability Science*, 3(2), pp.215–239.

Kaya, İ., and Kahraman, C., 2014. A Comparison of Fuzzy Multicriteria Decision Making Methods for Intelligent Building Assessment. *Journal of Civil Engineering and Management*, 20(1), pp.59–69.

Kiliccote, S., Piette, M. A., and Ghatikar, G., 2011. Smart Buildings and Demand Response. *AIP Conference Proceedings*, 1401, pp.328–338.

Kumara, W. H. C. D., Waidyasekara, K. G. A. S., and Weerasinghe, R. P. N. P., 2016. Building Management System for Sustainable Built Environment in Sri Lanka. *Built Environment Project and Asset Management*, 6(3), pp.302–316.

Love, P., and Arthur Bullen, P., 2009. Toward the Sustainable Adaptation of Existing Facilities. *Facilities*, 27(9/10), pp.357–367.

Miyatake, Y., 1996. Technology Development and Sustainable Construction. *Journal of Management in Engineering*, 12(4), pp.23–27.

Morelli, J., 2013. Environmental Sustainability: A Definition for Environmental Professionals. *Journal of Environmental Sustainability*, 1(1), pp.1–10.

Oswald, D., Zhang, R.P., Lingard, H., Pirzadeh, P. and Le, T., 2018. The use and abuse of safety indicators in construction. *Engineering, construction and architectural management*, *25*(9), pp.1188-1209.

Pitt, M., Tucker, M., Riley, M., and Longden, J., 2009. Towards Sustainable Construction: Promotion and Best Practices. *Construction Innovation*, 9(2), pp.201–224.

Schoolman, E. D., Guest, J. S., Bush, K. F., and Bell, A. R., 2012. How Interdisciplinary is Sustainability Research? Analysing the Structure of An Emerging Scientific Field. *Sustainability Science*, 7(1), pp.67–80.

Sfakianaki, E., 2015. Resource-Efficient Construction: Rethinking Construction Towards Sustainability. *World Journal of Science, Technology and Sustainable Development*, 12(3), pp.233–242.

Shabha, G., 2006. A Critical Review of The Impact of Embedded Smart Sensors on Productivity in The Workplace. *Facilities*, 24(13/14), pp.538–549.

Shari, Z., and Soebarto, V., 2013. Investigating Sustainable Practices in The Malaysian Office Building Developments. *Construction Innovation*, 14(1), pp.17–37.

The Climate Group., 2008. SMART 2020 Enabling the Low Carbon Economy in The Information Age. available from: www.smart2020.org/

Vyas, S., Ahmed, A. S., and Parashar, A. A., 2014. Bureau of Energy Efficiency and Green Buildings. *International Journal of Research*, 1(3), pp.23–32.

Wolfgang, F. E., 2002. Intelligent Office Building Performance Evaluation. *Facilities*, 20(7/8), pp.279–287.

Wong, J. K. W., and Li, H., 2009. Development of Intelligence Analytic Models for Integrated Building Management Systems (IBMS) in Intelligent Building. *Intelligent Buildings International*, 1(1), pp.5–22.

Wong, J.K.W., Li, H., and Lai, J., 2008. Evaluating the System Intelligence of The Intelligent Building Systems Part 1: Development of Key Intelligent Indicators and Conceptual Analytical Framework. *Automation in Construction*, 17(3), pp.284–302.

Yang, R., 2013. *Development of Integrated Building Control Systems for Energy and Comfort Management in Intelligent Buildings.* Thesis (PhD). University of Toledo.

Zhang, D., Shah, N., and Papageorgiou, L. G., 2013. Efficient Energy Consumption and Operation Management in A Smart Building with Microgrid. *Energy Conversion and Management*, 74, pp.209–222.

Zhou, L., and Lowe, D. J., 2003. Economic Challenge of Sustainable Construction. *RICS COBRA Foundation Construction and Building Research Conference*, pp.1–2.

Haupt, T.C., Akinlolu, M. and Raliile, M.T., 2019. Applications of digital technologies for health and safety management in construction. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 88 -97. DOI: doi.org/10.31705/WCS.2019.9. Available at: https://2019.ciobwcs.com/papers

APPLICATIONS OF DIGITAL TECHNOLOGIES FOR HEALTH AND SAFETY MANAGEMENT IN CONSTRUCTION

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ABSTRACT

The construction industry has been known for many decades as a high-risk industry with low levels of innovation and reluctance to adopt change. Common causes of construction accidents are associated with human error, hazardous work activities, defective equipment and dangerous working environments. However, to provide a better and safe working environment, the industry can exploit the benefits of emerging health and safety technologies. The purpose of this study is to explore the application of various emerging technologies and how they can be used to improve construction health and safety management. The paper reviewed extensive literature from previous studies on emerging technologies and interventions for construction job site safety such as; Virtual Reality (VR), online databases, Geographic Information Systems (GIS), Building Information Modelling (BIM), Unmanned Aerial Vehicle (UAV), 4D Computer-Aided Design (4D CAD), wearables, robotics, laser scanning, photogrammetry and sensor-based technologies. Furthermore, these technologies were grouped into three categories; people technologies, process technologies and environmental technologies for better analysis. Keywords such as 'construction health and safety technologies', 'digital technologies' and 'emerging technologies' were used to search online databases. This study identified emerging technologies and their application in the construction industry to improve health and safety.

Keywords: *Construction; Digital; Emerging; Health and Safety; Technologies.*

1. INTRODUCTION

Regardless of the countless efforts made by health and safety authorities and government agencies to improve health and safety standards on construction sites, worker's injuries and fatalities continue to occur at alarming rates (Li, 2015). Defective equipment, human behaviour, dangerous work areas and unsafe working conditions are cited as common causes of construction site injuries and fatalities (Li, 2015; Hinze and Teizer, 2011). In light of these, various types of technologies and interventions have been developed to prevent worker's injuries, accidents and enhance construction job site health and safety (Welch *et al*., 2015; Dodge Data and Analytics, 2017; Zhou, Whyte and Sacks, 2011).

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There has been a rapid increase in the use of emerging technological innovations to enhance health and safety on job sites in recent years. Several studies have concentrated on the application of digital technologies such as Virtual Reality (VR), online databases, Geographic Information Systems (GIS), Building Information Modelling (BIM), Unmanned Aerial Vehicle (UAV), 4D Computer-Aided Design (4D CAD), wearable robotics, laser scanning, photogrammetry and sensor-based technologies for accident prevention and onsite safety (Dodge Data and Analytics, 2017; Teizer, 2016; Bock, Linner and Ikeda, 2012; Li and Ng, 2017; Zhou *et al*., 2011).

Utilising emerging technologies provides significant prospects to improve construction health and safety management and ensure efficiency in construction work (Teizer, 2016); (Zhou *et al*., 2013). This paper aims to explore the various emerging technologies implemented for construction health and safety management. A comprehensive review of previous studies is conducted to establish the emerging technology adoptions as reported in numerous studies. The study categorizes these technologies into groups; people technologies, process technologies and environmental technologies. The main characteristics of these technologies are discussed in detail in the study.

2. DIGITAL TECHNOLOGIES AND TRENDS IN CONSTRUCTION H&S MANAGEMENT

Digital technologies in construction have been in existence since hard hats and protective glasses (Li and Ng, 2017). In recent times, the combination of big data, technological genius and construction has improved the health and safety of workers on construction sites (ibid). With the development of new technologies, the use of technology continues to draw attention (Zhou *et al*., 2013). A variety of tools have been developed to assist contractors to achieve health and safety on their construction projects. Numerous studies have identified the use of digital technologies such as BIM, VR and AR, drones, GIS, automation and robotics, unmanned machinery, sensing and warning technologies, 4D CAD as effective technologies for an accident, prevention and safe project delivery (Zhou *et al*., 2011).

2.1 PEOPLE TECHNOLOGIES

People technologies are digital tools applied to ensure the health and safety of workers by what they wear. Teizer *et al*. (2007) revealed that through the application of emerging technologies in health and safety, construction workers could be provided with layers of protection. Previous research efforts have explored the interaction and collision between heavy equipment and workers on construction sites (Li and Leung, 2017). The awareness of workers and visibility of equipment operators decreases because of the repetitive nature of construction activities (Teizer *et al*., 2007). Numerous studies have identified automation and robotics as effective technologies with good prospects to enhance proactive workers' safety on construction sites (Zhou *et al*., 2011). Automated platforms have been developed for the construction of high-rise structures (Li and Leung, 2017). This building system requires less labour and aims to reduce and eliminate injuries caused by over-exertion (Teizer, 2015). Workers competences and limitations are accommodated by transforming the work environment to provide an accident- free zone (ibid).

2.1.1 Robotics and Automation

Adopting robotic systems is a current trend for accelerating and automating construction tasks (Chu *et al.*, 2013; Bock *et al.*, 2012). Controlled by computers on-site and dependent on advanced detection and control, robots are employed in the autonomous installation and gathering of heavy construction materials, which usually require enormous labor, and to construct structures such as skyscraper towers (Niu *et al*., 2017; Jung *et al*., 2013; Li and Leung, 2017). One of the pioneer automation systems was a masonry robot that used seam adhesive to glue bricks and could lay brick walls up to 8m long. Yu (2009) discovered an automated machine called "Blockbot" which is utilised on-site to erect straight bonded brick walls accurately.

Navon and Kolton (2006) developed a model for automation in monitoring and managing fall hazards in scheduled building construction projects. This model determines high-risk areas in construction activities and gives a graphical presentation on the project's drawings (Azmy and Zain, 2016). Balaguer *et al*. (2002) proposed the use of ROMA climbing robots for inspection of steel-based infrastructures in construction. This robotic system is a self-supporting locomotion system that conducts inspections in 3D complex environments and operates similarly to a caterpillar.

2.1.2 Wearable Technology and Smart PPE

Wearables are clothing or accessories that have technologies incorporated into them, such as hats or watches. Physical processes and gestures such as waving heartbeat are captured and used to control a physical process or external event (Zhang *et al*., 2017). Wearable technologies have been designed to eliminate falls, electrocutions, and caught-in-between accidents. The smart hat or helmet is a warning technology equipped with special lenses, 4D augmented reality and a transparent visor. DAQRI developed a hard hat with a sensor bar for alignment and tracking activities. The hat detects potential site hazards and provides instructions and warnings (Teizer *et al*., 2010). Similarly, smart PPE's such as safety vests with sensors and GPS incorporated in them have been designed to protect construction workers during fall accidents (Zhou *et al.*, 2013).

2.2 PROCESS TECHNOLOGIES

These are digital tools applied to ensure safe construction activities on job sites. At the process level, considerable efforts have been made to promote and ensure health and safety (Zhou *et al*., 2011). Online databases are generally used in combination with various research tools to assess stakeholder competence and enable the communication of safety information within companies (Yu, 2009). The 3D and 4D CAD have been applied in construction projects to identify potential design risks and analyse on-site dynamics to enable safe project delivery (Ku and Mills, 2010). Hu *et al*. (2008); Bansal (2011); Merivirta *et al*., (2011) revealed that combining BIM and 4D CAD was adopted for the assessment and planning of construction health and safety as well as management of safety information.

2.2.1 Online Databases

Online systems have been used to improve several aspects of construction health and safety such as safety training and education, risk identification, safety monitoring and evaluation and safety inspections (Dodge Data and Analytics, 2017). Online databases can be utilized to detect potential site hazards and evaluate competence (Zhou *et al*., 2012). Yu (2009) designed a prototype web tool to assist in the evaluation of potential designers, contractors and coordinators. The online system applies Artificial Intelligence (AI) during the evaluation process to support decision making through risk identification and assessment, and information capture and analysis (Zhou *et al*., 2012).

The Construction Safety and Health System (CSHM) is a web-safety monitoring system that detects potential site risks and gives warning signals for activities that need immediate interventions (Cheung *et al.*, 2004). The system enhances quick data search, uploads, collection and documentation through remote internet access (Azmy and Zain, 2016). Health and safety indicators from diverse projects are understood, and valuable information is obtained to improve construction health and safety management. Project performance is monitored over a specified period by analyzing scores assigned to specific parameters (Yu, 2009). Azmy and Zain (2016) identified the development of a real-time communication system for monitoring construction safety on diverse projects. A centralized database is used to store transmitted data and is analyzed by site managers to inform decisions on construction sites (ibid). This system is an alternative platform for sourcing construction health and safety reports and statistics.

2.2.2 Internet of Things (IoT)

IoT has recently become an enormous innovation and trend in the history of technological advancement (Cheung *et al.,* 2004). The network comprises the interaction of embedded tools and devices accessed and connected to the internet through wired and wireless networks. IoT monitoring technologies are adapted to monitor site activities that require constant close attention (Dodge Data and Analytics, 2017). Applications are designed to enhance decision-making processes by transmitting real-time responses among workers (Jing *et al*., 2014). For smart construction health and safety information is collected with the use of sensors and gateways, clouds are then used to wirelessly store, analyse and review the data collected (Hopah and Vayvay, 2018).

Riaz *et al*. (2006) developed a proactive communication system to reduce human and equipment collisions on construction sites. A combination of GPS, smart sensors and wireless networks are applied to track site workers and equipment and inform operatives about impending site hazards. The system generates reports on dangerous activities and near-miss accidents (Azmy and Zain, 2016). Wireless Application Protocol (WAP) and Multimedia Messaging Service (MMS) have been used to manage safety-related issues on site by sending notifications to site workers who then swiftly communicate via text message when corrective action is taken (Bowden *et al*., 2006).

2.2.3 Building Information Modelling (BIM)

Implementing BIM enables visual assessment of construction site and identify potential hazards (Azhar *et al*., 2012; Watson, 2010). A result of incorporating BIM in construction activities is developing health and safety-training videos for workers (ibid). Using the BIM model to conduct visual health and safety training enables site workers to develop a better understanding of the actual site conditions (Watson, 2010). Construction workers are provided with sufficient time and information for safety planning and management before executing construction activities. With the use of sensors for data collection, the BIM can adequately reduce the likelihood of site accidents by checking the procedure of data acquisition (Druley *et al*., 2016); (Ganah and John, 2015). In adopting the BIM technology, health and safety issues are considered during construction planning, with provision of a clearer layout of site and safety plans giving strategies to manage site information as well as enhancing health and safety communication among project partners through time-controlled simulation (Azhar *et al*., 2012; Ku and Mills, 2010).

Ku and Mills (2010) assessed the capability of BIM as a safety tool. The study indicated that BIM promotes teamwork between project stakeholders using automated specifications and guidelines such as codes and regulatory information. By using a theoretical framework, the effectiveness of BIM for safety was evaluated. Given the concept introduced by Ku and Mills (2010), Qi *et al*. (2011) developed a safety checking system for construction activities. This system automatically checks the BIM model for fall dangers.

2.2.4 3D and 4D CAD

Health and Safety experts use 3D CAD for safety planning, accident investigation and facility maintenance safety (Rajendran and Clarke, 2011). Additionally, 4D CAD is utilized to simulate safety processes to display safety components and high-risk areas during the project's life cycle (Azhar *et al*., 2012). Rwamamara *et al*. (2010) concluded that the use of 3D and 4D technologies in the early stages of construction projects allows the project team to identify potential risks. Identifying risks at an early stage minimizes cost over-runs that occur because of design changes (Azmy and Zain, 2016).

In one case study, Mallasi (2006) applied 4D visualisation technology to detect and analyse workplace time-space congestion. Critical Space-Time Analysis (CSA) was used to analyse competition between various construction activities sharing similar execution space (Zhou *et al.*, 2012). Benjaoaran and Bhokha (2009) developed a rule-based construction safety management system using the 4D CAD visualisation model. The system focused on automatically identifying fall from heights hazards since fall accidents and injuries occurred more frequently compared to other accidents on construction sites (Azmy and Zain, 2016). Data relating to activities and building's component, placement, arrangement, materials, equipment are inputted and analysed to detect any height-related hazards (Zhou *et al*., 2012). The system proposes appropriate safety requirements and measures.

2.3 ENVIRONMENT TECHNOLOGIES

Environment technologies are tools adopted to ensure the health and safety of the construction environment. GIS and Global Position Systems (GPS) have been combined to understand issues of construction safety by taking into consideration design information, project structure and impact of construction activities on the external environment (Zhou *et al*., 2011); (Bansal, 2011). Similarly, integration of the GPS and RFID wireless sensor networks was developed to provide real-time information and monitor site workers, equipment, alert employees, and contractors about impending danger (Riaz *et al*., 2006; Teizer *et al*., 2015).

2.3.1 Smart Sensors and Wireless Networks

The application of sensors plays a significant role in implementing construction health and safety through real-time monitoring of buildings or building components (Zhang *et al*., 2017). Sensor-based technologies have been applied to prevent accidents and prevent worker – equipment collisions by monitoring the entire environment on construction sites. Ahsan *et al*. (2007) highlighted the sensor-based location, vision-based sensing and wireless sensor networks as the various types of sensor technologies applied to construction safety management.

Wireless sensor networks have been found to enhance and facilitate information flow among design teams on construction sites (Ward *et al*., 2004; Brilakis, 2007). Complexities of the construction environment make the circulation of a network a difficult task; however, wireless networks present solutions to this problem (Ahsan *et al*., 2007). Brilakis (2006) found that visual inspection methods employed to monitor bridge construction projects do not provide detailed and reliable information. New technologies such as wireless radio transmitters have been developed to monitor and inspect bridge construction projects (ibid). GSM, Wireless Local Area Network (WLAN), Terrestrial Trunked Radio (TETRA) are the various types of wireless technologies that have been tested on construction site operations (Zhang *et al*., 2017). Ahsan *et al.* (2007) identified a wireless network known as Wi-MESH to provide remote backend access and connection to the internet on construction sites where telephone access is restricted (Brilakis, 2007).

2.3.2 Virtual Reality (VR)

Virtual Reality is an artificial, computer-generated experience of a real-life situation or environment (Bouchlaghem *et al*., 2005). It generates realistic imagery and hearing, making the user feel like they are experiencing the simulated reality first-hand. In construction, virtual reality has been used by the health and safety teams to review safety tie-off points and coordinating major crane picks over occupied facilities that cannot be disrupted. This allows for effective means to visualize and communicate the impact of major construction activities in existing facilities that could be overlooked when viewing through traditional techniques (Zhang *et al*., 2017). Virtual Reality also creates a genuine health and safety work experience viable for construction health and safety training (Li and Leung, 2017). These benefits health and safety training as exercises on health and safety can be carried out in the absence of a qualified safety administer by merely simulating the training environment on a personal computer (ibid).

Zhou *et al.* (2011) argued that traditional paper-based handouts, videotapes or slide shows hardly present electrical hazards vividly to the trainees and furthermore do not provide sufficient opportunities for trainees to interact in activities. This form of participatory training brings a real-life situation into the training in an "it can happen to you" scenario and allows the trainee to relate these regulations and conditions to real-life situations of with life and death significance (ibid).

2.3.3 Augmented Reality (AR)

As opposed to virtual reality which uses computer-generated imagery to simulate real-life scenarios; augmented reality enhances reality using technology (Bouchlaghem *et al*., 2005). However, the enhancements can be distinguished where such interactions are developed into applications and mobile devices (Patrucco *et al*., 2010). Augmented Reality projects 3D imagery on a person’s physical surroundings as they walk through construction sites with mobile devices or special helmets and using GPS and cameras to present real-time data geospatially giving updated user feedback (Bouchlaghem *et al*., 2005). Health and safety training may be conducted with this technology by enabling workers to wear augmented reality headsets to give virtual drills, instructions and safety scenarios at low training costs and downtimes (ibid).

2.3.4 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) uses radiofrequency waves to transmit data, retrieve data and store data to identify the status of workers and objects (Yin *et al*., 2013). RFID systems are composed of an RFID tag and RFID reader, with RFID tags consisting of a small microchip and antenna. Data are stored in the tag, generally as a unique serial number. RFID tags can either be active (using battery) or passive (no battery) or have a read range of 10 to 100 meter (ibid).

In construction health and safety applications, RFID technology has been used to demonstrate real-time data gathering (Li and Leung, 2017). RFID tags have been used in simulated construction environment to track the movement of workers, equipment and materials and the resulting tag data examined to determine if a near-miss accident has occurred (Zhou *et al*., 2013). This information can further be used to prevent future occurrences (ibid). Chae (2009) designed a Collision Accident Prevention Device (CAPS) that uses RFID (Radio Frequency Identification) technology to estimate the size of the working area. The device supports accident prevention involving vehicles, heavy equipment and workers using data from the working area of each object. CAPS estimates and calculates the positional relation of heavy equipment and workers and once determined that a worker is in the restricted area of heavy equipment, a warning message is sent to the worker and concerned parties (ibid).

3. METHODOLOGY

The study adopts a traditional literature review approach to explore the different existing emerging technologies used in construction health and safety management. Relevant research and studies on advanced technology implementation and construction health and safety were primarily obtained from multiple research databases and online-computerized search engines including Elsevier (Science Direct), Taylor and Francis, Emerald Insight, Research Gate and other internet sources. A systematic and extensive database search was conducted using initial descriptors such as technology, health and safety and construction site and technologies categorised according to their functionalities; people technologies, process technologies and environmental technologies. Other keywords related to advanced and emerging technologies such as 'sensor', 'wireless network', 'robotics', 'remote sensing' and 'laser scan' were identified. Articles reviewed and cited in this study includes articles published in reputable scholarly journals and reports. Significant papers and articles relating to the study were selected and collated to construct a database.

4. DISCUSSION AND RECOMMENDATIONS

In this study, it was found that standard health and safety practices and policies combined with the implementation of digital health and safety tools and techniques could assist site managers, supervisors and coordinators ensure the efficiency of their construction projects. Accidents can be reduced tremendously with the use of people technologies to ensure workers safety by what they wear and how they interact with their work environment. Furthermore, process technologies may be used to eliminate hazards during the design stage and with the assistance of environmental technologies used to give updated feedback on the work environment. The industry must take advantage of breakthroughs in technological advances such as the Internet of Things (IoT). With this technology, the interaction of all mechanical devices, digital devices and computers combine the digital and physical worlds. Advanced Artificial Intelligence (AI) systems can be used to improve site health and safety, assist in information sharing and instantly report dangerous activities. Therefore, investing in emerging technologies enhances health and safety performance on construction sites.

5. CONCLUSIONS

This paper has provided a comprehensive and traditional review of previous literature on technology adoptions and implementations in construction health and safety management. The technologies were grouped into three categories, people technologies, process technologies and environmental technologies. The importance of construction workers' health and safety continues to grow in the construction industry. It is discovered that the application of digital technologies can effectively promote construction health and safety management. Numerous studies have been conducted on the application of various types of technologies in aspects of construction health and safety such as site safety education and training, safety communication and information and site monitoring and control. The adoption of various safety technologies like 3D and 4D CAD, RFID, augmented reality, virtual reality, Building Information Modelling, smart sensor and wireless technology, online databases, robotics and automation have significantly increased the effectiveness of health and safety management on construction sites. Applying advanced technologies in construction health and safety may provide a practical means for safety personnel and practitioners to track and monitor interactions on construction sites.

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7. REFERENCES

Ahsan, S., El-Hamalawi, A., Bouchlaghem, D. and Ahmad, S. 2007. Mobile Technologies for Improved Collaboration on Construction Sites, *Architectural Engineering and Design Management*, 3, pp.257-272.

Azhar, S., Bahringer, A., Khalfan, M., Sattineni, A. and Maqsood,T. 2012. BIM for Facilitating Construction Safety Planning and Management at Jobsite, *Proceeding of the CIB W099 International Conference on Modelling and Building Health and Safety*, pp.82-92.

Azmy, N. and Zain, A. 2016. The Applications of Technology in Enhancing Safety and Health Aspects on Malaysian Construction Projects, *ARPN Journal of Engineering and Applied Sciences*, 11, pp.7209-7213.

Balaguer, C. and Abderrahim, M. 2008. *Trends in Robotics and Automation in Construction, Robotics and Automation in Construction*, Intechopen.

Bansal, V.K. 2011. Application of geographic information systems in construction safety planning," *International Journal of Project Management*, 29, pp.66-77.

Benjaoran, V. and Bhokha, S. 2009. Enhancing visualization of 4D CAD model compared to conventional methods. *Engineering, Construction and Architectural Management,* 16(4), pp.392-408.

Bock, T., Linner, T. and Ikeda, W. 2012. *Exoskeleton and Humanoid Robotic Technology in Construction and Built Environment,* The Future of Humanoid Robots - Research and Applications, Intechopen.

Bouchlaghem, D., Shang,H. and Whyte,J., Ganah,A. 2005. Visualisation in architecture, engineering and construction (AEC), *Automation in Construction*, 14 (3), pp.287–295.

Bowden, S., Dorr, A., Thorpe, A. and Anumba, C. 2006. Mobile ICT support for construction process improvement, *Automation in Construction*, 15(5), pp.664-676.

Brilakis, I. 2006. Remote Wireless Communications for Construction Management: A Case Study, *Joint International Conference on Computing and Decision Making in Civil and Building Engineering*, pp.135 -144.

Brilakis, I., 2007. Long-distance wireless networking for site – office data communications*, ITCon*, 12, pp.151–164.

Chae, S. 2009. Development of Warning System for Preventing Collision Accident on Construction Site, *26th International Symposium on Automation and Robotics in Construction*.

Cheung, S.O, Cheung, K.K.W and Seun, H.C.H. 2004. CSHM: Web-based safety and health monitoring system for construction management, *Journal of Safety Research*, 35(2), pp.159–170.

Chu, B., Jung, K., Lim, M.T. and Hong, D., 2013. Robot-based construction automation: An application to steel beam assembly (Part I). *Automation in Construction*, *32*, pp.46-61.

Dodge Data and Analytics 2017. Safety Management in the Construction Industry, *Smart Market Report*, Bedford, MA.

Druley, K., Musick, T. and Trotto, S., 2016. Researcher explores how to make temporary structures on the construction site safer. *Safety & Heath*, *193*(3), p.35.

Ganah, A. and John, G.A. 2015. Integrating building information modelling and health and safety for onsite construction, *Safety and Health at Work*, 6, pp.39-45.

Hinze, J. and Teizer, J. 2011. Visibility-related fatalities related to construction equipment, *Safety Science*, 49, pp.709-718.

Hopah, E. and Vayvay, O. 2018. Internet of Things (IoT) and its Challenges for Usability in Developing Countries, *International Journal of Innovation Engineering and Science Research,* 2(1), pp.1-9.

Hu, Z., Zhang, J. and Lu, X. 2010. Development of a sub building information model for 4D structural safety analysis during construction, *Proceedings of the International Conference on Computing in Civil and Building Engineering (ICCCBE 2010)*, Nottingham, UK.

Jing, Q., Vasilakos, A. Wan, J., Lu, J. and Qiu, D. 2014. Security of the Internet of Things: Perspectives and challenges, *Wireless Networks*, 20, pp.2481-2501

Jung, K., Chu, B. and Hong. 2013. Robot-based construction automation: An application to steel beam assembly (part ii), *Automation in Construction*, 32, pp.62–79.

Ku, K. and Mills, T. 2010. Research needs for Building Information Modelling for Construction Safety, *International Proceedings of Associated Schools of Construction 45th Annual Conference*, Boston, MA.

Li, R.Y. 2015. Generation x and y's demand for homeownership in Hong Kong, *Pacific Rim Real Estate Journal*, 21, pp.15–36.

Li, R.Y.M., and Ng, P.L. 2017. Wearable robotics and construction workers safety and health. In: *8th International Conference on Applied Human Factors and Ergonomics*, Los Angeles.

Li, R. Y. and Leung, T. 2017. Leading safety indicators and automated tools in the construction industry, *34th International Symposium on Automation and Robotics in Construction*.

Mallasi, Z. 2006. Dynamic quantification and analysis of the construction workspace congestion utilizing 4D visualization, *Automation in Construction*, 15, pp.640–655.

Merivirta, M., Ma¨kela¨, T., Kiviniemi, M., Ka¨hko¨nen, K., Sulankivi, K. and Koppinen, T. 2011. Exploitation of BIM based information displays for construction site safety communication, in *Proceedings of CIB W99 Conference 2011*: Washington, USA, 24–26 August, pp.402–415.

Navon, R. and Kolton, O., 2006. Model for automated monitoring of fall hazards in building construction. *Journal of Construction Engineering and Management*, *132*(7), pp.733-740.

Niu, Y., Lu, W. and Liu, D. 2017. The application scenarios of smart construction objects (SCOs) in Construction, *Proceedings of the 20th International Symposium on Advancement of Construction Management and Real Estate*, pp.969–980.

Patrucco, M., Bursano, D., Cigna, C. and Fissore, F. 2010. Computer image generation for job simulation: an effective approach to occupational risk analysis, *Safety Science* ,48, pp.508–516.

Qi, J., Issa, R., Hinze, J. and Olbina, S. 2011. Integration of safety in design through the use of building information modeling. *International Conference on Computing in Civil Engineering,* Miami, U.S., pp.698–705.

Rajendran, S. and Clarke, B. 2011. Building Information Modeling: Safety benefits and opportunities, *Professional Safety*, pp.44-51.

Riaz, Z, Edward, D. and Thorpe, A. 2006. SightSafety: A hybrid information and communication technology system for reducing vehicle/pedestrian collisions, *Automation in Construction*, 15, pp.719-728.

Rwamamara, R., Norberg, H., Olofsson, T. and Lagerqvist, O. 2010. Using Visualization Technologies for Design and Planning of a Healthy Construction Workplace, *Construction Innovation*, 10, 248-266.

Teizer, J. 2015. Wearable, Wireless Identification Sensing Platform: Self- Monitoring Alert and Reporting Technology for Hazard Avoidance and Training (SmartHat), *Journal of Information Technology in Construction,* 20, pp.295-312.

Teizer, J., Caldas, C.H., and Haas, C.T. 2007. Real-Time Three-Dimensional Occupancy Grid Modeling for the Detection and Tracking of Construction Resources. *ASCE Journal of Construction Engineering and Management*, 133, pp.880-888.

Teizer, J., Allread, B.S., Fullerton, C.E. and Hinze, J. 2010. Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system. *Automation in Construction*, 19 (5), pp.630-640.

Teizer, J. 2016. Right-time vs real-time pro-active construction safety and health system architecture, *Construction Innovation,* 16 (3), pp.253-280

Ward, M., Thorpe, T., Price, A. and Wren, C. 2004. Implementation and control of wireless data collection on construction sites, *Journal of Information Technology in Construction*, 9, pp.299-311.

Watson, A. 2010) “BIM - driver for change, Proceedings of the International Conference on Computing in Civil and Building Engineering, *ICCBE 2010*, Nottingham.

Welch, L., Russell, D., Weinstock. D. and Betit, E. 2015. Best Practices for Health and Safety Technology Transfer in Construction, *American Journal of Industrial Medicine*, 58, pp.849-857.

Yin, S.Y.L., Tserng, H.P., Wang, J.C.and Tsai, S.C. 2009. Developing a precast production management system using RFID technology, *Automation in Construction*, 18, pp.677-691.

Yu H. 2009. *A knowledge-based system for construction health and safety competence assessment*. University of Wolverhampton. United Kingdom.

Zhang, M., Cao, T. and Zhao, X. 2017. Applying Sensor-Based Technology to Improve Construction Safety Management, *Sensors*, 17, pp.1-24.

Zhou, W., Whyte, J. and Sacks, R. 2012. Construction safety and digital design: A review, *Automation in Construction*, 22, pp.102–111.

Zhou, N., Ding, L.Y and Chen, L.Y. 2011. Application of 4D visualization technology for safety management in metro construction, *Automation in Construction*, 34, pp.25–36.

Zhou, Z., Irizarry, J. and Li, Q. 2013. Applying advanced technology to improve safety management in the construction industry: a literature review, *Construction Management and Economics*, 31, pp.606-622.

Siriwardena, M., Ross, A., Abbott, A. and Manewa, A., 2019. Apprentice perceptions of work based learning: Preliminary observations. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 98 -106. DOI: doi.org/10.31705/WCS.2019.10. Available at: https://2019.ciobwcs.com/papers

APPRENTICE PERCEPTIONS OF WORK BASED LEARNING: PRELIMINARY OBSERVATIONS

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ABSTRACT

The degree apprenticeships programme involves a tripartite agreement involving the student apprentice, employer and the university. The programme introduced few years ago in the UK, which now caters to a significant number of apprentices in built environment related degree programmes. Although the Degree Apprenticeships involve a significant component of work based learning, limited evidence exist to justify Chartered Surveying Degree Apprenticeships Standard as a successful work based learning facilitator, mainly due to the scarcity of research. The findings of this paper are based on an ongoing research project, therefore is limited to evaluating Degree Apprenticeships apprentice perception of work based learning. Research method comprised of a literature review and the inspection of the guidance documents related to the delivery of the Degree Apprenticeships programme, followed by seven semi-structured interviews with selected degree apprentices. Qualitative data analysis paved the way for identification of several success areas and the aspects that require further improvement. Lack of shared understanding among the three parties and the absence of explicit evidence of implementation of work based learning were noteworthy, and suggestions for improvement are proposed. Further research involving a wider sample of apprentices and employers suggested.

Keywords: *Apprentice Perception; Degree Apprenticeships; Surveying Education; Work Based Learning.*

1. INTRODUCTION

The Degree Apprenticeship (DA) programme introduced few years back in the United Kingdom (UK) has attracted a significant amount of attention. This is evidenced as there is a continuous improvement in number of active apprentices enrolled on such programs over the past few years (House of Commons, 2019). Whilst research reports on various aspects of the degree apprenticeship programme, research into the implementation of the work based learning element within the Chartered Surveying Degree Apprenticeship Standard is rare.

This paper reports on the preliminary findings of an attempt to evaluate the apprentice perception of work based learning, which is a part of an ongoing research project. The

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background to the degree apprenticeship programme in the UK is first introduced, followed by a detailed description of the current model. This is followed by a brief introduction to work based learning. The research method is presented next, followed by results, discussion and conclusions.

2. DEGREE APPRENTICESHIPS INITIATIVE

The skills shortage in the UK's workforce is well recognised. The skills gap in the built environment was highlighted in a review of industry reports and government publications (CITB, 2017). These skills gaps appear to be worsened by the perceived knowledge and abilities of graduates leaving higher education (HE) and the expectations and demands of business and employers (Hernández-March, Martín del Peso, and Leguey, 2009).

The construction industry being a labour intensive industry is significantly affected as a result. On the other hand, the vital role of the construction industry in the context of the UK economy is well documented. Publications such as the Government Industrial Strategy (BEIS, 2017) further reinforces the important role of the construction industry in the future economy of UK. The UK's universities are a key supplier of the skilled workforce to the construction industry but as a result of the higher education funding reviews which took place during the latter part of the last decade (Browne, 2010), significant increases in the tuition fees were introduced. As a result, employability of graduates became a key criterion for course selection as well as performance measurement of universities. Within this backdrop, Degree Apprenticeships were introduced as a way of developing the skilled workforce.

The UK government pledged itself to continue with an ambitious programme of reforms to apprenticeships, which were set out in 2015 and were informed by the 2011 Wolf Review of vocational education. The Wolf Review's (Wolf, 2011) findings impugned a system where too many apprentices were locked into dead-end jobs and where many high-quality apprenticeships were rare. The drivers behind the government's apprenticeship reforms are cited by the Skills Funding Agency (SFA) as being:

1. A need to improve productivity through up-skilling
2. A desire to force employers to invest more in high-quality training
3. An ambition to improve social mobility and create more opportunities for young people
4. The ongoing policy directives around getting universities and business to collaborate

As well as increasing the quantity of apprenticeships available, the government aimed to increase their quality by setting up the Institute for Apprenticeships (https://www.instituteforapprenticeships.org/). This new body, which was launched in April 2017, was made up primarily of employers who were responsible for setting the new apprenticeship standards, which were developed and proposed by employer consortia (Trailblazer groups) in consultation with educational providers.

The Richard Review of Apprenticeships (Richard, 2012) set out to define the future of apprenticeships in the UK and defined a vision of how apprenticeships could meet the needs of the changing economy. The strategy also aimed at redefining the shape of the existing system and examine how the apprenticeship system must work towards the betterment of the UK economy in future. In his independent report, Richard makes recommendations to the UK government to improve the quality of apprenticeships and make them tailored to the needs of employers. Some of the recommendations of Richard (2012) as noted by Dawson and Osborne (2018) include:

- A redefinition of apprenticeships: Where they should be targeted only at those who are new to a job or role that requires sustained and substantial training.
- A new focus on the end goal of an apprenticeship - what the apprentice is capable of doing when they complete their training – and giving more freedom in the design of the actual process as to how they get there. Trusted, independent assessment is key where recognised industry standards should form the basis of every apprenticeship. RICS is the expected standard for the surveying apprenticeships.
- All apprentices should reach a required minimum standard in English and Mathematics before they can complete their apprenticeship.
- Government funding must create the right incentives for apprenticeship training. The purchasing power for investing in apprenticeship training should lie with the employer. This has been handled by the levy system.
- Greater diversity and innovation in training - with employers and government safeguarding quality.

3. DEGREE APPRENTICESHIPS MODEL

The DA programme involves a tripartite agreement involving the student (apprentice), employer and the university. Students enrolled on degree apprenticeships programme share their time between the workplace and flexible university study. 80% of their time can be spent on their workplace activities catering to work based learning, training etc and the rest of 20% require to be devoted to off-the-job training, learning undertaken outside of their day-to-day workplace role that contributes to the apprenticeship such as university learning, research, attending Continuous professional Development (CPD) activties etc.

The DA scheme is designed by employers, universities and professional bodies, which aims to deliver high-tech and high-level skills and offer an alternative to a traditional degree course (National Audit Office, 2016). However, current accountability frameworks may result in an unnecessary confusion around the roles and responsibilities of individual actors associated with degree apprenticeship delivery resulting in a missed opportunity to maximise the value arising from the tri-partite delivery relationship (Lambert, 2016).

Developments in the area of employer engagement in academic degree programs have been inconsistent and difficult to predict. Although there are established models of industry-academia collaboration in different sectors (Gorschek, Garre, Larsson, and Wohlin, 2006), many of these relate to research interaction rather than skills and capacity building. The Degree Apprentice initiative is one of the first structured frameworks to formally drive the collaboration of industry and academia in large scale educational delivery (Ross and Riley, 2018).

Outputs of the DA programs are designed by the degree apprenticeships standards that have in turn been designed by the industry. Consequently, industrial partners are stakeholders in the development of knowledge, skills and behaviours within the Degree Apprentice. The University component of the apprentice’s End Point Assessment (EPA) is a Level 6 award, based upon a curriculum that is delivered to full and part time students uniformly.

Although the Degree Apprenticeships require (and promise) the provision of work based learning, evidence of Chartered Surveying Degree Apprenticeships Standard as a successful work based learning facilitator is lacking, mainly due to the scarcity of research. Hence, there is a need for a study to address this gap in knowledge. This research aims to evaluate the preliminary findings in relation to the perceptions of current degree apprentices in relation to the work based learning element of the degree apprenticeship provision.

4. WORK BASED LEARNING

Work based learning (WBL) has become an umbrella term and occur in many forms. Lester and Costley (2010, p.562) state that the term 'work-based learning' as "any learning that is situated in the workplace or arises directly out of workplace concerns". Moreover, they have noted that although most of the work based programmes are a combination of teaching and research elements, facilitation of active and enquiry-based learning from purposive (work) activity is a cornerstone of work based learning.

In relation to higher education, Garnet (2016) observes that WBL is used to describe higher education programmes of study where the learning takes place primarily and continue throughout for the purposes of work. A much more inclusive and overarching definition in relation to higher education is provided by Gibbs and Garnett (2007, p. 411) who define WBL as "a learning process which focuses university-level critical thinking upon work (paid or unpaid), in order to facilitate the recognition, acquisition and application of individual and collective knowledge, skills and abilities, to achieve specific outcomes of significance to the learner, their work and the university". Having considered the available definitions for WBL this study is closely aligned with the definition provided by Gibbs and Garnett (2007).

5. RESEARCH METHOD

A literature review was performed to gain an understanding of the inception and the evolution of the current degree apprenticeship provision in the UK in general and, in particular to the built environment sector. A critical evaluation of work base learning was also undertaken appropriately.

Document reviews were carried out to explore the details, requirements and the process of Chartered Surveying Degree Apprenticeships standard. Seven (07) semi-structured interviews were conducted with current degree apprentices who follow the chartered surveying degree apprenticeships standard at a university in the Northwest of UK, to gain an insight into the current status of work based learning within the current degree apprenticeships provision. A list of questions were devised to elicit responses from the subjects to best uncover the information required for the study (Stewart, Campbell, McMillan, and Wheeler, 2019). These semi-structured interviews are more formal than the unstructured interview whereby there are several specific topics which the questionnaire covers. The interview uses both open and close ended questions but there was no specific order to the questions again using the interviewer's experience to decide on exactly how the interview should be conducted. The task is to discover the most possible in relation to the subject area (Naoum, 2013).

Seven apprentices (07) belonging to six (06) employers were selected to take part in the study. They were geographically spread across the Northwest of England and considered to be representative of the population of employers delivering degree apprenticeships in the quantity surveying profession.

Qualitative and thematic data analysis was conducted. The qualitative data from the interview transcripts were initially structured and analysed using categorisation of themes, and the conclusions derived accordingly.

6. RESULTS AND DISCUSSION

The apprentices' perspectives on current setting of the DA programme, fit for purpose of in-class or university (theoretical) learning in relation to practice (work based learning), were assessed to evaluate the current model and identify further improvements. Empirical data collected can be presented under several themes as discussed below.

- **Employers' attitude and awareness of the degree apprenticeship framework**

Employers' disconnect with the degree apprenticeship framework was one of the noteworthy aspects that emerged from these interviews. For example, comments such as *"my annual appraisal does not take into account university work… like we always say, textbooks are different from the real world"* reflects the limited awareness of employers on Degree Apprentice requirements.

Moreover, most of the in-house training programs are not designed to align with the required skills of the EPA, hence not being aligned with the work based learning requirements of degree apprenticeship framework. This issue derived from one of apprentices who further explained that

> *"my company has a developmental programme. There are competencies that I need to hit as well. But that is more tailored toward each person's individual role, not everyone goes round the houses and does everything. It's not one programme for everyone it is a tailored towards whatever role you are in".*

In a way this is commonplace between education and workplace that the work focus tends to be narrower than the naturally wider educational curriculum. As a result, apprentices tend to reside within a specific comfort zone. This was confirmed by few of the interviewees as *"I do not have plans to get exposure to the estimating side of things. I quite like what I do*."

More importantly, the attitude of an employer towards university and EPA can be challenging: *"I suppose it depends who your boss is. My boss says I have never been to university, all I've got is GCSEs and that, you don't need to do all that …."*This displays a prevalent attitude in the workplace that what is taught in university is irrelevant to the real world business objectives.

However, it is worth noting that there are those who disagreed with the above-mentioned position. Some of the interviewees suggested that their employers are reliant on university to provide the knowledge:

> *"My company expects me to get the knowledge from university – there is no learning structure inside the company. They expect a certain level of knowledge like construction technology."*

The findings such as 'employers disconnect with DA programme', training not aligning with the APC requirements, attitudes on university education, letting students to learn/master on one single or limited number of skills rather providing overarching support, reflects employers limited awareness of current Degree Apprentice framework.

- **Relevance of education curriculum towards achieving work place learning**

One view is that learning in the workplace tends to be 'hands on' helping a more experienced colleague. To confirm this argument one apprentice noted that

> *"Our Managing Director wants to get me involved in filling out demolition orders before work starts on site. When I told him I don't have any experience in procurement he said "well you can help me with this then".*

However, the above observation should not be interpreted as if university curriculum is not fit for purpose as another apprentice clearly explained that

> *"Yes, university is relevant to my work. Most of the stuff that I see as relevant is such as we went through procurement and sustainability to promote sustainability throughout your specifications. The measurement side that you do I don't really do that work. We have a whole team that do measurement so if I was doing one of their jobs then it would definitely be relevant."*

Supportively*, "You use things from the course without realising most of the time."* Demonstrates the importance of education curriculum in work based learning. Therefore, it is worth further investigating what makes one think that it is irrelevant. One possible explanation is the mismatch in terms of timing of the delivery rather with the content of the course. Comments below do shed some light in this regard.

> *"I would say the first couple of years in university was not relevant. I don't think they were up to speed in terms of what you were doing on the job. There was stuff I needed to know straight away in terms of tendering and procurement. That came in maybe last year so maybe the speed of learning isn't aligned."*

The fit for purpose of the academic curriculum in work based learning is argued and both positive and negative perceptions were noted in terms of contents of the curriculum and the timing of delivery.

- **Assessment in the workplace**

Given the strong connection between learning and assessments, apprentice views were sought on possible changes to the current university assessments regime by conducting some of the assessments within the workplace. Whilst the responses were mixed, it was obvious that it did generate a significant amount of reflection on the part of the apprentice.

> *"Assessment in the workplace – how would that work with confidentiality and stuff like that? Yeah but I'm thinking if it is part of my course such as a validation of account with subcontractors. Certain modules…I don't know. I don't know what benefit you are trying to get out of it are you trying to make it more align it more with the industry. I can just issue you with work that I have already done. Yeah, I think that could have some benefit, definitely because if you are doing something very similar, yeah. I think that would be very good, when you go out and see stuff yeah, I think you could learn more. Actually, doing something practical, yeah."*

Most apprentices acknowledged the value of such approach and the reservations were more related to the practicalities of such an approach.

> *"If part of the university assessment took place in work I think it would be interesting but it is very subjective. When you are doing assessments you want to be objective so it is easy to mark against. Also, there is a problem with confidentiality."*

It also became clear that for such an approach to succeed, a significant level of trust building is required between the apprentice and the employer.

> *"I would not like some university assessments to be done in work by my employer. I don't like the sound of that. It will make the assignment easier but it gives the employer reason to see your mistakes."*

The apprentices' perceptions on assessments in work place is interesting. Few of the apprentices agreed with such approaches as it will help them to understand the theory in practice, provide a room to create good bond between employer and the apprentice. However, one argued that it will help employers to detect the apprentice's mistakes easily, which the apprentice perceived as a possible threat.

- **Work life balance for student apprentices**

Degree apprenticeship route requires the apprentice to study for a Level 6 degree qualification, and also to prepare and submit themselves to the Assessment of Professional Competencies (APC) as their end point assessment. The nature of workload pressures was also part of the investigation of this research.

Responses were varied and demonstrated a level of correlation with the level of maturity of the apprentice. The more mature apprentices seem to respond well to the challenge.

> *"My work life balance is good. I like being busy I go to the gym all the time as well."*

However, several challenges were also highlighted by the respondents.

> *"My work life balancing – I found the last semester to be quite challenging, in parts in work and also university because I think you get to a point in the third year where everything racks up so you are expected to do different work and also the modules in university get harder so I found last year quite hard."*

- **Acquiring RICS professional competencies**

Submitting to the end point assessment is a requirement of the degree apprenticeship scheme. Work based learning element of the degree apprenticeship scheme is expected to provide the leading support in this regard. Preliminary observations indicate more progress is required.

Where there is progress, reflection appear to be lacking. For example, in instances where there are company mandated route(s) for achieving RICS competencies, there is a lack of engagement in terms of the reflective nature required.

"My counsellor picks the competencies. I'm clear on the way forward (but) the RICS website is hard to follow." Although reflection is expected to be an integral part of learning, it appears that such an activity is seen as an added burden by some of the apprentices.

"I do not do the reflection. I see this as extra which is too much work." However, it would be wrong to conclude that the attitude towards working to acquire the necessary competencies is all negative. Perhaps more guidance is needed.

> *"I need examples of the knowledge required to pass the APC – you choose your case study and have to know it inside out. I don't know what my case study is. As soon as I know that I can start… My supervisor is giving me a case study but I do not have it yet."*

- **Do you get the 20% off the job training?**

Degree apprentices are required to obtain 20% off the job training during their entire apprenticeship. During term-time, this equates to one day of attending lectures and tutorials at the university. This research investigated the implementation of the 20% off the job training during non-term time. Findings painted a mixed picture and explicit evidence of implementation is sketchy.

> *"Doing my job if I need something else in order to fill out a competency I am allowed to go and do that. There are a couple of whole day events for CPD – 7 and a half hours CPD. Some of them are really good."*

> *"Yes, my manager has always been happy for me to continue learning and they do give me the time. My manager has always been happy for me to continue learning. Obviously, it is part of my framework."*

Whilst comments such as the one above demonstrate explicit employer support, there appear to be some level of confusion in terms of the purpose of 20% off the job training.

> *"It depends who you work for. If I need a day off to revise, they give it to me. It depends on your employer really."*

The issue with these positive comments about being given sufficient time to study is that there is no significant evidence that any of the students are in fact receiving the required equivalent of one day per week off the job training during non-term time. This is made worse by the fact that many of the apprentices who are at the early years of their apprenticeship in particular, expressing a lack of awareness of the need and the entitlement of 20% off the job training during non-term time.

7. CONCLUSIONS

A key expectation of the degree apprenticeship scheme is that it will facilitate work based learning for the apprentice. Following a review of literature and related documentation, this research attempted to evaluate the apprentice perceptions on the status of work based learning within a selected group of apprentices.

Preliminary observations indicate that whilst there are number of success areas, the extent of room for improvement is also significant. Removal of the burden of having inherit graduate debt and the opportunity to obtain work experience whilst studying for a degree still appear to be the core drivers for engaging in the degree apprenticeship programme by the apprentices. However, evidence of implementation of the specific activities as mandated by the degree apprenticeship standard, and the attainment of work based learning is rather sketchy. This is not to conclude that the activities are not taking place or that work based learning is non-existent, but a recognition that the evidence should be made more explicit. Development of a collaboratively authored and accessed, user friendly, information system may help to overcome some of the difficulties in this regard. Improving the shared understanding of the purpose and the requirements of the degree apprenticeship scheme among apprentices, employers and the university, and development of bespoke work based learning plans based on the work context of each apprentice are some of the suggestions to improve the current delivery. Furthermore, future research requires a greater sample of apprentices be included and the employers' and university staff perceptions be taken into account in order to arrive at more holistic understanding of the current status.

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9. REFERENCES

BEIS (Department for Business, Energy and Industrial Strategy). 2017. *Industrial Strategy: Building a Britain Fit for the Future*. London: HM Government.

Browne, J., 2010. *Securing a sustainable future for higher education: an independent review of higher education funding and student finance*, Department for Business, Innovation and Skills

CITB. 2017. *Industry insights. Construction skills network forecast 2017-2021*. Experian.

Dawson, S., and Osborne, A., 2018. *Reshaping built environment education: The impact of degree apprenticeships* [online], Project Report. Council of Heads of the Built Environment, Available from http://nrl.northumbria.ac.uk/id/eprint/36461 [Accessed 12 Aug 2019]

Garnett, J., 2016. Work-based learning: A critical challenge to the subject discipline structures and practices of higher education. *Higher Education, Skills and Work-Based Learning*, 6(3), pp.305-314.

Gibbs, P. and Garnett, J., 2007. Work-based learning as a field of study. *Research in Post-Compulsory Education*, 12(3), pp.409-421.

Gorschek, T., Garre, P., Larsson, S. and Wohlin, C., 2006. A model for technology transfer in practice. *IEEE software*, 23(6), pp.88-95.

Hernández-March, J., Del Peso, M. M., and Leguey, S., 2009. Graduates' skills and higher education: The employers' perspective. *Tertiary Education and Management*, 15(1), pp.1-16.

House of Commons., 2019. *Apprenticeship Statistics: England,* Briefing paper, Number 06113.

Lambert, S. 2016. Are current accountability frameworks appropriate for degree apprenticeships? *Higher Education, Skills and Work-based Learning*, 6(4), pp.345-356.

Lester, S. and Costley, C., 2010. Work-based learning at higher education level: value, practice and critique, *Studies in Higher Education*, 35(5), pp.561-575.

Naoum, S., 2012. *Dissertation research and writing for construction students*. 3rd ed. Oxon: Routledge.

National Audit Office, 2016. *Delivering Value through apprenticeships programme*, Report by the Comptroller and Auditor General – prepared for the Department of Education, UK.

Richard, D., 2012. *Richard review of apprenticeships*. London: Business, Innovation & Skills.

Ross, A. and Riley M., 2018. Degree apprenticeships: Disruption or business as usual, *Proceedings of the Annual Conference of the Associated Schools of Construction*, Minnesota.

Stewart, V., Campbell, M., McMillan, S.S., and Wheeler, A.J., 2019. Postgraduate work-based learning: a qualitative study. *Higher Education, Skills and Work-Based Learning*, pp.637-649.

Wolf, A., 2011. *Review of Vocational Education–The Wolf Report*, Department for Education, UK.

Hajjath, A.K.M. and Rathnayake, M.D., 2019. Appropriateness of CIDA price fluctuation formula for road construction in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 107-115. DOI: doi.org/10.31705/WCS.2019.11. Available at: https://2019.ciobwcs.com/papers

APPROPRIATENESS OF CIDA PRICE FLUCTUATION FORMULA FOR ROAD CONSTRUCTION IN SRI LANKA

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ABSTRACT

The use of the construction industry development authority (CIDA) formula of price fluctuation will help to claim unpredicted costs in construction projects at least up to a satisfying level. However, some limitations were made when preparing the formula to ease the calculation. Therefore, the project aims to find out the factors affecting the CIDA price fluctuation formula and to identify the appropriate use of the CIDA price fluctuation formula for road construction. A mixed approach was utilized for the study. A broad study of the literature review was intended to a price fluctuation concept and price fluctuation reclamation methods and the significance of road construction projects. The semi-structured and structured close-ended questionnaires were carried out to collect data to identify issues and factors affecting the formula. The qualitative data were analyzed through Qualitative Data Analysis (QDA) Miner lite software while quantitative data were analyzed through SPSS software. A framework was developed concerning outcomes. The price indices, coefficient (0.966), input percentage of construction inputs were found as internal factors which are affecting the formula with their issues and also the difficulties faced while calculation of those internal factors, type of the contract, assumptions which are used to make the formula were found as the external factors. This framework can be recommended to use as a tool before commencing the price fluctuation calculation using the CIDA formula for understanding which factors are mostly helping to increase the appropriateness of the CIDA formula in the road construction sector.

Keywords: *CIDA Price Fluctuation Formula; Price Fluctuation; Road Construction Project.*

1. INTRODUCTION

Due to its standard, easiness and High obtainability of information, the CIDA formula was the most popular and commonly used method in the Sri Lankan construction industry (Dilshani and Disaratna, 2014). According to Dilshani and Disaratna, (2014) the increase or decrease in construction costs was calculated using price indices under a contract of price fluctuation. Generally, the rise or fall in the price of goods, materials, and services was defined as price fluctuation (Mishra and Regmi, 2017). According to Mishra and Regmi (2017), if a contractor bids at a fixed price will face the risk that his payment for material and labor may increase more than the price which was agreed at the tender stage.

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The price of construction inputs can be increased because of the following reasons; disasters by nature, construction demand was increased, rise in rate, and rise in fuel prices (Silva, 2011). The escalation clauses in the contract can be practiced even on average and below-average size constructions because of the changes in the economy due to the prices of gas and oil (Rodriguez, 2018).

The constitution of road construction is a major part of the construction industry for developing the economy of the nation (Kaliba *et al*, 2008). Price fluctuation in the various inputs and the type of project effects the cost escalation factors in between 3.5% < X < 7 % in Transportation projects (Raniga, 2015). According to the Construction Industry Council (2011), by comparing other countries' price fluctuation adjustment practices, it says that a single formula not fits all rules and regulations and also can't satisfy the construction main stakeholders. In Sri Lanka, the price fluctuations were calculated by using formula and traditional methods (Liyanage, 2005). According to Ranathunge (2010), the formula method has an easy and quick process of price fluctuation calculation than the traditional method (As cited at Jayaweera *et al*, 2015). It is better to use the CIDA price fluctuation formula for projects which have lots of work items and gets a longer duration than the traditional method because it is a boring and lengthy task (Jayalath, 2013). According to Jayalath, (2013) the simplified CIDA formula was appropriate for small contracts that have a minor number of works. In another place of his research Jayalath, (2013) stated that the government was approved to use the formula method for price fluctuation compensation and the use of formula method acts as a pointed rule for government projects. The Procurement Guidelines (2006) states that the price fluctuation formula should be inserted in the bidding document as well as in the contract agreement for the Sri Lankan money for construction contracts which have more than 3 months' duration.

The aim of the research is to find out the factors affecting the CIDA formula in road construction and to suggest an appropriate use of the CIDA formula for the construction of roads.

2. LITERATURE REVIEW

Price escalation refers that, the goods and services that have changed over an economic period in their cost or price (Jayasinghe *et al*, 2015). There was an unstable situation in price fluctuation that it was very tough to expect what may be the price of a tender (Douglas, 2010). The contractors were failed to complete their projects within the agreed period and qualify for the client when the prices of construction inputs have been increased (Mishra and Regmi, 2017). World over the necessities of price adjustment as a result of a fluctuation in prices of construction inputs was practiced to prepare bids at the maximum level of accuracy and also to complete the contracts on an even-handed and simply manner (PECI, 2009). Price adjustment provisions/ clauses are included formulas designed to address problems to protect both the borrower and contractors from price fluctuations by allowing contractors to offer more realistic prices at the time of bidding (Asian Development Bank, 2018). CIDA (2007) states the provisions of the price fluctuation under the clause number 13.7, which was titled as "Adjustment for Changes in Cost (in construction)" and also the price fluctuation amount due to the changes in cost of the construction inputs like labour, material and machinery or plant, which was calculated using the formula mentioned in the clause should be added or deducted in contractors' payment. The Procurement Guidelines (2006) states that the price fluctuation formula should be inserted in the bidding document as well as in the contract agreement for the Sri Lankan money for construction contracts which have more than 3 months' duration. For such cases, it is better to go with the CIDA formula even though other recovery methods can be used for price fluctuation calculation (Jayaweera *et al*, 2015.)

2.1 REASONS FOR FLUCTUATION IN PRICE OF CONSTRUCTION INPUTS

An increase in the price of oil in the world market and a new era in technology and a rise in price are some reasons which fluctuate the cost of goods and services (Sendooran, 2005). Even though the country's economy and political issues are cause the fluctuations in the price of oil, the OPEC (Organisation of the Petroleum Exporting Countries) has major constitution in oil price not only that but also the factors of basic demand and supply, costs for production, and percentage of interest (Lioudis, 2018). Hanna and Blair (1993) say that the basic factors which cause the fluctuation in price are the current situation of the market, rise in the price of inputs, Government policies, duties, and political impacts.

2.2 IMPACT OF PRICE FLUCTUATION IN CONSTRUCTION CONTRACTS

Numerous aspects impact the construction project costs like changes in the scope of the project, unpredictable estimation of the project cost, Instruction changes, an extension of time or duration, and the lengthy design stage. But it is essential to consider volatility, not only because of causing price escalations but because of fluctuation in price affects the allocation of resources and decisions which are making for selecting the project (Macdonald, 2013). The difference between final project cost and the initial estimated cost was defined as construction cost escalation (Dawood *et al.*, 2001). Changes in material prices are one of the primary factors which cause the construction cost escalation (Moynihan and Al-Zarrad, 2015). These price increases in construction inputs give rise to entitlements, cost escalation, shortage in housing supply causing in a great cost of urban housing scheme, losing quality in estimation process quickly, difficult to plan a project and also to estimate it, and regular price fluctuation in contracts, as a whole it leads to termination of the project (Nwuba, 2004).

2.3 PRICE FLUCTUATION RECOVERY METHODS PRACTICED BY THE CONSTRUCTION INDUSTRY

According to Liyanage (2005), the parties in construction are using two methods in order to compensate in a contract for fluctuations, i.e. through traditional method the actual cost was paid for the contractor which incurred due to price fluctuation, and through formula method, reliant on the value of work done the contractor was paid for price fluctuation. The contractor was provided with a list of the major inputs like materials, labour, and plant and machinery which will be used in the construction at the time of tender and based on the rates in bill the prices per unit for those inputs will be inserted according to the conventional method (Jayasinghe *et al*, 2015). Suraweera (2001) states that the losses due to cost escalation will compensate by the amount in the contract which was calculated by the formula method and there should be some differences between the usage of formula and traditional methods with the level of recovery.

2.4 CIDA FORMULA METHOD FOR PRICE FLUCTUATION

The contracts in Sri Lanka are administered by the Construction Industry Development Authority (CIDA) of our Country by maintaining the quality of state's-specific documents (Jayalath, 2013). Price fluctuation recovery using formula method is calculating fluctuation amount in a contract by offering a realistic origin for calculation. Project values more than ten million can use the formula method for the contract and it is appropriate for price fluctuation costs inside the nation (Jayaweera *et al.,* 2015). CIDA price fluctuation formula is given in equation (01).

$$F = \frac{0.966(V - Vna)}{100} \sum_{All\ inputs} \frac{Px\ (I_{xb} - I_{xc})}{I_{xb}} \tag{01}$$

Where, V = Valuation of work done for period; Vna = Non-adjustable elements; Px = Input percentage; I_{xb} = Base index for input X, published by CIDA; I_{xc} = Current index for input X, published by CIDA.

De Mel (2008) detailed that there are some assumptions were made to establish the CIDA formula for minimizing the difficulty and developed it as user-friendly. Mainly two assumptions were made when the formula was established, it should be considered as the inputs are evenly spread in the contract (Mel, 2013) and also the major cost was considered as 90 % of the project value and balance should be minor cost, i.e. the major cost recovered when the work items completed up to 40 % (CIDA, 2008). Also, it was assumed the payment for a price adjustment should be paid on a monthly cumulative basis as a part of the monthly interim payment application to the contractor (Jayalath, 2013).

2.5 ROAD CONSTRUCTION INDUSTRY

The infrastructure is vital for the transport of products and ensures business and private travel quality, so the investment needed in infrastructure projects is far higher compared to different tiny building projects (Kaare and Koppel, 2012). Although Sri Lanka's infrastructure was suffered by civil war it has a higher density of roads in South Asia, and the government needs to increase the capacity of roads due to the traffic problems which were encountered while contributing to the maintenance of roads (World Bank, 2016). Due to its long project duration and high investment of money, road construction faces the risks due to price fluctuation. So, it will surely affect the economy of Sri Lanka significantly.

3. RESEARCH METHODOLOGY

A mixed base approach was carried out to attain the research aim which is to. Initially, a deep comprehensive study of literature survey was carried out through previous research papers, government and non-government publications, journals and articles, conference proceedings and internet data to review the price fluctuation concept and the methods of price fluctuation reclamation and the status of road construction in Sri Lanka. Interview guidelines and questionnaires were prepared for data collection. Qualitative data were collected via interviews and the quantitative data were collected via questionnaires to identify and analyse the factors affecting the formula in road construction, classify the issues when applying the formula in road construction projects and to find the limitations with the calculation using the formula in road construction. Data was collected from experts who are working in the construction industry. The analysis of the collected data was done by two different methods. The quantitative data were analyzed through SPSS software and the qualitative data were analyzed through QDA Miner Lite software to develop a framework to minimise future problems of using the formula in road construction projects.

4. RESULTS AND DISCUSSION

4.1 INTERVIEW SURVEY ANALYSIS AND DISCUSSION

After analyzing the received results, it was found that the CIDA formula and FIDIC formula for price fluctuation are a widely used method in the road construction industry. Normally the FIDIC formula is used for foreign-funded projects at the same time the CIDA formula is used for local projects. There are some advantages of Using CIDA formula for price fluctuation in construction contracts. Those are,

- Easy, availability, user-friendly and it should be applicable for any type of contract
- Easy to maintain the cost of construction
- Both client and consultant are benefited
- Simple and less time allocation for calculation
- Some assumptions were made in order to establish the price fluctuation formula which are making the calculation process of the formula easy

4.1.1 Difficulties faced During Calculation Process

Receiving the CIDA bulletin lately is the main difficulty which was faced by the industry. Because it will make the calculation process slow. And the calculation of input percentage is a difficult process and tedious task. Because it requires more time and more documents to calculate that. The items like Tar, Gravel want to be included in the CIDA bulletin. Those materials are major materials that are used in road construction projects. The usage is higher than other materials. At the same time, heavy machinery should be categorized in the bulletin. There are one price indices for all heavy machinery. But the rates between machinery have a huge difference. So, the price fluctuation can be varied.

4.1.2 Factors Affecting CIDA Formula

Fluctuation in material prices is the main factor that is affecting the usage of CIDA formula in road projects. Materials like Asphalt products (Bitumen, Tar), Metal and other major material prices are increasing rapidly. Further, using a large number of precast structures for construction of roads, increase in heavy vehicle usage, road furniture, increase in skilled labor requirements, usage of gravel, etc. Those new aspects are affecting the calculation process of price fluctuation using the CIDA formula. Other than normal assumptions further, they are not considering the CPI (consumer price index), Provisional sum items not considered for the calculation and there are some other assumption like Input indices as per contract, not considering high taxes on imported material, work considered for the IPA (Interim Payment Application) within its month are followed when using the CIDA formula. Highway schedule of rates (HSR) and CIDA bulletin are the main norms used for calculation. The main issues with the Bulletin are, receiving the bulletin lately and the accuracy of Indices is low due to the location changes. The issue in HSR is, the HSR is not updated.

4.1.3 Suggestions for Identified Problems

- Prepare the bulletin in location-wise,
- Receive the bulletin in time
- Increase the accuracy of the bulletin by considering location,
- Separate the indices for every heavy machinery,
- Insert the identified inputs in the bulletin

4.2 QUESTIONNAIRE SURVEY ANALYSIS AND DISCUSSION

Pre-determined questionnaires with 10 optional close-ended questions were provided among 15 practitioners in the industry to collect quantitative data and full freedom was provided to them to select their answer with their experience. All the data collected through the questionnaire were updated in the SPSS software and the results were produced in bar charts. The following findings were revealed from the analysis.

CIDA and the FIDIC formulas are suitable for the calculation of Price fluctuation amount in road construction (see Figure 1).

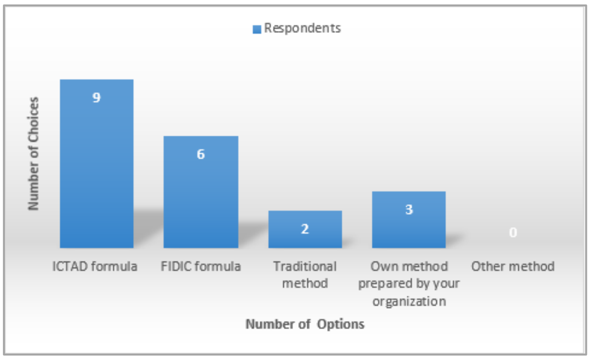

Figure 1: Analysis of questionnaires

But, there should be considerable changes in price indices, total input percentage, coefficient (0.966) to make the CIDA formula more accurate when it is used for road construction. It is important to recall that a cost index measures the price movement for some objects over time and/or location using a series of values.

CIDA suggested a method for input percentage calculation is more suitable for price fluctuation calculation by using the CIDA formula. But some professionals are doing that by using past projects and sometimes in their own experience. Better to maintain input percentage at 90% (refer Figure 2). But sometimes it may be increased according to the contribution of materials. Fuel and bitumen have a high impact on the price fluctuation amount due to the fluctuation in the price of Petroleum.

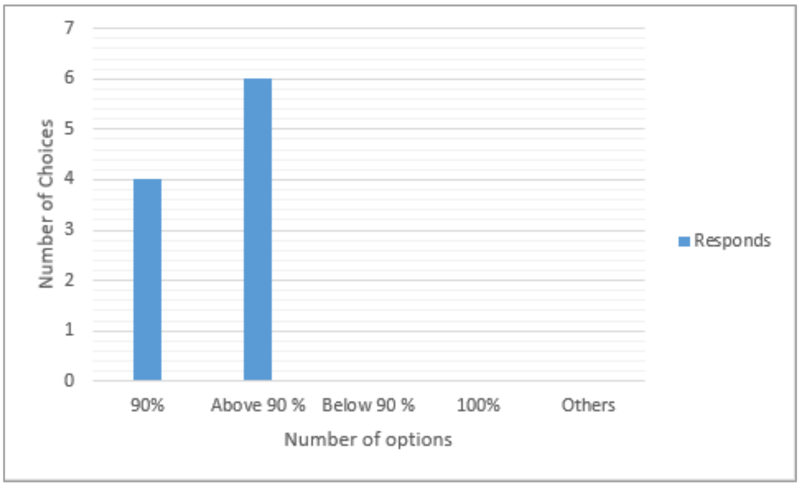

Figure 2: Analysis of suitable input percentage

Materials are not uniformly distributed throughout the construction period. Because the contribution of input material is high in wearing course and finishing course and sometimes in other construction works of roads (refer Figure 3).

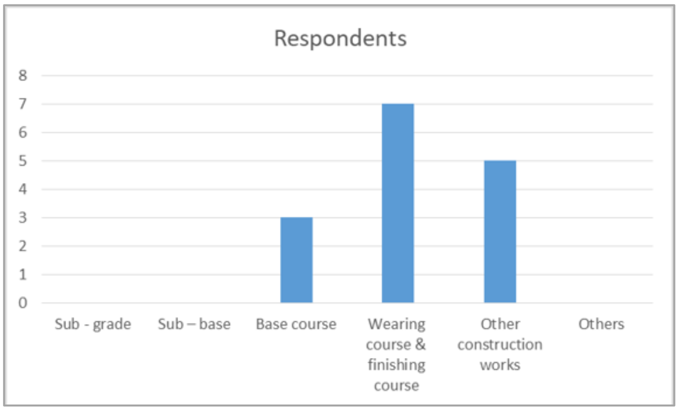

Figure 3: Analysis of material distribution through construction

Using the CIDA formula in fixed contracts can be made a high risk for the client due to the fixed amount. The risk is high when the formula loses the effectiveness in the unit price contract.

5. SUMMARY AND CONCLUSIONS

This study was focused on to find out the factors affect the CIDA price fluctuation formula in road construction projects and to identify the appropriate use of the CIDA price fluctuation formula for road construction. Throughout this study, it was found that normally in the road construction industry they are using CIDA formula than other calculation methods like FIDIC formula. But, FIDIC formula also in practice. That means nowadays in Sri Lanka most of the road construction projects are funded by ADB and other foreign countries. So, they have to follow the FIDIC formula for the construction projects. But from the results were identified that they mostly following the CIDA formula because of the easy, simple and less time consuming and further advantages. As well as there are some considerations and considerable changes want to be there before using the formula as the results of the respondents' opinion. Without those changes, the

CIDA formula is not appropriate to use in road construction. Therefore, improvement efforts need to be taken to improve the current condition.

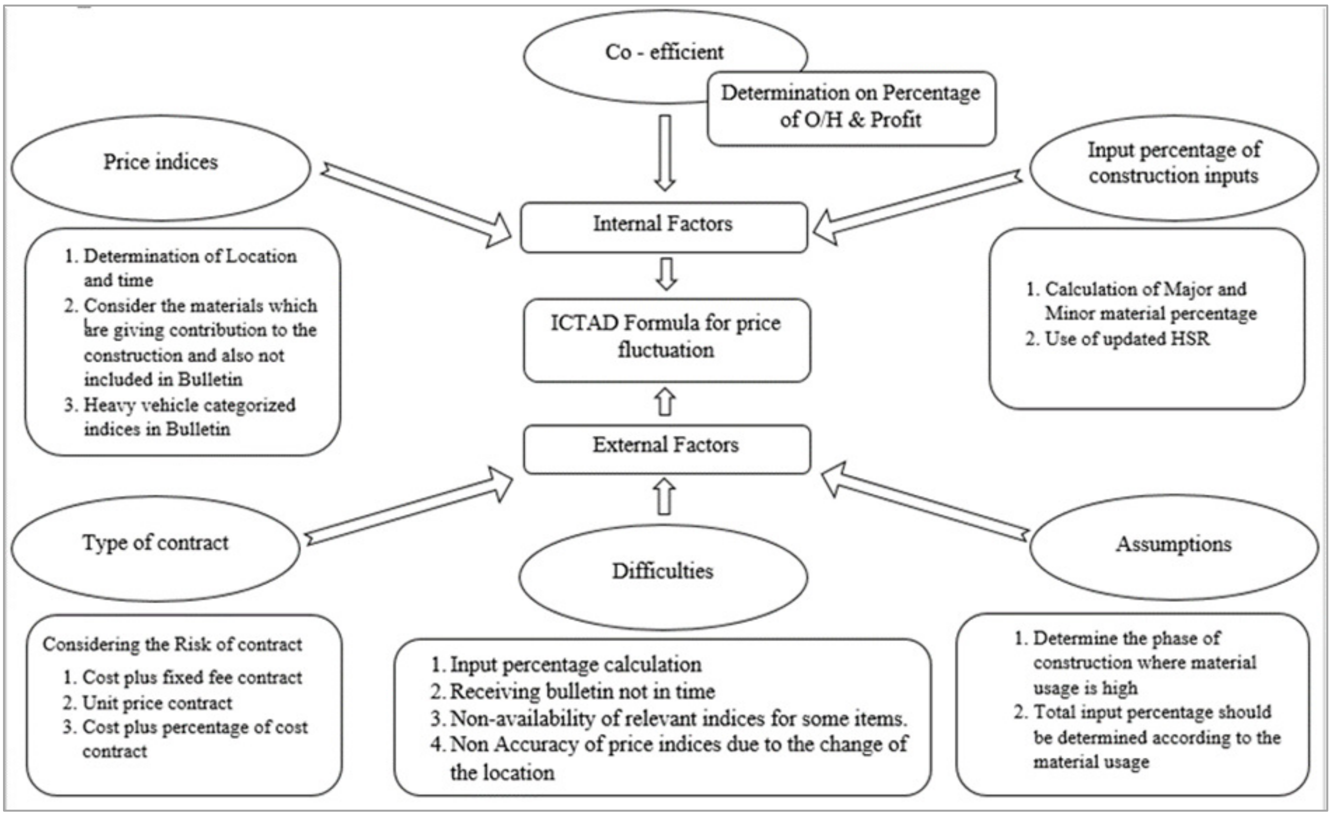

Figure 4: Summary of significant factors affecting CIDA formula in road construction

6. REFERENCES

Asian Development Bank 2018. *Price adjustment guidance note on procurement*. Available from https:// www.adb.org / sites/ default/ files/ procurement-price-adjustment.pdf.

Construction industry council 2011, *Guidelines on contract price fluctuation system*, Hong Kong, CIC.

Dawood, N., Yasuhara, T., Usuda, Y., Matsuda, C. and Sawada, A., 2001. Analysis of cost escalation and risk assessment of infrastructure project. In *Proceedings of 17th Annual ARCOM Conference*, Salford, UK, pp.835-844.

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

Dilshani, L. D. T. and Disaratna, P. A. P. V. D. S., 2014. A Review of CIDA Standard Bidding Document 02 (2007) for Major Contracts. *In Proceedings of the Third World Construction Symposium 2014: Sustainability and Development in Built Environment* (pp.36-46). Colombo: Ceylon Institute of Builders, Sri Lanka.

Douglas, G., 2010. *Agriculture, Roads, and Economic Development in Uganda,* NBER Working Paper No. 15863, and Issued in April 2010, NBER program: PE-PR.

Hanna, A.S. and Blair, A.N., 1993. A Rational Method for the Treatment of Escalation in Construction Costs. *Organisation and Management of Construction the Way Forward*, 1(3), pp.1415-1425.

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

Institute for Construction Training and Development (CIDA), 2008, *ICTAD formula method for adjustments to contract price due to fluctuation in prices*, Colombo, Institute for Construction Training and Development.

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

Jayasinghe, S. A. Y. B., Alahakoon, C. S., and Wijewardena, L. S. S., 2015. Sensitivity of the CIDA Price Fluctuation Formula Procedure for the True Material Price Fluctuations in Construction Industry. *Journal of Engineering and Technology of the Open University of Sri Lanka (JET-OUSL),* 3(1), pp.19-40.

Jayaweera, S.C., Perera, B.A.K.S., and Jayasinghe, S.J.A.R.S., 2015. *Applicability of CIDA price fluctuation formula for Government funded intelligent building projects*. Department of Building Economics, University of Moratuwa, Sri Lanka.

Kaare, K. K. and Koppel, O., 2012. Improving the road construction supply chain by developing a national level performance measuring system. *International Journal of Social and Human Sciences*, 6(2), pp.225-231

Kaliba, C., Muya, M. and Mumba, K., 2009. Cost escalation and schedule delays in road construction projects in Zambia. *International journal of project management*, *27*(5), pp.522-531.

Lioudis, N.K., 2018. *What causes oil prices to fluctuate*? Available from https:// www.investopedia.com/ ask/answers/ 012715/what-causes-oil-prices fluctuate.asp.

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

Macdonald, R., 2013. *Cost risk mitigation on construction projects*, University of Alabama, Tuscaloosa, Alabama, August 2013.

Mel, J.D., 2013, *Basic concepts and logical approach of CIDA formula*, Colombo, CIDA.

Mishra, A.K. and Regmi, U., 2017. Effects of Price Fluctuation on the Financial Capacity of "Class A" Contractors. *International Journal of Creative Research Thoughts*, *5*(4), pp.1920-1937.

Moynihan, G.P., Al-Zarrad, M.A., 2015. Application of Hedging Principles to Construction Material Cost Risk Mitigation in Construction Projects. *International Journal of Construction Engineering and Management*, 4(5), pp.180-190.

National Procurement Agency, 2006, January. *Procurement Guideline 2006: Good and Works [online]. Colombo*: Department of Government Printing. Available from: www.treasury.gov.lk // ProcurementGuidelines2006 _ amded12June.pdf [Accessed 20 April 2014].

Nwuba, C., 2004. An analysis of housing construction costs trends in Nigeria, 1986-2002. *The Quantity Surveyor*, 47, pp.4-9

PECI, 2009. *Standard Procedure and Formula for Price Adjustment*. Pakistan Engineering Council, Islamabad.

Raniga, P., 2015. Cost Escalation in Road and Rail Construction Projects - NSW Experience. *In Proceedings of Australasian Transport Research Forum 2015*.

Rodriguez, J., 2018. *How to Include Price Escalation Clauses in a Construction Contract*. Retrieved from https:// www. thebalancesmb. com/ escalation- clause- construction- contracting- 844531

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

Silva, L., 2011. Forecasting of Cost Escalations in Post Disaster Construction with Tsunami Reconstruction in Sri Lanka. *Built-Environment Sri Lanka,* 09(01- 02), pp.56-63.

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

World Bank, 2016. *10 Years of Better Roads in Sri Lanka*. Retrieved from, http://www.worldbank.org/en/news/feature/2016/05/05/10-years-of-better-roads-in-sri lanka

Bevan, W.J. and Nolan, L., 2019. Barriers for renewable technology in commercial buildings. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 116-124. DOI: doi.org/10.31705/WCS.2019.12. Available at: https://2019.ciobwcs.com/papers

BARRIERS FOR RENEWABLE TECHNOLOGY IN COMMERCIAL BUILDINGS

W.J. Bevan[1] and L. Nolan[2]

ABSTRACT

Policies within the United Kingdom (UK), such as the Renewable Energy Strategy, demand the construction sector to adopt renewable technology within buildings. Moreover, as commercial buildings are responsible for 14% of the total UK carbon emissions, building professionals are required to integrate renewable technology within these properties to assist the targets. Despite the policies, the UK renewable technology uptake remains low. Within this context, existing literature identifies the barriers to the adoption of renewable technology in buildings. There are few studies, however, concerning the current uptake of renewable technology in commercial buildings, in addition to little detail of solutions to the barriers experienced by the construction sector. A study was conducted to investigate the integration of renewable technology in UK commercial buildings. Data collection consisted of a literature review, a survey involving 30 construction professionals and two semi-structured interviews with an engineer and a programme manager. Findings evidenced a range of social, economic, and technical barriers for the adoption of renewable technology in buildings. Primary data results support concerns of the financial cost associated with the technology, along with greater detail to explain the barriers associated with awareness, a lack of experience and knowledge of renewable technology options for integration within commercial buildings. Finally, in contribution to theory, results evidence similar findings to existing literature published over 10 years ago, which indicates the need for future research to study solutions to the barriers of renewable technology adoption in commercial buildings.

Keywords: *Commercial Buildings; Renewable Technology; Renewable Technology Barriers; Sustainable Buildings.*

1. INTRODUCTION

To aid the strict carbon emission reduction targets within the United Kingdom (UK), there are a number of strategies in place to encourage the generation of renewable energy. The key policies include the Non Fossil Fuel Obligation (NFFO), the Renewables Obligation (RO) (Parkes, 2012) and the UK Renewable Energy Strategy (HM Government, 2009). As a result of the strategies, which demand 30% of electricity and 12% heat generation from renewable energy by 2020 (HM Government, 2009), pressures are placed on the construction sector to integrate renewable technology within buildings. More specifically, as commercial buildings contribute to 14% of UK carbon emissions (PIA, 2016), the construction sector is required to recognise the potential for renewable technology adoption within these properties. Moreover, to enhance the uptake of renewable

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technology, financial incentives, such as the Feed-in tariff (FIT) and the Renewable Heat Incentive (RHI), have been implemented by government.

Despite the UK policies, renewable technology contributed to 22.3% of the UK energy market for power generation in 2015 and 4.6% of heat in 2014 (REA, 2016), which highlights the need for progress towards technology adoption in order to meet the 2020 targets. In an attempt to provide insight on the lack of renewable technology integration in buildings, prevailing literature states a number of barriers to technology adoption. The barriers include, but not exclusive to, economic, political, social and technical challenges. The problem, however, concerns the few investigations that focus on the uptake of renewable technology for commercial buildings. It appears to be the case that a large proportion of investigations study technology uptake within residential properties.

To worsen the problem, literature on the topic of renewable technology integration in buildings along with associated barriers to technology integration, are slightly out of date. There are valuable insights on the subject and detailed barriers to explain the lack of renewable technology uptake by different shareholders, but the research is approximately 10 or more years out of date. Furthermore, there appears to be little detail of solutions to the challenges for renewable technology adoption in buildings.

This paper investigates the barriers for the integration of renewable technology within commercial buildings. The research is novel as it provides empirical evidence in relation to the uptake of renewable technology by the construction sector. In addition, the study aims to enhance existing theory through the identification and explanation of barriers for the adoption of renewable technology within commercial buildings.

The paper is structured as follows. First, prevailing literature on the subject is reviewed. Second, the research design and methods are detailed. Third, the results and discussion are presented. Finally, the conclusions and contribution to theory are provided, along with the limitations to the study and further areas for research.

2. RENEWABLE TECHNOLOGY ADOPTION FOR SUSTAINABLE BUILDINGS

2.1 BARRIERS TO RENEWABLE TECHNOLOGY

Current construction innovation literature provides valuable insights on the barriers to renewable technology integration in buildings. A barrier can be known as "man-made factors or attributes of factors that operate in between actual and potential renewable energy (RE) development or use" (Verbruggen *et al*., 2010: p. 852), which can be intentional or unintentional. The dominant barriers described in the literature are connected to social, economic and political barriers, in addition to the technology specific barriers. The boundaries between each classification, however, are not distinct.

2.1.1 Social Barriers

Social barriers are associated with a lack of awareness of renewable technology options available to citizens (Menz, 2005), in addition to a lack of information and knowledge provided to the public, which can be crucial in the early stages of technology uptake (Neuhoff, 2005). To worsen the problem, the lack knowledge among adopters can then lead to an improper use or inability to maintain renewable systems (Karakaya *et al*., 2015).

2.1.2 Economic Barriers

The cost associated with technology adoption has been highlighted as the most significant barrier to the integration of RE projects (Balcombe *et al*., 2013). Economic challenges are primarily associated with either the initial capital costs or the payback periods for the renewable technology. High costs and long payback periods can hinder the desire for technology investment and current policies appear to be failing to address the barrier. Policies, such as the FIT, have been implemented to aid the expense of solar technology integration, a technology which is deemed to not be of profit without policy support (Karakaya, 2015). Moreover, the perception of cost appears to be a barrier. It can be the case where the initial expense of renewable technology installation is perceived high, or assumed far greater than the actual cost (Koinegg *et al*., 2013).

2.1.3 Political Barriers

In order to drive the uptake of renewable technology and help achieve its full potential, stable and consistent policy frameworks, in particular policies aimed at improving risk and reward associated with the technology, are required (Foxon *et al*., 2005). Government can promote investment in technology through appropriate financial support, guidance and understandable frameworks.

2.1.4 Renewable Technology Specific Barriers

To gain an understanding of the technical barriers to renewable technology adoption in buildings, previous investigations appear to link the technical barriers to the technology itself. As Table 1 (shown below) evidences, challenges can be unique to the individual renewable technology or the energy system adopted within buildings.

Table 1: Technology specific barriers

Technology	Barriers (literature source)
Solar Energy	• The architecture of an area; limited space and roof tops in urban areas. • Lack of knowledge, improper use and insufficient maintenance. • Lack of appropriate management • Cost of the technology and perception of cost. (Karakaya and Sriwannawit, 2015) • Negative public perception. • Regulatory barriers. (Solar Electric Power Association, 2002)
Biomass	• Uncertainty of biomass resource availability. • Not financially competitive to conventional fossil fuels. (Rourke *et al*., 2009) • Lack of knowledge in regard to the technology, surrounding policies and finance. (Foxon *et al*., 2005)
Combined Heat and Power (CHP)	• Long payback periods • Commercial risk. • A lack of clear, long-term policy frameworks and incentives. (Foxon *et al*., 2005)

2.2 SUSTAINABLE COMMERCIAL BUILDINGS

As commercial property in the UK accounts for 13% of the built environment (PIA, 2016), there is significant potential for the sector to contribute to carbon emission reduction targets. Furthermore, due to the increasing desire to describe UK commercial property as 'sustainable' (Rydin, 2014), there is greater encouragement to consider the integration of renewable technology within these buildings.

Existing studies highlight and suggest a diverse number of barriers to explain low levels of renewable technology adoption, which include social, political and technical. Much of the literature, however, is focussed on residential building and is out of date. There is a need for empirical evidence on the current uptake of renewable technology in commercial buildings, along with additional insight of the challenges to the adoption and integration of the technology.

3. RESEARCH DESIGN AND METHODS

In line with aims and objectives of the study, the research adopted a qualitative approach to the investigation. Both primary and secondary data were required for the investigation in order to understand the current problem surrounding renewable technology integration in buildings, in addition to gaining insight into the adoption of the technology in commercial properties. Prior to data collection, ethics forms were completed and submitted to the University Ethics Committee.

3.1 DATA COLLECTION

The data collection consisted of a critical literature review, a survey and interviews with professionals of the building industry.

3.1.1 Literature Review

Secondary data collection involved a critical literature review of current construction innovation literature. The prevailing literature offered insight into the existing barriers towards renewable technology adoption in UK buildings, along with guidance for the interviews with professionals of the building industry.

3.1.2 Surveys

Primary data collection consisted of a survey involving professionals of the built environment, which identified perceptions of renewable technology and barriers to technology integration in commercial buildings. As the research focus was commercial buildings, those professionals involved in the specification of renewable technology integration in commercial properties were selected. Purposive sampling was adopted (Kelley *et al*., 2003), where a specific group of building services consultant engineers were selected in order to survey participants that had an understanding of the renewable technology specification for commercial buildings. Due to the provision of real-time, up-to date empirical data and the potential to produce a great deal of data in a short amount of time (Kelley *et al*., 20013), an online survey was the chosen method for the investigation. The survey questions were created based on the aims of the research by using an online tool, known as Survey Monkey. Surveys were circulated using a web-link, which allowed the specific sample of participants to complete the survey, along with participant anonymity.

3.1.3 Semi-structured Interviews

A primary data collection also adopted semi-structured interviews with professionals of the built environment. Candidates were selected in terms of involvement in the design and specification of renewable technology integration in UK commercial properties. Participant 1, a consultant engineer, was selected as a large proportion of the survey responses (63.33%) were completed by individuals in this job role. Participant 2, a manager of an NGO, was selected as a significant proportion of surveys suggested renewable technology adoption involved the client and developer understanding of the technology. Prior to interviews, an interview protocol was prepared and pretested. The interviews were carried out face to face and tape recorded. Following the interview, recordings were transcribed verbatim.

3.2 DATA ANALYSIS

The data collected was analysed in line with the aims of the research. Microsoft Excel was used to collate and display the survey responses for analysis, primarily the arrangement of answers in table and graphical format. To analyse the interviews conducted, content analysis was adopted (Bryman, 2016). Content analysis is referred to as a technique or research method adopted for the interpretation of data and identification of themes and patterns (Hsieh and Shannon, 2005; Bryman, 2016). Guided by the research aims and insight from the existing literature, the interview transcripts were studied for themes that emerged from the data.

4. RENEWABLE TECHNOLOGY ADOPTION FOR COMMERCIAL BUILDINGS

The investigation provided insight into perceptions of renewable technology from professionals within the built environment, along with empirical evidence to highlight the adoption and integration of the technology in commercial buildings. Respondents included consultant engineers (63%), architects (17%) and contractors (10%), in addition to a programme manager and a BREEAM assessor. The survey and interviews evidenced diverse levels of understanding associated with the renewable technology from the variety of construction sector roles. In addition, the primary data emphasised the complexity surrounding the integration of renewable technology in commercial buildings, i.e. the variety of barriers stated by building professionals.

4.1 TYPES OF RENEWABLE TECHNOLOGY

The research suggests there is an uptake of specific types of technology within commercial buildings. The surveys, for instance, evidenced the most common features adopted for commercial buildings were lighting, mechanical ventilation with heat recovery (MVHR) and photovoltaic (PV) panels, which suggests consideration of fabric measures. This was also supported in an interview with the engineer who indicated the value of energy efficient measures and the 'fabric first' approach, by mentioning *"…fabrics are becoming more energy efficient and certainly glazing needs to be really looked at…"*

Following the selection of what can be known as fabric methods (e.g. LED lighting and MVHR), solar PV, solar thermal, air source heat pumps (ASHP) and biomass were the technologies most discussed in terms of integration for commercial buildings. As the engineer stated,

> *"[in terms of technology for commercial buildings] I probably just know the standard ones, such as [solar] PV, solar thermal for hot water, biomass and I am aware of wind turbines, but they are not very cost effective for commercial properties." In further support, the programme manager expressed, "we have case studies where a lot of our members have installed PVs... we have a really good one from ASHP where British land at regent's place removed their gas boilers and installed an ASHP and reduced gas consumption by about 80%..."*

4.2 BARRIERS TO RENEWABLE TECHNOLOGY

In regard to the adoption of renewable technology and its selection for commercial buildings, the results evidenced primary barriers associated with these technologies (see Table 2 below). The dominant barriers can be broadly classified as economic, social and technical barriers.

Table 2: Barriers to the adoption of renewable technology

Survey response to barriers of renewable technology adoption within UK commercial buildings	Frequency of respondents
Cost	26
Lack of experience/knowledge/awareness	8
Financial return	8
Client/developer	7
Planning permission	3
Aesthetics	1
Design limitation	4

4.2.1 Economic Barriers

Findings evidenced a high level of concern, 87% of respondents surveyed, in terms of the cost associated with the adoption of renewable technology in commercial buildings. Within this context, cost was associated with the initial capital required for the technology and the payback period, once the technology has been adopted. These findings support the literature that state a primary barrier of renewable technology are concerns for the upfront costs and payback periods (Balcombe, *et al*., 2013). To further enhance the literature, this research suggested payback periods longer than 10 years were the issue. As stressed by the Senior Mechanical Engineer, for instance, *"…the client will probably be reluctant to pay for something, especially when the payback is more than 5 – 10 years."*

4.2.2 Social Barriers

The surveys highlighted a large proportion of respondents were aware (53%) or very aware (40%) of renewable technology options for commercial buildings. The interviews, however, provided insight of renewable technology awareness by building professionals, as mentioned a "*limited knowledge of renewables"* (engineer) and "*lack of understanding [of renewables] and knowledge of what is available*" (programme manager). The building professionals provided greater insight into the challenges towards a lack of renewable technology knowledge and its integration in commercial buildings, which can be linked to additional barriers. The level of knowledge and awareness of the renewable technology, for example, in addition to further impact of the barrier, was captured during an interview with the programme manager, who expressed,

> *"there is also bad examples of combined heat and power and lack of understanding from the industry in having the people who are able to run them, commission them and operate them…they [renewable technology] are not being used appropriately, they've been oversized so not fit for purpose."*

In greater support of the issues associated with understanding renewable technology adoption for commercial buildings, the engineer stated,

> *"a few years ago I did an exercise on biomass boilers…the reality of getting the pellets and trying to speak to people who understood what pellets were, trying to understand deliveries…renewable energy is a good thing, it just needs everyone to get more on board and make sure we know what is out there."*

The findings highlight there is an awareness of renewable technology and attempts by building professionals to understand the technology most appropriate for commercial buildings. There is a contrast with the prevailing literature due to ideas surrounding a lack of awareness of renewable technologies (Menz, 2005). There are studies, however, that offer insight for technology awareness in terms of the public and building end-users, as opposed to building professionals. Despite the individuals being studied, results resonate with previous research that states there is a need to enhance knowledge surrounding the integration of renewable technology.

4.2.3 Technical Barriers

Finally, the results provided indication where issues the renewable technology itself acted as a barrier to its adoption within commercial buildings. This is different to the above where the technology was deemed as costly or not understood, but a challenge due to its integration within or on the commercial building. The concerns with the renewable technology itself was evidenced by the programme manager, who stated,

> *"…the concerns regarding the technology, they [real estate] will always look for case studies to make sure that anything they are installing is tried and tested and assured…they [the renewable technology] are not being used appropriately, they've been oversized so not fit for purpose, issues with the technology not running properly but then that is sort of expected for new technology..."*

5. CONCLUSIONS

The investigation has highlighted the complexity associated with the adoption of renewable technology in buildings, in addition to empirical evidence of the uptake and challenges of technology integration within commercial buildings. Prevailing literature demonstrates a range of barriers for renewable technology uptake in buildings, in addition to issues specific to the type of technology. This research investigation supported the dominance of economic barriers towards the adoption of renewable technology in commercial buildings, in terms of initial capital costs and payback periods. The findings also evidenced a lack of technology awareness, understanding and experience in regards to challenges for the adoption of technology. Moreover, by discussing the barriers with construction professionals, the investigation extended existing ideas to highlight the potential wider impacts associated with limited awareness, knowledge and experience with the renewable technology.

5.1 CONTRIBUTION TO THEORY

The research supports previous studies in terms of the barriers to renewable technology adoption. The dominance of economic barriers, for example, along with evidence of social challenges and an understanding of the technology. This study enhances the literature to investigate commercial buildings and further highlight the complexity associated with renewable technology awareness and understanding. Moreover, results evidence similar findings to existing literature published over 10 years ago, which indicates the need for future research associated with solutions to the barriers of renewable technology integration in commercial buildings.

5.2 LIMITATIONS OF THE STUDY

The empirical evidence was based on a small sample of building professionals from an online survey (30 responses) and 2 interviews. Although the participants involved in the study did have a range of job roles, it would be valuable to conduct primary research involving diverse job roles within the built environment. The lack of relevant literature was also a limitation within the study. It would be beneficial to access more recent studies to the barriers of renewable technology, particularly as the technology and policy frameworks are constantly evolving and being updated.

5.3 FURTHER AREAS OF RESEARCH

Further research within the area of renewable technology adoption in commercial buildings will involve a larger sample size of building professionals and a greater number of interviews. A study that expands the sample size to potentially include diverse roles of building professionals involved in the selection and integration of renewable technology, is proposed. By enhancing the sample size, the investigation may also provide insight into the solutions to the barriers identified towards technology adoption in commercial buildings.

6. REFERENCES

Balcombe, P., Rigby, D. and Azapagic, A., 2013. Motivations and barriers associated with adopting microgeneration energy technologies in the UK. *Renewable and Sustainable Energy Reviews,* 22(1), pp.655-666.

Bryman, A., 2016. Social research methods. 5th Edn. Oxford, UK: Oxford University Press.

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A. and Anderson D., 2005. UK Innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. *Energy Policy,* 33(1), pp.2123-2137.

HM Government. 2009. The UK renewable energy strategy. [Online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228866/7686.pdf [Accessed 11 February 2019].

Hsieh, H.-F. and Shannon, S. E., 2005. Three approaches to qualitative content analysis. *Qualitative Health Research,* 15(9), pp.1277-1288.

Karakaya, E. and Sriwannawit, P., 2015. Barriers to the adoption of photovoltaic systems: The state of the art. *Renewable and Sustainable Energy Reviews,* 49(1), pp.60-66.

Kelley, K., Clark, B., Brown, V. and Sitzia, J., 2003. Good practice in the conduct and reporting of survey research. *International Journal of Quality in Health Care,* 15(3), pp.261-266.

Koinegg, J., Brudermann, T., Posch, A. and Mrotzek, M., 2013. "It would be a shame if we did not take advantage of the spirit of the time" An analysis of prospects and barriers of building integrated photovoltaics. *Ecological Perspectives for Science and Society,* 22(1), pp.39-45.

Menz, F., 2005. Green Electricity Policies in the United States: Case Study. *Energy Policy,* 33(18), pp.2398-2410.

Neuhoff, K., 2005. Large-scale deployment of renewables for electricity generation. *Oxford Review of Economic Policy,* 21(1), pp.88-110.

Parkes, R., 2012. Can the UK meet its renewable targets?. *Renewable Energy Focus,* 13(1), pp.24-27.

PIA (Property Industry Alliance), 2016. Property data report 2016 [Online] Available from: http://www.bpf.org.uk/sites/default/files/resources/PIA-Property-Report-2016-final-for-web.pdf [Accessed 14 February 2019].

REA *(Renewable Energy Association),* 2016. Overview of UK's renwable energy growth [Online] Available from: http://www.r-e-a.net/blog/overview-of-the-uks-renewable-energy-growth-08-06-2016 [Accessed 10 February 2019].

Rourke, F. O., Boyle, F. and Reynolds, A., 2009. Renewable energy resources and technologies applicable to Ireland. *Renewable and Sustainable Energy Reviews,* 13(8), pp.1975-1984.

Rydin, Y., 2014. *Sustainable Commercial Property*, London: UCL Bartlett School of Planning.

Solar Electric Power Association, 2002. *Solar Power Solutions: A business Case for Capturing Total Value,* Annandale, VA: Global Environment and Technology Foundation.

Verbruggen, A., Fischedick, M., Moomaw, W., Weir, T., Nadaï, A., Nilsson, L.J.. Nyboer, J. and Sathaye, J., 2010. Renewable energy costs, potentials, barriers: Conceptual issues. *Energy Policy*, 38(1), pp.850-861.

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BEYOND BARRIERS: EXPLORING THE CONSIDERATIONS HINDERING THE ADOPTION OF GREEN CONSTRUCTION FROM A BEHAVIOURAL ECONOMICS PERSPECTIVE

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ABSTRACT

Several academic researchers have investigated the barriers inhibiting the adoption of green construction. Numerous interventions including raising awareness through educational forums, monitoring and enforcement programmes, and financial incentives have been recommended as strategies to encourage the wider adoption of green construction. However, most of these interventions have failed to address the low adoption of green construction. This raises the question 'Why'? Drawing on the insights from Behavioural Economics, specifically Game Theory and Prospect Theory, and the broad social sciences, it is proposed that it is at the individual level of choice that building construction stakeholders are reluctant to adopt green construction, and building construction stakeholders' decision-making is influenced by the confluence of 'elements' which bring about the tendency for them to prefer non-adoption to adoption. Following this, this paper aimed at exploring the 'considerations' that can underlie the tendency for building construction stakeholders to prefer non-adoption to adoption through a literature review. Four key considerations were found. They are dilemma concern, trust in others' actions, fear of being a sucker, and short-term self-interest. It is concluded that, when given empirical support, policies to increase adoption of green construction should address whichever consideration(s) that strongly hinder green construction adoption in a particular setting.

Keywords: *Barriers; Behavioural Economics; Decision-Making; Game Theory; Green Construction; Policies; Prospect Theory.*

1. INTRODUCTION

As a result of the construction industry's huge environmental footprint, 'sustainable construction' was officially proposed in 1994 at the First International Conference on Sustainable Construction (Hill and Bowen, 1997). According to Hill and Bowen (1997),

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the conference convener proposed that sustainable construction means 'creating a healthy built environment using resource-efficient, ecologically-based principles'. Since then, the terms 'sustainable construction', 'green construction', and 'green building' amongst others are used interchangeably to refer to the pursuance of sustainability in the construction industry (Kibert, 2007). However, Kibert (2007) suggests that 'sustainable building' or 'green building' best describes the product of 'sustainable construction' or 'green construction'. Therefore, in this paper, the term 'green construction' is used and it is defined as *the use of healthier and more resource-efficient techniques and materials to deliver a building project*.

Even though there is a high-level consensus for the green construction agenda, building construction stakeholders are reluctant to adopt it (Shari and Soebarto, 2014; UN Environment and International Energy Agency, 2017; Dwaikat and Ali, 2018; Yu *et al*., 2018; Martek *et al*., 2019). Several countries, both developed and developing have instituted a plethora of policy tools and mechanisms to promote the adoption of green construction, yet, its extensive adoption is lacking. According to Wadu Mesthrige and Kwong (2018), the Hong Kong construction industry is lagging behind in the implementation of green construction despite all the efforts by the government to enhance public awareness, encourage property developers to embrace green building features, and improve green construction standards through a variety of programs. In Hong Kong, there has been considerable effort to promote green construction through a variety of programs for the past 10-15 years (Wadu Mesthrige and Kwong, 2018). Examples of such policy tools include Indoor Air Quality Management Programme and the Hong Kong Building Environmental Assessment Method [HK-BEAM]. In Malaysia, the government has introduced major regulatory and incentive policies to drive forward the green construction agenda (Shari and Soebarto, 2014, Algburi *et al*., 2016, Zaini and Endut, 2018). Quoting Isa *et al*. (2018), *"the government has introduced major incentives to foster green building investment…in the public and private sectors in Malaysia"*. However, these policy implementation efforts do not lead to extensive adoption and implementation of green construction in Malaysia (Shari and Soebarto, 2014; Isa *et al*., 2018; Zaini and Endut, 2018). Zhang *et al*. (2011c) also questioned why residential developers in China are not adopting green construction in spite of the strong green 'market' environment and the plethora of policy tools and mechanisms. Windapo and Goulding (2015) have also added that the implementation of green construction in South Africa is 'behind the expectations' raised by the legislations enacted to promote it. This misalignment between the high-level consensus and actual behaviour raises the question: why? Consequently, this study seeks to explore the considerations in the decision-making[5] that will bring about the tendency for building construction stakeholders to prefer non-adoption to adoption even though (a) almost everyone believes green construction is beneficial, and (b) a wide range of policy tools and mechanisms for the promotion of green construction such as educational campaign and financial incentives have been instituted.

Behavioural Economics has provided insights into the drivers of human behaviour. From the perspective of Behavioural Economics, a more representative model of human behaviour takes into consideration a range of factors comprising self-interest, social norms, levels of trust, defaults etc. It has also proven that it is due to the way intervention are framed, the methods through which they are transmitted, and the decision-making

[5] It is the individual-level decision-making (see Hammond *et al.,* 2019 for an explanation of the decision-making process).

environment, that impact how people respond to them. Applying insights from Behavioural Economics, this study argues that, the choice between non-adoption and adoption is driven by an interacting array element (see section 3). The interaction of these elements complicates issues at the individual level of choice, making building construction stakeholders reluctant to adopt green construction i.e. tend to prefer non-adoption to adoption. From this background, a range of *considerations* hindering the adoption of green construction, and more importantly drivers of non-adoption are identified through a literature review.

The paper is structured as follows: section two presents a review of the existing literature to provide the background to the study. Section three presents the theoretical foundation of the study. Section four outlines the considerations hindering the adoption of green construction. Section five concludes the paper.

2. LITERATURE REVIEW

Several academic studies have investigated the barriers hindering the adoption of green construction. The dominant narrative is that the major barriers hindering the adoption of green construction are lack of awareness and education, lack of regulations and building codes, high cost etc. (see Table 1).

Table 1: Barriers hindering the adoption and implementation of green construction

Barriers	Supporting references
High cost; lack of awareness and education; lack of financial incentives; lack of building codes and regulations	Zainul Abidin (2010); Zhang *et al*. (2011a); Zhang *et al*. (2011b); Zou and Couani (2012); Djokoto *et al*. (2014); Shari and Soebarto (2014); Ametepey *et al*. (2015a); Saleh and Alalouch (2015); Chan *et al*. (2018); Russ *et al*. (2018); Wadu Mesthrige and Kwong (2018)
Lack of demand	Djokoto *et al*. (2014); Daniel *et al*. (2018)
Insufficient codes and regulatory policies from government	Hoffman and Henn (2008); Djokoto *et al*. (2014); Gluch *et al*. (2014); Ametepey *et al*. (2015a); Ametepey *et al*. (2015b); Saleh and Alalouch (2015); Azeem *et al*. (2017); Zaini and Endut (2018)
Lack of knowledge and awareness	Choi (2009); Zainul Abidin (2010); Djokoto *et al*. (2014); Shari and Soebarto (2014); Zhai *et al*. (2014); AlSanad (2015); Ametepey *et al*. (2015b); Windapo and Goulding (2015); Saleh and Alalouch (2015); Bohari *et al*. (2016); Azeem *et al*. (2017); Nguyen *et al*. (2017); Wang *et al*. (2018)
Lack of financial incentives	Choi (2009); Zhang *et al*. (2012); Azeem *et al*. (2017); Chan *et al*. (2018); Wadu Mesthrige and Kwong (2018)
Over-discounting the future, egocentrism, positive illusions, presumed associations, mythical fixed-pie, environmental literacy	Hoffman and Henn (2008)
Cultural change resistance; lack of commitment; long payback periods; tendency to maintain current practices	Zou and Couani (2012); Ahn *et al*. (2013); Ametepey *et al*. (2015a); Ametepey *et al*. (2015b)

Therefore, these studies suggest that educational campaigns and financial incentives will positively impact on the adoption of green construction by increasing awareness, as well as change cognitive assessment of cost and benefits (Olubunmi *et al*., 2016).

On the contrary, Ofori and Kien (2004) pointed out that, architects in Singapore indicated they are aware of the environmental impacts of buildings and knowledgeable about possible measures which would help avoid these problems. However, they seem to be unable to translate their environmental awareness and knowledge into appropriate design solutions (Ofori and Kien, 2004). Why? Ajzen *et al*. (2011) conducted four studies that examined the relationship between knowledge and behaviour and concluded that having accurate information about an issue can be irrelevant for behaviour. Kollmuss and Agyeman (2010) also indicated that the question of what influences pro-environmental behaviour is a complex one that cannot be visualized through a single framework. Furthermore, a meta-analysis on factors that have been found to have some influence, positive or negative, on pro-environmental behaviours concluded that 80% of the factors did not result from knowledge and awareness (Kollmuss and Agyeman, 2010).

Most developers and building owners in Malaysia were concerned about having their buildings built at the minimum cost without giving so much thought about energy efficiency as it was considered an economic waste due to the subsidized electricity tariffs (Shari and Soebarto, 2014). In the same study, the majority of the respondents regarded minimizing the initial capital cost as more important than the long-term operational cost minimization which is a key attribute of green buildings (Shari and Soebarto, 2014). According to Deng *et al*. (2018), property developers in China claimed there is around 20% of additional time spent on designing green buildings compared to conventional buildings, and they are not willing to sacrifice such extra time expense. Developers in China also believe that the decision to choose to not do green construction is a safe choice, otherwise, they will incur 'unnecessary' cost which cannot help them be competitive in the market (Zhang *et al*., 2011c). Perception about complex project delivery process impedes green construction (Zhang *et al*., 2012). Transaction costs act as a disincentive for developers (Qian *et al*., 2015). Perception of a sophisticated level of expertise required to fabricate and install green building features hinder its adoption (Li *et al*., 2014). Ahn *et al*. (2013) also acknowledged that, long payback periods associated with investing in green buildings act as a deterrent.

Du Plessis (2007) asserted that, even when technology is available, and an enabling institutional environment has been created, it is a choice to adopt the technologies and make use of the opportunities created. Yet, with a large number of studies investigating why there is less adoption of green construction, all these studies have overlooked the influence of decision-making, and particularly the influence of the individual-level building construction stakeholder decision-making on the adoption of green construction. This is understandable because, the delivery of a building project is a complex process as (a) it involves numerous stakeholders with potentially incompatible concerns, and (b) there are a plethora of procurements methods which determines which of the numerous stakeholders' take overarching decisions with regards to the adoption or non-adoption of green features in a building project. For example, there are instances where a 'green building' has to be requested by a client and this request will be executed by a group of professionals for the client. While in some cases, e.g. real estate development, buildings are ready-made, and consumers just have to purchase. In this case, the decisions to adopt or not adopt green features lies with the professionals involved in the development.

Therefore, decision-making with regard to the adoption or non-adoption is generally regarded as complex and attributed to the group i.e. group decision processes (Mok *et al*., 2018). However, it has been shown that it is valuable to study individual-level decision-making because groups consist of individuals, which creates a feedback mechanism between the individuals within the group and the group as a unit (Savage, 2018). Also, beliefs that are commonly held by a significant number of individuals becomes the incumbent group belief, which is transmitted back to the group to be adopted by the remaining non-believers (Savage, 2018). It is from this background that, the investigation of the influence of individual building stakeholders' decision-making on the adoption of green construction becomes very important because individual stakeholders form the basis of groups – multiple stakeholders – and directly interact with the environment.

3. THE INFLUENCE OF INDIVIDUAL-LEVEL DECISION-MAKING ON GREEN CONSTRUCTION ADOPTION

The achievement of sustainability in the building construction industry, requiring the adoption and implementation of green construction is (a) an action that has a strategic interactive structure because it has an outcome interdependence – outcome depends on the decisions and behaviours of all building construction stakeholders (Geels, 2011); and (b) an action which present a 'present-future' trade-off of cost and benefits – it involves 'giving' time, money, and effort 'today' in return for gains in the 'future'. From this background, Game Theory and Prospect Theory seem well suited as the theoretical lens to use in exploring the considerations hindering the adoption of green construction.

Game Theory describes the behaviour of rational decision-makers (Von Neumann and Morgenstern, 1944, Frey, 2010) who make their decisions based on their expectations of the behaviour of others they are interdependent with i.e. they reason strategically (Osborne and Rubinstein, 1994; Koçkesen, 2007; Samuelson, 2016). Rationality denotes that, individuals choose actions that give the most preferable outcome, given what they expect their opponents to do (Von Neumann and Morgenstern, 1944; Bicchieri and Xiao, 2009; Samuelson, 2016). The important issues that arise from the strategic interactive structure of achieving sustainability are that a building construction stakeholder, for example, a property developer faces the problem of finding an appropriate construction process since his cost and benefits depend on the construction processes of other property developers. The dependence on others' choices makes the decision-making a complex one and justifies the search for strategies that result in Nash equilibrium[6].

The *homo economicus* model would predict that individual builders will not shift from conventional construction processes to green construction practices while taking personal losses, even if they individually believe that green practices are much better for the environment and society. The only way that an individual would switch to green construction while maintaining the losses generated by costs would be if the size of the social benefit was much larger than the costs. These behavioural insights come from the predictions of Kahneman and Tversky's (1979) Prospect Theory, which demonstrated that there is an asymmetric function for losses versus gains, such that humans overweigh losses much greater than for gains. A fundamental concept of Prospect Theory is loss aversion – the tendency to prefer avoiding losses to acquiring comparable gains using

[6] Nash equilibrium requires that all players choose their strategies optimally given their beliefs, and that all beliefs are consistent with the choices of the opponents (Nash, 1951).

some heuristics (Tversky and Kahneman, 1974; Kahneman *et al*., 1991; Tversky and Kahneman, 1992). Applied to this study, individual building construction stakeholders are likely to be under the influence of loss aversion because, an outcome framing as losses corresponds to the notion of 'giving' time, money, or effort to do green construction, while an outcome framing as gain corresponds to the benefits associated with adopting green construction. The influence of loss aversion will impact the decision-making process leading to a high tendency for non-adoption. Loss aversion leads to other biases such as status quo bias, regret avoidance, present bias all of which increases the tendency to prefer non-adoption to adoption in the decision-making process.

4. CONSIDERATIONS HINDERING THE ADOPTION OF GREEN CONSTRUCTION

Based on the theoretical foundation, it is submitted that there will be an inclination for building construction stakeholders to prefer non-adoption to adoption. From this theoretical conclusion, certain factors (*referred to in this study as considerations*) will be taken into account in the decision-making. In this section, four key considerations that can be hindering the adoption of green construction are discussed.

4.1 DILEMMA CONCERN

Dilemma concern is a concept that describes the degree to which people perceive environmental protection as a social dilemma and follow strategies of conditional cooperation (Franzen, 1995). Dilemma concern is about the extent to which people believe that their actions help to achieve collective goals (Van Lange *et al*., 1997). Many researchers studying social dilemma have argued that one of the main reasons people do not contribute to public goods is the fact that a single person's actions may have no noticeable effect on the situation (Kollock, 1998). Basically, it is about belief in individual action effectiveness. In this study, dilemma concern refers to the extent to which building construction stakeholders consider that their individual green construction adoption efforts help achieve sustainability and reduce the environmental impacts arising from construction activities. When building construction stakeholders have low dilemma concern, they will believe that their individual action has an impact and help achieve the optimum outcome of sustainability. Hence, they are likely to adopt green construction. However, when they have a high dilemma concern, they will see no need to devote efforts, money and time towards green construction.

Proposition 1: *Reducing an individual building stakeholder's 'dilemma concern' will increase the adoption of green construction*.

This is dependent on the expectation of overall co-operation from others – trust in others' cooperation (Dawes, 1980, Van Lange *et al*., 2013). People are more likely to believe that their action can make a significant impact and cooperate if they believe that others also do the same. However, they will choose to non-adopt if they believe others do not adopt, in order to protect themselves from wasting time, money and effort i.e. being a 'sucker'.

4.2 TRUST IN OTHERS' ACTIONS

This construct suggests that building construction stakeholders' belief about others to be cooperative or uncooperative in the quest for the achievement of sustainability can lead to the decision to adopt or non-adopt green construction. Trust in others' actions as a barrier to green construction adoption and implementation originates from the idea of conditional cooperation (Ostrom, 2000). A person may be happy to adopt green construction. But everyone's action will contribute to the best possible outcome. Therefore, if a person does not believe others will adopt, then the best decision is to not adopt as well.

Proposition 2: *Increasing an individual building stakeholder 'trust' in other's actions will increase the adoption of green construction*.

Trust in others' actions can also emanate from social norms. It has been proffered that, individuals take their cues from what others do and use it as a standard against which to compare their own behaviours (Clapp and McDonnell, 2000; Bicchieri, 2005; Bicchieri and Xiao, 2009; Dolan *et al*., 2012). According to Dolan *et al*. (2012), people obtain pleasure from choosing to behave like everyone else, even though this choice may not be maximising overall utility. Thus, social norms can lead to behaviours that are difficult to explain in terms of rationality. In the choice of green construction, 'stories' from other building construction stakeholders may lead others to overestimate or underestimate the 'costs' and 'benefits'. It has been revealed that social trust plays an important role in the decision-making process of green building technologies adoption because, people use trust as a risk reduction strategy (Liu *et al*., 2018; Rajaee *et al*., 2019).

4.3 FEAR OF BEING A SUCKER

A possible consideration is a fear of being a sucker ('sucker-effect), a fear that others will free ride on one's cooperative actions (Dawes, 1980; Kerr, 1983). From the game theoretic perspective, the highest benefits for an individual is the consequence of everyone behaving cooperatively, while the individual select the non-cooperative choice (Dawes, 1980; Kollock, 1998; Van Lange *et al*., 2013). The term free-riding generally refers to when an individual wants to benefit from the activities of others without making a fair contribution of one's own. If everyone else chooses to do green construction, the inaction of one individual would not harm the achievement of sustainability. Meanwhile, that individual would receive all the immediate benefits associated with failure to act. Thus, this individual will free ride on the cooperative behaviour of everyone else. This consideration means that people choose to exploit the interdependence situation. Due to a feeling of being exploited by free-riders, one also reduces one's own effort, because he or she does not want to be seen as a sucker who does all the work for his or her colleagues (Mulvey *et al*., 1998).

Proposition 3: *Reducing an individual building stakeholder's 'fear of being a sucker' will increase the adoption of green construction*.

Zhang *et al*. (2011c) found that real estate developers in China believe that, the decision to do green construction is not a safe choice. This is because they will incur 'unnecessary' cost which cannot help them to be competitive in the market. In addition, perceptions of 'lack of demand' is one of the barriers that is widely reported in the literature. If building stakeholders believe that others do not adopt green, everyone will choose to non-adopt, in order to protect themselves from wasting time, money and effort i.e. being a 'sucker'. However, it is likely that they will not think they will incur 'unnecessary cost' or waste time if they believe others also adopt green construction. This consideration will largely depend on the level of dilemma concern.

4.4 SHORT-TERM SELF-INTEREST

The lure of short-term self-interest discourages people from contributing time, money, or effort toward the provision of collectively beneficial goods (Van Lange *et al*., 2013). Failure to adopt green construction is associated with the immediate benefit. A person will not prefer to exert effort, waste time and spend additional money. It is recognised that green construction involves certain transaction costs (Qian *et al*., 2015). A sophisticated level of expertise is required to fabricate and install green building features (Li *et al*., 2014). Self-interest will trigger the tendency to choose non-adoption which will help to circumvent these inherent features of green construction adoption. Profit motive and time is an important element in self-interest. Empirical research on barriers impeding green construction provides evidence for the manifestation of profit motive among building construction stakeholders. According to Choi (2009), people are not interested in green construction because the benefits can only be realised over a lengthy period.

Proposition 4: *Reducing an individual building stakeholder's 'propensity for short-term self-interests' will increase the adoption of green construction*.

Most developers and building owners in Malaysia consider investment in green buildings as economic waste because, they are concerned about having their buildings built at the minimum cost (Shari and Soebarto, 2014). Similarly, the majority of the respondents regarded minimizing the initial capital cost as more important than the long-term operational cost minimisation which is a key attribute of green buildings (Shari and Soebarto, 2014). Property developers in China claimed there is around 20% of additional time spent on designing green buildings compared to conventional buildings, and they are not willing to sacrifice such extra time expense (Deng *et al*., 2018). Likewise, a study by Ahn *et al*. (2013) in the US found that long payback periods concomitant with investing in green buildings act as a deterrent. A yearning to preserve habits – old ways of doing things will also make people resistant to change behaviour in the face of new ways of doing things.

5. CONCLUSIONS, IMPLICATIONS FOR POLICY-MAKING AND FURTHER RESEARCH

Even though there is a high-level consensus for the green construction agenda, building construction stakeholders are reluctant to adopt it. A lot of studies have investigated the barriers hindering the adoption of green construction, and the dominant account is that the major barriers are lack of awareness and education, lack of regulations and building codes, lack of incentive programs etc. Taking a Behavioural Economics perspective, this study has identified four (4) key factors that can be acting as an impediment to the adoption and implementation of green construction: dilemma concern, trust in others' action, fear of being a sucker, and short-term self-interest.

The study makes four propositions that could assist with high-level policy-making. Any policy assisting in *reducing an individual building stakeholder's 'dilemma concern', 'fear of being a sucker' and 'propensity for short-term self-interest', while increasing the 'trust in other's actions' will increase the adoption of green construction*.

Although the findings of this study have well-founded theoretical support, empirical investigation is required to (a) support, rebut or modify them; and (b) ascertain which of them strongly drive green construction non-adoption in a particular setting, so that policies to increase adoption of green construction will address those specific factors.

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7. REFERENCES

Ahn, Y.H., Pearce, A.R., Wang, Y. and Wang, G., 2013. Drivers and barriers of sustainable design and construction: The perception of green building experience. *International Journal of Sustainable Building Technology and Urban Development,* 4**,** pp.35-45.

Ajzen, I., Joyce, N., Sheikh, S. and Cote, N.G., 2011. Knowledge and the Prediction of Behavior: The Role of Information Accuracy in the Theory of Planned Behavior. *Basic and Applied Social Psychology,* 33**,** pp.101-117.

Algburi, S.M., Faieza, A.A. and Baharudin, B.T.H.T., 2016. Review of green building index in Malaysia; existing work and challenges. *International Journal of Applied Engineering Research,* 11**,** pp.3160-3167.

Alsanad, S., 2015. Awareness, Drivers, Actions, and Barriers of Sustainable Construction in Kuwait. *Procedia Engineering,* 118**,** pp.969-983.

Ametepey, O., Aigbavboa, C. and Ansah, K., 2015a. Barriers to Successful Implementation of Sustainable Construction in the Ghanaian Construction Industry. *Procedia Manufacturing,* 3**,** pp.1682-1689.

Ametepey, S.O., Gyadu-Asiedu, W. and Assah-Kissiedu, M., 2015b. Sustainable Construction Implementation in Ghana: Focusing on Awareness and Challenges. *Civil and Environmental Research,* 7**,** pp.109-119.

Azeem, S., Naeem, M.A., Waheed, A. and Thaheem, M.J., 2017. Examining barriers and measures to promote the adoption of green building practices in Pakistan. *Smart and Sustainable Built Environment,* 6**,** pp.86-100.

Bicchieri, C., 2005. *The Grammar of Society: The Nature and Dynamics of Social Norms*: Cambridge University Press.

Bicchieri, C. and Xiao, E., 2009. Do the right thing: But only if others do so. *Journal of Behavioral Decision Making,* 22**,** pp.191-208.

Bohari, A.a.M., Skitmore, M., Xia, B. and Zhang, X., 2016. Insights into the adoption of green construction in Malaysia: The drivers and challenges. *7th Asia-Pacific International Conference on Environment-Behaviour Studies.* St Leonard Hall, Edinburgh University, United Kingdom: e-International Publishing House, Ltd., pp.45-53.

Chan, A.P.C., Darko, A., Olanipekun, A.O. and Ameyaw, E.E., 2018. Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *Journal of Cleaner Production,* 172**,** pp.1067-1079.

Choi, C., 2009. Removing Market Barriers to Green Development: Principles and Action Projects to Promote Widespread Adoption of Green Development Practices. *Journal of Sustainable Real Estate,* 1**,** pp.107-138.

Clapp, J.D. and Mcdonnell, A.L., 2000. The relationship of perceptions of alcohol promotion and peer drinking norms to alcohol problems reported by college students. *Journal of College Student Development,* 41**,** pp.19-26.

Daniel, E.I., Oshineye, O. and Oshodi, O., 2018. Barriers to sustainable construction practice in Nigeria. *In*: C. Gorse and C.J. Neilson, eds. *34th Annual Association of Researchers in Construction Management Conference, ARCOM 2018,* Association of Researchers in Construction Management, pp.149-158.

Dawes, R.M., 1980. Social Dilemmas. *Annual Review of Psychology,* 31**,** pp.169-193.

Deng, W., Yang, T., Tang, L. and Tang, Y.-T., 2018. Barriers and policy recommendations for developing green buildings from local government perspective: a case study of Ningbo China. *Intelligent Buildings International,* 10**,** pp.61-77.

Djokoto, S.D., Dadzie, J. and Ohemeng-Ababio, E., 2014. Barriers to sustainable construction in the Ghanaian construction industry: consultants perspectives. *Journal of Sustainable Development*, *7*(1), p.134.

Dolan, P., Hallsworth, M., Halpern, D., King, D., Metcalfe, R. and Vlaev, I., 2012. Influencing behaviour: The mindspace way. *Journal of Economic Psychology,* 33**,** pp.264-277.

Du Plessis, C., 2007. A strategic framework for sustainable construction in developing countries. *Construction Management and Economics,* 25**,** pp.67-76.

Dwaikat, L.N. and Ali, K.N., 2018. The economic benefits of a green building – Evidence from Malaysia. *Journal of Building Engineering,* 18**,** pp.448-453.

Franzen, A., 1995. Group Size `and One-Shot Collective Action. *Rationality and Society,* 7**,** pp.183-200.

Frey, E., 2010. Evolutionary game theory: Theoretical concepts and applications to microbial communities. *Physica A: Statistical Mechanics and its Applications,* 389**,** pp.4265-4298.

Geels, F.W., 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions,* 1**,** pp.24-40.

Gluch, P., Gustafsson, M., Thuvander, L. and Baumann, H., 2014. Charting corporate greening: environmental management trends in Sweden. *Building Research and Information,* 42**,** pp.318-329.

Hammond, S.F., Savage, D.A., Gajendran, T. and Maund, K. 2019. Stakeholders Embrace Green Construction as the Right Direction: But as Individuals they make Self-Interested Decisions. *CIB World Building Congress 2019*. Hong Kong Polytechnic University, Hong Kong.

Hill, R.C. and Bowen, P.A., 1997. Sustainable construction: principles and a framework for attainment. *Construction Management and Economics,* 15**,** pp.223-239.

Hoffman, A.J. and Henn, R., 2008. Overcoming the Social and Psychological Barriers to Green Building. *Organization and Environment,* 21**,** pp.390-419.

Isa, N.K.M., Yunos, M.Y.M., Ibrahim, M.H., Ismail, K. and Marzuki, M., 2018. An exploration of drivers and strategies for encouraging the delivery of green building projects in housing development. *International Journal of Technology,* 9**,** pp.1702-1714.

Kahneman, D., Knetsch, J.L. and Thaler, R.H., 1991. Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias. *The Journal of Economic Perspectives, 5***,** pp.193-206.

Kahneman, D. and Tversky, A., 1979. Prospect Theory: An Analysis of Decision under Risk. *Econometrica,* 47**,** pp.263-291.

Kerr, N.L., 1983. Motivation losses in small groups: A social dilemma analysis. *Journal of Personality and Social Psychology,* 45**,** pp.819-828.

Kibert, C.J., 2007. The next generation of sustainable construction. *Building Research and Information,* 35**,** pp.595-601.

Koçkesen, L., 2007. Unobservable Contracts as Precommitments. *Economic Theory,* 31**,** pp.539-552.

Kollmuss, A. and Agyeman, J., 2010. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research,* 8**,** pp.239-260.

Kollock, P., 1998. Social dilemmas: The anatomy of cooperation. *Annual Review of Sociology*, *24*(1), pp.183-214.

Li, Y., Yang, L., He, B. and Zhao, D., 2014. Green building in China: Needs great promotion. *Sustainable Cities and Society,* 11**,** pp.1-6.

Liu, Y., Hong, Z., Zhu, J., Yan, J., Qi, J. and Liu, P., 2018. Promoting green residential buildings: Residents' environmental attitude, subjective knowledge, and social trust matter. *Energy Policy,* 112**,** pp.152-161.

Martek, I., Hosseini, M.R., Shrestha, A., Edwards, D.J. and Durdyev, S., 2019. Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions. *Journal of Cleaner Production,* 211**,** pp.281-292.

Mok, K.Y., Shen, G.Q. and Yang, R., 2018. Stakeholder complexity in large scale green building projects: A holistic analysis towards a better understanding. *Engineering, Construction and Architectural Management,* 25**,** pp.1454-1474.

Mulvey, P.W., Bowes-Sperry, L. and Klein, H.J., 1998. The Effects of Perceived Loafing and Defensive Impression Management on Group Effectiveness. *Small Group Research,* 29**,** pp.394-415.

Nguyen, H.D., Nguyen, L.D., Chih, Y.Y. and Le-Hoai, L., 2017. Influence of participants' characteristics on sustainable building practices in emerging economies: Empirical case study. *Journal of Construction Engineering and Management*, *143*(8), p.05017014.

Ofori, G. and Kien, H.L., 2004. Translating Singapore architects' environmental awareness into decision making. *Building Research and Information,* 32**,** pp.27-37.

Olubunmi, O.A., Xia, P.B. and Skitmore, M., 2016. Green building incentives: A review. *Renewable and Sustainable Energy Reviews,* 59**,** pp.1611-1621.

Osborne, M.J. and Rubinstein, A., 1994. *A Course in Game Theory*: MIT Press.

Ostrom, E., 2000. Collective Action and the Evolution of Social Norms. *The Journal of Economic Perspectives,* 14**,** pp.137-158.

Qian, Q., Chan, E. and Khalid, A., 2015. Challenges in Delivering Green Building Projects: Unearthing the Transaction Costs (TCs). *Sustainability,* 7**,** pp.3615-3636.

Rajaee, M., Hoseini, S.M. and Malekmohammadi, I., 2019. Proposing a socio-psychological model for adopting green building technologies: A case study from Iran. *Sustainable Cities and Society,* 45**,** pp.657-668.

Russ, N.M., Hanid, M. and Ye, K.M., 2018. Literature review on green cost premium elements of sustainable building construction. *International Journal of Technology,* 9**,** pp.1715-1725.

Saleh, M.S. and Alalouch, C., 2015. Towards Sustainable Construction in Oman: Challenges and Opportunities. *Procedia Engineering,* 118**,** pp.177-184.

Samuelson, L., 2016. Game Theory in Economics and Beyond. *Journal of Economic Perspectives,* 30**,** pp.107-130.

Savage, D.A., 2018. *Towards a Complex Model of Disaster Behaviour*. Australia: University of Newcastle, 1-2.

Shari, Z. and Soebarto, V., 2014. Investigating sustainable practices in the Malaysian office building developments. *Construction Innovation,* 14**,** pp.17-35.

Tversky, A. and Kahneman, D., 1974. Judgment under Uncertainty: Heuristics and Biases. *Science,* 185**,** pp.1124-1131.

Tversky, A. and Kahneman, D., 1992. Advances in prospect theory: Cumulative representation of uncertainty. *Journal of Risk and Uncertainty,* 5**,** pp.297-323.

Un Environment and International Energy Agency, 2017. *Towards a zero-emission, efficient, and resilient buildings and construction sector*.

Van Lange, P.a.M., De Bruin, E.M.N., Otten, W. and Joireman, J.A., 1997. Development of prosocial, individualistic, and competitive orientations: Theory and preliminary evidence. *Journal of Personality and Social Psychology,* 73**,** pp.733-746.

Van Lange, P.a.M., Joireman, J., Parks, C.D. and Van Dijk, E., 2013. The psychology of social dilemmas: A review. *Organizational Behavior and Human Decision Processes,* 120**,** pp.125-141.

Von Neumann, J. and Morgenstern, O., 1944. *Theory of games and economic behavior* Princeton, NJ, US: Princeton University Press.

Wadu Mesthrige, J. and Kwong, H.Y., 2018. Criteria and barriers for the application of green building features in Hong Kong. *Smart and Sustainable Built Environment*, *7*(3/4), pp.251-276.

Wang, W., Zhang, S., Su, Y. and Deng, X., 2018. Key Factors to Green Building Technologies Adoption in Developing Countries: The Perspective of Chinese Designers. *Sustainability*, *10*(11), p.4135.

Windapo, A.O. and Goulding, J.S., 2015. Understanding the gap between green building practice and legislation requirements in South Africa. *Smart and Sustainable Built Environment,* 4**,** pp.67-96.

Yu, T., Shi, Q., Zuo, J. and Chen, R., 2018. Critical factors for implementing sustainable construction practice in HOPSCA projects: A case study in China. *Sustainable Cities and Society,* 37**,** pp.93-103.

Zaini, A.A. and Endut, I.R., 2018. Major challenges in implementing green construction. *Journal of Engineering and Applied Sciences,* 13**,** pp.8865-8869.

Zainul Abidin, N., 2010. Investigating the awareness and application of sustainable construction concept by Malaysian developers. *Habitat International,* 34**,** pp.421-426.

Zhai, X., Reed, R. and Mills, A., 2014. Addressing sustainable challenges in China: The contribution of off-site industrialisation. *Smart and Sustainable Built Environment,* 3**,** pp.261-274.

Zhang, X., Platten, A. and Shen, L., 2011a. Green property development practice in China: Costs and barriers. *Building and Environment,* 46**,** pp.2153-2160.

Zhang, X., Shen, L., Tam, V.W.Y. and Lee, W.W.Y., 2012. Barriers to implement extensive green roof systems: A Hong Kong study. *Renewable and Sustainable Energy Reviews,* 16**,** pp.314-319.

Zhang, X., Shen, L. and Wu, Y., 2011b. Green strategy for gaining competitive advantage in housing development: a China study. *Journal of Cleaner Production,* 19**,** pp.157-167.

Zhang, X., Shen, L., Wu, Y. and Qi, G., 2011c. Barriers to Implement Green Strategy in the Process of Developing Real Estate Projects. *The Open Waste Management Journal,* 4**,** pp.33-37.

Zou, P.X.W. and Couani, P., 2012. Managing risks in green building supply chain. *Architectural Engineering and Design Management,* 8**,** pp.143-158.

Hewavitharana, T., Nanayakkara, S. and Perera, S., 2019. Blockchain as a project management platform. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 137-146. DOI: doi.org/10.31705/WCS.2019.14. Available at: https://2019.ciobwcs.com/papers

BLOCKCHAIN AS A PROJECT MANAGEMENT PLATFORM

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ABSTRACT

The construction industry will continue to be a key driver of economic growth for any country. It is one of the biggest industries in the world which contributes heavily to the economic development of a country. However, the productivity and the effectiveness of the industry have often been called into a question. Therefore, a number of different modelling tools and software have introduced to upgrade the standards of the construction industry. This review seeks to identify how blockchain can address the project management perspectives of the construction industry with respect to the guidelines mentioned in the Project Management Body of Knowledge. Five major criterions namely purchase management, contract management, asset and inventory management, finance management and subcontractor management were selected for the analysis using the PMBOK guidelines. For that, literature review using articles in ScienceDirect which appeared the context "blockchain in construction", "blockchain and project management", "application of blockchain" were referred. It is identified that the blockchain technology can assist financial management without involving third parties, subcontractor management by linking derivable and payment schemes, contract administration by using smart contracts, inventory and asset management by tracking and tracing material movements and purchase management by linking key stakeholders in supply chains.

Keywords: *Blockchain; Construction Industry; Project Management; Smart Contract*

1. INTRODUCTION

The construction industry has been dared for a long time to enhance its efficiency, productivity and to embrace opportunities coming along with disruptive technologies. However, with the fourth industrial revolution, the construction industry had to move forward with digital technologies such as the Internet of Things (IoT), 3D Printing, Building Information Modelling (BIM) and others. The blockchain is the latest technology which is embarked upon the digitalisation of the construction industry, and it has created a new era for the utilisation of the internet. That is mainly because the information on the blockchain is updating continuously and shared among members. It does not locate in one place and opens for the public with the ability to verify in public blockchain, and private blockchain networks facilitate for handling sensitive data. Therefore, it empowers companies to do business with one another more easily using shared business processes encoded within a common platform.

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The manufacturing industry is trying to utilise blockchain for their operations primarily in the supply chain management. It provides a transparent mechanism in the transaction process of goods, data and financial resources. Healthcare sector and Banking sectors are two other industries who are trying to use blockchain technologies. Further, the legal sector is focusing blockchain for smart contracts as well as future election systems will be deviated from traditional procedures and will move with blockchain technologies to improve trust and transparency.

There are many advantages of blockchain technology. It is used to make payments without show and to improve trust. Smart contracts are using the technology to reduce delays, outside interferences and to reduce the documentations in contractual decision-making processes. Further distributed data storage mechanism will mitigate some data risk. Also, with the blockchain has a capability to easily to track and monitor digital identities because of the authorisation systems adopted in the blockchain. Subsequently, blockchain can work as a low-cost notary system which can reduce the expenses. It has the ability to communicate with distributed IoT devices for extracting information and share with member nodes. Therefore, blockchain technology can be identified as a bridge to the digital future.

However, there are some disadvantages in blockchain technology. Some blockchain technologies use excessive energy consumption processes such as mining or introducing new data block to ledger. Blockchain technology does not allow to overwrite or change the data. So, it will limit the flexibility of correction if wrong data was fed. As a novel and distributed technology, it is challenging to develop and implement blockchain-based solutions when compared with traditional software solutions.

In spite of the disadvantages of blockchain technology, many industries have gained the advantages out of it, as mentioned above. Therefore, it is essential to investigate how blockchain technology can be utilised in the construction industry.

There is a high probability of changing construction project management if the construction industry utilises the blockchain technologies. The success of project management is essential because it is considered as the nerves of construction projects. Concerning that, the involvement of blockchain on project management practices in the construction industry needs to be evaluated. As one of the latest technologies, researchers have focused on the implementation of the blockchain in many industries. Hence this review would be a preliminary study about the applicability of blockchain in the construction industry.

2. METHODOLOGY

The literature review can be labelled as a well-established method for an accumulating existing knowledge within a domain of interest. Because of that, as the methodology for this article, it is expected to apply a literature review approach. To find the relevant articles for reviewing, various keywords searches within the ScienceDirect have been proceeded. The publishing period was decided to lie between 2000-2019 to reduce the searching scope. Different keywords such as “blockchain in project management”, “blockchain in construction industry”, “blockchain in construction”, “blockchain and project management practices”, “application of blockchain” were used to find relevant articles to choose the topic. However, articles were identified relating to the targeted topic in specific. Therefore, the topics were broadened, and the articles’ abstracts were carefully read to check their relevance. After reviewing a forty number of articles, the impact of blockchain technology to project management practises were analysed. Project management practises were categorised according to the Project Management Body of Knowledge (PMBOK) guidelines. It was divided into five criterions, namely inventory and asset management, finance and petty cash management, contract administration, subcontractor management and purchases management.

3. DISCUSSION

3.1 BLOCKCHAIN TECHNOLOGY

Blockchain is made up of blocks, which comprise a number of transactions that chained together by the cryptographic hashes (Gupta, 2018). It consists of three main components namely blocks, blockchain or ledger and network. Selected transactions are stored to a ledger during a given period in a place called block. Those blocks can differ from their objectives, size, period and the triggering event. The blockchain is made up of a number of blocks which are linked together. The tool that links blocks together is cryptographic hash functions (Rodrigo *et al*., 2018). They are fingerprints of data from the previous block (called as parent block) which links to the current block. Making new block by computing proper hash value is called mining and miners are the people who compete with each other to search the correct hash function (Turk and Klinc, 2017). Further, in the blockchain nodes are interconnected, and each of these nodes holds a complete record of all transaction (Novotny, 2018). Figure 1 illustrates a cryptographically linked blockchain ledger with three blocks.

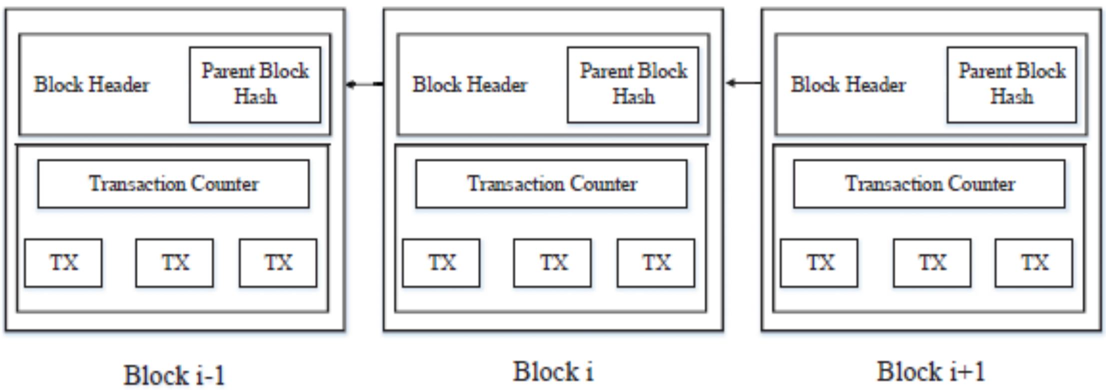

Figure 1: An example of blockchain which consists of continuous sequence blocks

3.2 BLOCKCHAIN TECHNOLOGY AND CONSTRUCTION INDUSTRY

Researchers have identified how blockchain technology can be utilised in the construction industry. Novotny and Turk have discussed how blockchain technology can communicate with the delivery of a project along with smart contracts (Novotny, 2018; Turk and Klinc, 2017). According to the McKinsey's point of view, blockchain is capable of handling government policies which need to be fulfilled for the sustainable development (Fiander-McCann, 2017). According to the Rothrie (2018), the quality and the accuracy of the surveying data can be enhanced with the blockchain technology as it allows to store a large number of previous records. Abeyratne and Monfared (2016) have researched how blockchain technology can be utilised with project management aspects such as project planning. Likewise, many researchers have expanded their research in many operations in the constrcution industry. Following details will provide ellaborated picture about how blockchain technology can be used in the construction industry.

Blockchain and the construction industry are aligned with each other with four basic processes. They are smart contracts, projected modelling, inspection and delivery. The initial step for producing a project is modelling. Project modelling demonstrates how final projects will look like and how needs are accomplished. Once this is completed smart contracts come in to play. For that, each transaction in the project model will be linked with smart contracts. This process will support to make the budget, and it will make ensure that people engaging on the project will be paid. Once the obligations of the contracts are over, they start the works that are scheduled. After the contractor completed his tasks, inspections were done, and approvals or rejections were provided for the tasks completed. If the work is accepted and approved, then the funding will be released, and relevant parties will be paid. After that, the project would be delivered based on the completed works and the payments made. This process provides how blockchain technology can be used throughout the life cycle of the project. It helps to streamline the project delivery and payments so that it would save money by minimising most of the mediators involved in contract processing and payment. Instead of a third party, blockchain permanently stores the transaction record ones it is approved by the participants and this action improves the security and transparency of the transaction. All the data related to the transaction also saved and it will ease the document sharing (Novotny, 2018; Turk and Klinc, 2017).

When it comes to digitalised land acquisition and building rights (when constructing a structure), blockchain solutions show an effective performance. According to Fiander-McCann (2017) point of view, blockchain can handle government policies relating to land acquisition and building regulation to have a sustainable construction. Basically, blockchain creates vast advantages over the paper-based activities which allow having quick approvals where it requires multi-party signatures on physical documents. As a good example, the Rajasthan state in India is trying to utilise blockchain technology for their land registration purposes (Rothrie, 2018).

In the construction industry, an inspection of the buildings are done in a fragmented way (Shehu and Akintoye, 2010). Because of this, surveyors do not have details of previous records of the past scrutiny leading to produce bias reports on specific inspectors and cumulative errors. This issue can be prevented using blockchain technologies on building surveying. It makes the opportunity to overlook the past records of a certain building throughout its life cycle (e.g. Structural or maintenance activity) and ensure the corrective activity (Rothrie, 2018).

Planning is another area where blockchain can address in the construction industry. At the current moment, construction organisations have to drag the projects by several months due to improper planning. Together with the Building Information Modelling (BIM) blockchain can make a single source of trust which fulfils all project planning aspects. It will become a trusted twin, which will enhance the predictability of the whole project delivery (Abeyratne and Monfared, 2016).

Further, communication and availability of the information should be significantly improved to move towards smart cities and blockchain-based solutions. For example, sensors data through a public blockchain-based solution can share and utilised to identify the traffic flow in a particular area. Those type of blockchain-based solutions enable quick construction investments in road improvements and traffic reassuring measures or other means (Rothrie, 2018).

Blockchain technology will impact construction functions in many ways. Mainly, it influences project management practices of the construction field. As construction projects are based on a pre-defined specification, blockchain combined with smart contract functionalities brings outstanding opportunities to modernise construction project management. It covers whole project lifecycle of construction from initiation to closure and everything in between (Hewavitharana and Perera, 2019). Project Management Body of Knowledge (PMBOK) is the standard guideline, which is followed by project managers to carry on the site operations (Project Management Institute, 2012). According to the writer of project-management.com, Joes Maria De Los Santos, the project manager is the person who gets the heist benefits from the application of blockchain technology to the construction industry as it will result in time-saving, cost removal, and risk reduction (Santos, 2017). Therefore, through this research, it is expected to investigate how blockchain will influence the project management practices mentioned in PMBOK guidelines.

3.3 BLOCKCHAIN AND PROJECT MANAGEMENT PRACTISES

3.3.1 Blockchain and Purchase Management

Purchase management is a subpart of broad supply chain management. Supply chain management plays a significant role in the construction industry. There are lots of activities from planning to distribution for the clients, and those have to manage in a most streamlined and cost-effective way. The essential element of supply chain management is traceability and communication (Nanayakkara *et al*., 2015). In construction, it is specified that there are insufficient traceability and communication throughout the supply chain. In the start of 2018, the UK government contract Carillion collapsed affecting the jobs around 43,000 people due to the worthless credit management, lack of prominence over projects and required supplies. Also, still the communication and coordination are handled using telephones, mails and documentation on paper. Therefore, purchase orders, delivery notes and invoices are still operated with papers or centralised software systems. Blockchain technology removes this manual operation system, and it switches all these operations into distributed digitalised form (Sat, 2000; Jang, 2007).

Moreover, blockchain technology impacts to the supply chain management. It helps to do the correct decision making with clear information regarding product and its components. The success of blockchain technology in the supply chain has proven through the partnership between Walmart and IBM (Mancone, 2018). Further, the ProBuild, one of Australia's leading building firm, has joined with US blockchain innovator for developing its global supply chain management though blockchain technology. Also, blockchains based supply chain can track where project assets are at any point in time. Therefore, it built an unbroken chain of trust between all key stakeholders and isolated projects from being document-driven to being data-driven (Hughes, 2017). Moreover, blockchain technology is an effective way to carry out transactions that are stored in decentralised and transparent records. The network itself monitors its security. It can also contain data that monitors costs, labour and wastes at every point in the supply chain (Zheng *et al.,* 2017). The typical structure of a supply chain is shown in Figure 2.

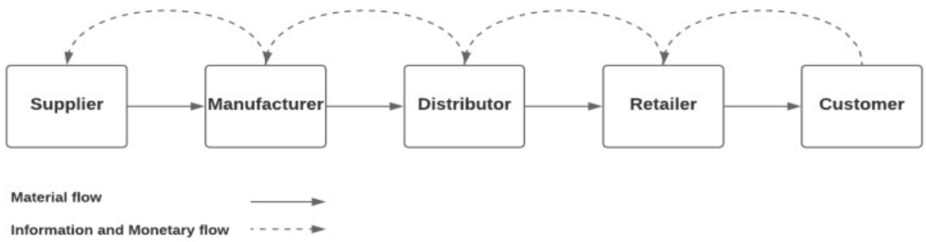

Figure 2: Typical structure of the supply chain

3.3.2 Blockchain in Asset and Inventory Management

Construction organizations are unique from other organizations due to its features. Basically, they are project-based entities where the end customers have different preferences and necessities regarding the products (Hewavitharana *et al*., 2019). Because of this nature, it is necessary to have proper quality control from the starting to the end of the projects. And as it opens up the opportunity to choose their own resources and materials, construction people need to maintain a well-organised supply chain (Perera *et al*., 2014). By using blockchain technology, authorised parties can certify where materials come from, who are the manufacturers and how they are transported. From that corruption such as child labour, wrong certifications and others can be identified and eliminated.

In the initial stage, barcode systems were used in the inventory management systems, and it was replaced by Radio-frequency Identification (RFID) tagging and Internet of Things (IoT). The blockchain technology can be used to store and properly track the information. "Track Transfer Trust" is one such software which is doing transactions once the work is completed (Abeyratne and Monfared, 2016; Rothrie, 2018).

Further, this could help the purchaser to identify proper suppliers along with the transparency of tracking, material handling at the required time so that construction companies able to operate a "Just in time planning" system, which reduces wastes, lower the cost and accelerate the schedules (Hughes, 2017). Because at the current situation construction firms do not have any clue regarding the inventory control. They do not know whether the supplies they need are in the stock when they start the project. This unplanned situation leads to delay and incur costs (Rothrie, 2018).

Linking the information of BIM into immutable and transparent blockchain will leverage the potential of BIM. Engineering projects contain vast amounts and types of data and similarly high volumes of corresponding design and managerial decisions. Through the blockchain solutions, additional data can be added to the BIM model as well as high accountability and transparency can be ensured due to the irrefutable nature of the ledger. Blockchain can support BIM in two major ways for asset management. It can transfer material requirements, details of other designing as an input to the supply chain management. It also can assign information to the blockchain, like design decisions, a source of data or model modification orders. This information can be used by smart contracts to initiate further actions, such as payments or material orders. One of the main consequences of using blockchain is the introduction of inherent trust within the system. As every system is logged and traceable on the blockchain, many time-consuming, redundant checks can be eliminated. By capturing a comprehensive collection of datasets on the blockchain such as design decisions, content checks, procurement and transactional data and linking them to BIM model will enable to identify the origin of the transaction (Shehu and Akintoye, 2010).

Also, the current practice of asset management is constructing its own asset management platform using server-based database. Such practices create issues relating to interoperability specially when there are multiple asset management platforms. This can be sorted out using an Application Programming Interface (API) integrated solution which is connected to a blockchain (Wang *et al*., 2017).

3.3.3 Blockchain and Contract Administration

The initial stage of the construction project is usually much expensive and more significant than other stages as there are inherent risk and fear. Stakeholders often try to mitigate that risk by using proper contract planning and data hoarding. Therefore, blockchains and smart contracts are introduced with the aim of minimising the risk (Hughes, 2017).

A smart contract is a computer program that executes on if/then principle and can execute automatically. Each of these if/then scenarios are recorded on the blockchain. There are two types of smart contracts namely deterministic and non-deterministic. Deterministic contracts only require information exists in the blockchain. As they do not need any outside information, deterministic contracts can execute and work efficiently. Those type of contracts is executed and functioned with the data available within the blockchain. Non-deterministic contracts are smart contracts that need additional information than the available information in the blockchain. For these types of contracts, the trusted third party from outside the blockchain needs to be brought to execute the contracts, and they are called as "Oracles". However, these parties needed to be approved by contractual parties. Oracles are capable of providing smart contracts with the required information (Morabito, 2017).

Moreover, by using smart contracts traditional lump-sum contract and lowest bidder approach can be modified. There are several facts to be considered. As construction companies are operating in a very dynamic environment, it is quite challengeable to trust on the completion of construction projects. For example, with this kind of environment extrinsic and economic incentives such as employees work will be usually overestimated and intrinsic and non-monetary incentives such as social recognition will be underestimated. However, blockchain technology is built upon the trust of fulfilling each operation. Because of this reason though smart contracts are considered as alternatives for the traditional approach, it is advisable to investigate the feasibility of it before the practical implementation (Nanayakkara *et al*., 2019; Wang *et al*., 2017).

The investigation has found that smart contracts are cost-effective in many ways. Since the contract is performed entirely in programming languages, unnecessary cost on written text, counselling with lawyers and drafting the contract documents would be avoided. The risk of opportunistic behaviour is also mitigated since the potentially written interpretations of the terms are eliminated. Once one milestone is completed a smart contract is fulfilled and therefore, when the project is scheduled hundreds of smart contracts would be visible to all in Common Data Environment (CDE) (Ramage, 2018). Moreover, smart contracts can replace traditional contracts without the need for laws and courts to a significant extent (Sklaroff, 2018).

3.3.4 Blockchain and Finance Management

In the construction industry, late payments and cash flow issues are enduring problems. The average payment time for construction companies and SME's (Small and Medium-sized Enterprises) became 82 days. They could sometimes even rise as high as up to 120 days. Such practices can easily put the whole supply chain at risk.

Especially the SME's who cannot tolerate the significant upfront costs without continuing payment and healthy cashflow fail to continue a proper supply chain. In 2012 a survey showed that 97% of 250 SME's experienced unfair, overdue payments. Therefore, it is clear that there is a high need for transparency and tractability of payments in the construction industry. Especially with regard to the fact that there is an increasing trend of managing project funding in public-private partnership which requires more control from the client's side and enhanced accountability from every participant (Ramachandra and Rotimi, 2011).

With the blockchain technology, organisations may able to send money across borders with lower fees in the absence of the middle person. However, it enables virtual currencies such as Bitcoin to be used by the people who even do not have access to traditional banks. In the finance operation, most of the transactions are based upon the authorisation of top management and petty cash handling are depending upon various factors. As there is no involvement of a third party at the transactions, the process is much easier and quicker than the usual way. This process will enhance the productivity of the construction organisation in terms of cash flow handling (Nanayakkara *et al*., 2019; Turk and Klinc, 2017).

3.3.5 Blockchain and Subcontractor Management

The construction industry is unique comparing to other industrial field as it is based on projects which cannot communicate to each other. Subcontractors are the employees who are not permanently involved in the projects. Mostly, they are handled by main contractors as they can perform specific tasks. As there are several types of subcontractors within one project, project managers face lots of difficulties with measuring the work done and the interim payments (Ramachandra and Rotimi, 2011). This problem can be solved by the implementation of blockchain solutions. The subcontractors' works can be linked to the blockchain associated with payments and verifiable milestones. Each of these verifiable elements will be presented on the BIM model, and once it has completed, it will be recorded in blockchain ledger (Ramage, 2018). As an example, once the transactions are connected with blockchain technology all orders, deliveries and invoicing could able to handle by smart contracts. Then the payments could be linked with contracts automatic payments. This approach prevents the involvement of the third party and streamlines faster payments.

4. CONCLUSIONS

Through this literature review, it is identified that blockchain technology can influence construction project management practices. In here, five basic functionalities in the project management area were addressed namely a) Contract administration, b) Purchase management (supply chain management), c) Subcontractor management, d) Finance management and e) Asset and inventory management.

It will maintain the security and trust between all parties and will able to monitor costs, schedules, labour, waste and others at many points of the supply chain. If the blockchain technology is used in financial management, it will speed up the payments without involving third parties and eliminate long term delays in the cash flow. The subcontractors' work can be related to the blockchain technology associated with payments and verifiable deliverable milestones. Smart contracts could build for each and every work done item; once the work is done completed orders, deliveries and invoicing will be linked to the payment. This will improve the efficiency and the productivity of the subcontractor handling. Blockchain technology supports material and asset management by tracking and tracing material movements. Further, it will enable just in purchasing systems and will eliminate unnecessary storage cost, maintenance cost and reduce wastage.

Therefore, it is identified that blockchain would impact traditional construction practices and bridge the future while creating the best project management tool for the construction industry.

5. REFERENCES

Abeyratne, S.A. and Monfared, R.P., 2016. Blockchain ready manufacturing supply chain using distributed ledger. *International Journal of Research in Engineering and Technology*, 05(09), pp.1-10.

Fiander-McCann, D. 2017. *Blockchain could transform the construction industry - Designing Buildings Wiki* [Online]. Designing Buildings Wiki. Available: https://www.designingbuildings.co.uk/wiki/Blockchain_could_transform_the_construction_industry [Accessed 2018-01-29 2018].

Gupta, M., 2018. *Blockchain for Dummies*, 51, 2nd edn, pp. 3–10. Hoboken, NY: Wiley.

Hewavitharana, T., Nanayakkara, S., Perera, A. and Perera, J. 2019. Impact of Enterprise Resource Planning (ERP) Systems to the Construction Industry. *International Journal of Research in Electronics and Computer Engineering,* 7, pp.887-893.

Hewavitharana, T. and Perera, A. 2019. Gap Analysis between ERP procedures and Construction procedures. *MATEC Web of Conferences.* Kuala Lumpur, Malaysia: Web of Conferences.

Hughes, D. 2017. The Impact of Blockchain Technology on the Construction Industry. *animal Media*.

Jang, W. S. 2007. *Embedded system for construction material tracking using combination of radio frequency and ultrasound signal* (Doctoral Thesis).

Mancone, R. 2018. *Blockchain Services and Strategy*, IBM.

Morabito, V., 2017. Business innovation through blockchain. *Cham: Springer International Publishing*.

Nanayakkara, S., Perera, P. and Perera, A. 2015. Factors Incompatibility of Selection and Implementation of ERP Systems for Construction Organizations. *International Journal of Computer Science and Technology,* 6, pp.9-15.

Nanayakkara, S., Perera, S. and Senaratne, S. 2019. Stakeholders' Perspective on Blockchain and Smart Contracts Solutions for Construction Supply Chains. *CIB World Building Congress.* Hong Kong.

Novotny, R. 2018. Blockchain and the Construction Industry: Hype or an Industry Innovation? - eSUB Construction Software.

Perera, P., Nanayakkara, S. and Perera, A. 2014. Application of Proper Asset Management Methodology and Technology. *International Journal of Computer Science and Technology,* 5, pp.33-41.

Project Management Institute 2012. *A Guide to the Project Management Body of Knowledge,* USA, Project Management Institute.

Ramachandra, T. and Rotimi, J. O. 2011. The nature of payment problems in the New Zealand construction industry. *Australasian Journal of Construction Economics and Building,* 11, pp.22-33.

Ramage, M., 2018. From BIM to Blockchain in Construction: What You Need to Know. *Trimble Inc*.

Rodrigo, M. N. N., Perera, S., Senaratne, S. and Jin, X. 2018. Blockchain for Construction Supply Chains: A literature Synthesis. *Proceedings of ICEC-PAQS Conference 2018.* Sydney, Australia.

Rothrie, S. 2018. *How Blockchain and Construction Will Build a New World* [Online]. Coin Central. Available from: https://coincentral.com/blockchain-and-construction [Accessed 2018-01-18 2018].

Santos, J. M. D. 2017. Blockchain as a Project Management Platform. *PM.com*.

Sat, T. 2000. A Design Method. *Production Economics,* 64**,** pp.92-95.

Shehu, Z. and Akintoye, A. 2010. Major challenges to the successful implementation and practice of programme management in the construction environment: A critical analysis. *International Journal of Project Management,* 28**,** pp.26-39.

Turk, Ž. and Klinc, R. 2017. Potentials of Blockchain Technology for Construction Management. *Procedia Engineering,* 196**,** pp.638-645.

Wang, J., Wu, P., Wang, X. and Shou, W. 2017. The outlook of blockchain technology for construction engineering management. *Frontiers of Engineering Management,* 4**,** pp.67-75.

Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H., 2017. An overview of blockchain technology: Architecture, consensus, and future trends. 2017 IEEE International Congress on Big Data (BigData Congress), 2017. IEEE, pp.557-564.

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BRIDGING THE THEORY-PRACTICE GAP IN VALUE MANAGEMENT IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Construction process is one of the most complex and dynamic procedures. Therefore, it is vital to use resources efficiently and effectively. Considering this requirement of any construction project, creating value for money is becoming important. It contributes to the economic, social and environmental aspects of a country. The concept of value is based on the relationship between satisfying needs, expectations and the resources required to achieve them. Value Management (VM) is recognised as a suitable approach to ensure value for money in construction projects. Although, VM concept is significantly used in developed countries, its applications do not seem to be well established in the construction industry in most of the developing countries including Sri Lanka. This is mainly due to lack of understanding of VM concept. Hence, this study aims to investigate how to bridge the theory-practice gap in VM in Sri Lankan construction industry, through seven case studies. Case study data collection was based on interviews, document review and observations and analysed using content analysis. The research findings revealed that these projects employed different kinds of VM methodologies derived from standard VM methodologies with the focus of various VM objectives. The study further identified number of reasons for theory-practice gap in VM such as lack of a formal guideline and less knowledge on VM, which dilute successful VM implementation. The experts further proposed train in-house VM facilitators, proper project planning, motivate investors, train Sri Lankan professionals by foreign experts and govern VM knowledge sharing as strategies to bridge the gap in order to deliver best value for client's money.

Keywords: *Sri Lankan Construction Industry; Theory-Practice Gap; Value Management; Value Management Practice.*

1. INTRODUCTION

Construction contributes to national economic growth necessities by means of cost-effectiveness, timelines and would certainly contribute to cost saving for the country as a whole (Aibinu and Jagboro, 2002). Therefore, it is vital that resources applied as efficiently as possible and waste in any form should reduce to a minimum for a project due to its complexity (Coetzee, 2009). Considering this requirement as the fundamental purpose of any project, creating value for money is becoming vital (Gillier *et al*., 2015). Value for money is a crucial construct in project delivery (Barima, 2010). The concept of

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value is based on the relationship between satisfying needs, expectations and the resources required to achieve them (Institute of Value Management Australia [IVMA], 2017). Rameezdeen and De Silva (2002) stated that enhancing the value of construction projects could create positive impact on the economy of a country. Managing value in construction projects leads to complete projects within stipulated time, anticipated cost and expected level of quality that meets requirements (Bowen *et al*., 2010).

As one of important tools for managing value of projects is VM, which is widely accepted concept in the construction industry (Ellis *et al*., 2005). Hayles *et al*. (2010) defined, VM as a proactive, problem solving or solution seeking process. Karim (2016) emphasised that this concept focuses not only about cost, but also emphasises about the relationship between function, value, quality and cost with functional analysis as its principal components. VM can be undertaken at any time, but best results can be obtained by applying early in a programme (Toy, 1995). The author further emphasised that the best time apply VM concept is at the stage where there is enough room for the planned action or design and sufficient cost information or procedure timetable to pursue realistic alternatives. Although, many researchers have addressed VM concept theoretically with published body of knowledge, there is a lack of VM implementation in construction industry (Jaapar *et al*., 2011).

The concept of VM is becoming more significant to Sri Lankan construction industry (Perera, *et al*., 2003). However, currently there is a need for VM in Sri Lanka to enhance efficiency and to deliver maximum value to benefit the stakeholders. Perera, *et al*., (2003) further disclosed that the practice of VM applications in the Sri Lankan context is not popular among the industry practitioners. Moreover, Ekanayake and Sandanayake (2017) highlighted that Sri Lankan construction industry need a proper value managing practice. As Karunasena and Gamage (2011) stated, although VM has introduced in Sri Lanka, there are challenges with its implementation and application. Authors further remarked major reason for less practice of VM in the country as less number of publications and manuals in the local construction industry, which are conversant with international VM methodology. There is a scarcity of resource persons in VM and it resultes the habit of non-formal usage of VM as well as limited use of formal methods (Perera *et al*., 2011). Although, researches have explored the VM in different perspectives in researches, there is a lack of evidences in research on how to bridge the theory and practice gap of VM concept in Sri Lankan construction industry. Finding out strategies to overcome the VM implementation barriers will pave the way for bridging the theory and practice gap.

2. LITERATURE SYNTHESIS

2.1 THE CONCEPT OF VALUE AND ITS IMPORTANCE TO CONSTRUCTION INDUSTRY

Value can be defined as the relationship between the satisfaction of various needs and the resources used for achieving it (Abidin and Pasquire, 2007). In simple form, value is "the ratio between the customer satisfaction (benefits) and the resources used (cost)" (Gillier *et al*., 2015, p. 948). In construction industry perspective, value maximisation of a construction project has been stated as one of the key goals in project portfolio management (Martinsuo and Killen, 2014). On other hand, managing projects for achieving value is very important in achieving goals of the project (Perera *et al*., 2003).

In an effort to achieve value maximisation, many innovative control strategies are termed as best practices, value improving practices, and within that VM has shown successful results in achieving better performance (Cha and O'Connor, 2006). As a value enhancement technique, VM should not compromise the quality of project outcomes (Abidin and Pasquire, 2005). Value Analysis (VA) is early concept in VM journey and it was first introduced to the USA manufacturing industry by Lawrence D. Miles during World War II (Spaulding *et al*., 2005). Having originated in 1940's in the USA manufacturing industry, in 1954, the term Value Engineering (VE) was used by replacing VA due to its application in the USA military. Later, United Kingdom (UK) construction industry replaced the term VE to VM due to its core activity to fulfil the requirements for the examination of value instead of cost (Maznan *et al*., 2012).

There is no universally accepted definition for VM concept and it has many definitions from various authors' texts, guides and standards (Kelly *et al*., 2015). "VM is a service which maximises the functional value of a project by managing its evolution and development from concept to completion, through the comparison and audit of all decisions against a value system determined by the client or customer" (Kelly and Male, 1993). Jaapar *et al*. (2012) defined VM as an approach that improve the work relationship among the team and at the same time able to achieve better value for money for the projects.

In formal VM process, VM job plan is important (Shen *et al*., 2016). Authors further stated that VM job plan is a sequential approach to implement the basic and major elements of VM implementation. As identified by Kelly and Male (1993), the North American construction industry uses four formal approaches of VM job plan in different phases of a construction project namely, the Charette, the 40-hour workshop, The VE audit, and contractor's change proposal which are known as VM methods. The SAVE 40-hour workshop, which was developed by SAVE International is one of the most popular VM job plans in the construction industry (Shen *et al*., 2016). Furthermore, 40-hour workshop consists of three main phases and six sub phases in workshop stage. This name was given due to the duration required for conducting the workshop (SAVE International, 1998a).

Shen and Liu (2004) have identified the various compositions of VM teams. Authors further identified, in most of the cases apart from the internal project team, invited VM experts and external resource persons related to construction become the VM team who come up with VM proposals.

VM concept has been proposed as an appropriate way to enhance the functionality of projects (Martinsuo and Killen, 2014). Further to Shen *et al*. (2016), VM is not a cost cutting technique, but is a concept, which focuses on best value at the lowest life cycle cost of a construction project.

According to Coetzee (2009), application of VM can result in savings of up to 5-15% of the total costs involved in the project and therefore it is very effective to apply VM to large, expensive, complex, repetitive, restricted budgeted projects and projects with compressed design programmes. The application of VM in construction projects would highly depend on the value of a particular project and the level of the risks involved inside it (CIOB, 2017).

2.2 BARRIERS OF IMPLEMENTING VM IN CONSTRUCTION INDUSTRY

The VM approach often faces challenges when applying in developing countries (Kim *et al*., 2016). Project stakeholders, especially the clients and consultants, depending on their less experience on VM studies their unwillingness to try something new can be identified as barriers for it (Oke and Aigbavboa, 2017). In Sri Lankan context it seems very clear that negative perception of the clients', less support from government/regulatory bodies and even if VM implemented the team not having formal VM experience dilutes VM applications (Perera, *et al*., 2003). Thus, to promote the application of VM, it was determined that identifying factors that impedes the adoption of VM would help. Then practitioners able to assess the barriers which prevents application, acceptance and implementation of VM strategies (Kim *et al*., 2016).

2.3 THEORY AND PRACTICE OF VM

As Kim *et al*., (2016) found out, especially in most of the developing countries, there is an issue of theory-practice gap of VM in construction industry. In terms of Malaysian construction industry context, there are minimal publications, guidelines, manuals and usage of VM knowledge became as major reasons for reluctance to follow VM approach for the construction projects in the country (Jaapur *et al*., 2009).

Bridging theory-practice gap of VM will provide new insights to enhance understanding of VM implementation in construction industry (Jaapar *et al*., 2011). In addition, authors stated that bridging the gap will lead to cost savings. Perera *et al*. (2003) stated that Sri Lankan construction industry can successfully implement VM by following and obtaining the knowledge from other developing countries on how they have successfully implemented VM.

3. RESEARCH METHODOLOGY

This research used qualitative research approach for achieving the research aim. Initially a comprehensive literature survey was carried out to identify the VM concept and its practice in both global and local construction industry. Based on the literature review, research question, which is "how to bridge the VM theory-practice gap in Sri Lankan construction industry?" was established.

Case studies were identified as the best method to achieve the research problem. Number of case studies were limited seven building construction projects, which have implemented VM concept due to lack of suitable projects. Interviews, observations and document review were identified as suitable data collection techniques. Collection of in-depth information from the case studies was conducted until data saturation is reached. Content analysis is a qualitative data analysis technique, which is widely used for analysing documents and interviews (Hsieh and Shannon, 2005). Manual code based content analysis was used for the analysing the research findings.

Finally, interviews with two subject matter experts were carried out to validate the research findings in order to confirm the comprehensiveness of the findings.

4. RESEARCH FINDINGS

The seven case studies carried out through the research process, consisted of two apartment complexes, two hotel projects, one mixed development, laundry complex and a viewing gallery. In each case, four VM team members were selected for interviews among Clients, Architects, Engineers, Quantity Surveyors and Project Managers. VM reports of completed projects, VM workshop agendas and important e-mail copies were considered in document reviewing process. Further, VM applied projects were observed to get further knowledge on its applications. According to respondents' details, although nobody had formal VM qualification, most of them had previous VM experience.

4.1 VM CONCEPT IN SRI LANKAN CONSTRUCTION INDUSTRY

The research findings revealed that VM is still at its infant stage in Sri Lankan construction industry and there is no path to obtain formal VM qualification in Sri Lanka. The following section further elaborates the VM concept, awareness of it and the reasons for VM implementation in construction projects in Sri Lanka.

4.1.1 Value Management

The most frequently highlighted explanations for the term 'value management' in the context of construction industry given by the respondents are summarised below:

- Enhancing value of the output against its input
- Creating value through input resources to the project, which contribute to the whole life cycle of the project
- Completing a project at reduced cost without sacrificing any project component
- Getting the best output for client's money
- Managing cost without compromising value of the project

The above answers reveal that the respondents have marginal knowledge on VM concept, which affects the successful implementation of VM concept. Moreover, most of them do not have thorough idea on how it could improve sustainability, reduce life cycle cost and enhance functionality of elements.

4.1.2 Awareness of VM Concept and Reasons for VM Implementation

The respondents' ideas and knowledge on VM concept were collected in order to establish their view on VM, requirement of applying VM to the project and to identify the relation of them with available literature on theoretical aspect of VM.

All selected projects have practiced VM concept based on its own method and deviations from the standard VM practice can be observed. This was the main reason behind the selection of above mentioned research aim. Nevertheless, it is evident that the reasons for implementing VM for most of the selected building projects were, as a cost cutting technique and to optimise project cost in line with client's budget. The next common reason was to accelerate the project. However, it seems that although VM is a value improvement concept, it has gone to the industry nowadays as a cost cutting strategy rather than a value adding technique.

There should be a person or party to initiate VM application in a construction project. It depends on the nature of the project and the VM knowledge of each persons or professionals who involve in VM activities of the project. As per research findings, the situations where, VM implementing with client's opinion was very low. The only project VM initiated by client had a foreign client. It seems that in the Sri Lankan construction industry perspective, the traditional clients in Sri Lanka are not initiating ideas for VM implementation for the projects. However, in the contractors' perspective, Sri Lanka has the culture of implementing VM through contractors change proposals. In the case study, where VM implementation ideas initiated by the Engineer, the project has a foreign Engineer. In one of the cases, an Engineer performed the VM initiation as a result of being the consultant and the client of the same organisation.

4.2 VM APPLICATION IN SRI LANKAN BUILDING PROJECTS

Implementation of VM activities during pre-contract and post contract stages affect the benefits of VM application. It was observed that among selected projects, only three projects have been implemented VM in both pre and post contract stages. The implementation of VM in pre-contract stage in a construction project, depends on the collaboration of client and the contractor with the engineer. To create the collaborative approach, contractor's contribution for the ideas is a requirement. The contractor's arrival at the pre-contract stage helps to pool the knowledge of all parties.

For the purpose of collecting information regarding VM composition of value team, respondents were asked about the criteria for selecting them. The most common answer given was according to the nature of the requirement of VM application, the team composition selected according to the element that VM is applied to. The most prominent feature identified from observed all the cases, the VM team for each case were the design team or project team or combination of both team members of the project. As revealed by case studies, when deciding the team composition, the stage of implementing VM is important as identified through cases. According to the observation of cases, it reveals that, VM team composition also depend on VM methodology followed.

Shen *et al*. (2016) stated that in a VM team, it is always beneficial to have a VM facilitator or a certified value specialist. However, when observing the case studies, there were no project found with a VM facilitator. The person who have the most overall knowledge in the project become in-house VM facilitator to the project in Sri Lankan context.

The intended purposes of implementing VM in each project are presented in Table 1.

Table 1: Objectives of VM implementation

Case	Planned duration	Actual duration	Value Objectives
Case A	14 months	14 months	Controlling the budget overrun, Time saving, Cost optimisation
Case B	3 years	40 months	To reduce the extra initial cost and optimise project cost, Reducing energy consumption, Life cycle improvements, Client satisfaction, Functional improvement, Sustainability, Improving functions
Case C	4 years	6 years	Design optimisation as fit to the client's budget, Sustainability
Case D	6 years	Time overrun due to arbitration	Quality, Complying with hotel chain standards, Unnecessary cost cutting, Saving huge labour cost, Not affecting to the overall function
Case E	2.5 years	2 years	Structural stability, Acceleration, Fewer issues to the MEP work and durability of material, Making convenience on maintenance

Case	Planned duration	Actual duration	Value Objectives
Case F	1 year	9 months	To obtain constructability, Sustainability, Cost reduction, Time acceleration, Quality improvement
Case G	2 years	Not finalised	To reduce excessive cost allocated for pile deck ponding, To accelerate the project to complete within allocated time period, To save unnecessary additional cost

It can be identified that, objectives of VM application in each project were different. But in most of the cases, the main purpose of implementing VM was for cost cutting.

4.3 THEORY-PRACTICE GAP OF VM

One of the objectives of this study is to identify the teary-practice gap of VM. The identified practices of VM from case studies compared to the theoretical aspects are summarised in Table 2.

Table 2: VM theory vs practice

	Systematic VM Applications (Theory)	VM Application in Sri Lanka (Practice)
VM Team	Comprise of VM experts, Design/ Project team and the Client	Comprise of design / project team
VM Facilitator	Qualified VM facilitator (Certified Value Specialist) is available	Person who has overall idea of the project will be the VM facilitator
VM Approach	Collaborative approach of Client, Consultant, Contractor and VM experts	VM approach is based on client or project team requirements
VM Workshop	Conduct systematic formal VM workshops	Conduct VM discussion meetings in ad-hoc manner
VM Focus	Cost optimisation, time acceleration, quality improvement, functional improvement and performance improvement	Cost reduction and time acceleration
VM Implementation	Implement at the inception or design stage to gain best output	Implement to overcome issues such as cost or time overrun, specially during construction stage
Documentation	Whole process and expected outcomes are formally documented.	Very less documentation
Decision Making	VM team and VM specialist responsible for decisions	Proposer has the responsibility and risk
Project Programme	Allocate time for VM workshop in project programme	Specific time is not allocated for VM workshop
Monitoring Results	VM team monitor the interim progress and compare the results with established expected outcomes	No one monitors the interim progress compared to expected outcomes.

Aforementioned findings presented in Table 2 confirms that Sri Lankan construction industry practitioners do not have thorough knowledge on VM concept and its correct implementation. Hence, it is evident that there is a theory and practice gap in VM implementation in Sri Lanka. Therefore, there is a need to investigate the strategies to bridge the VM theory-practice gap.

4.4 STRATEGIES TO BRIDGE VM THEORY-PRACTICE GAP

For investigating theory and practice gap of VM concept in Sri Lankan construction industry, it is very important to identify the barriers. Strategies to overcome from the barriers identified in this study are mapped in Figure 1.

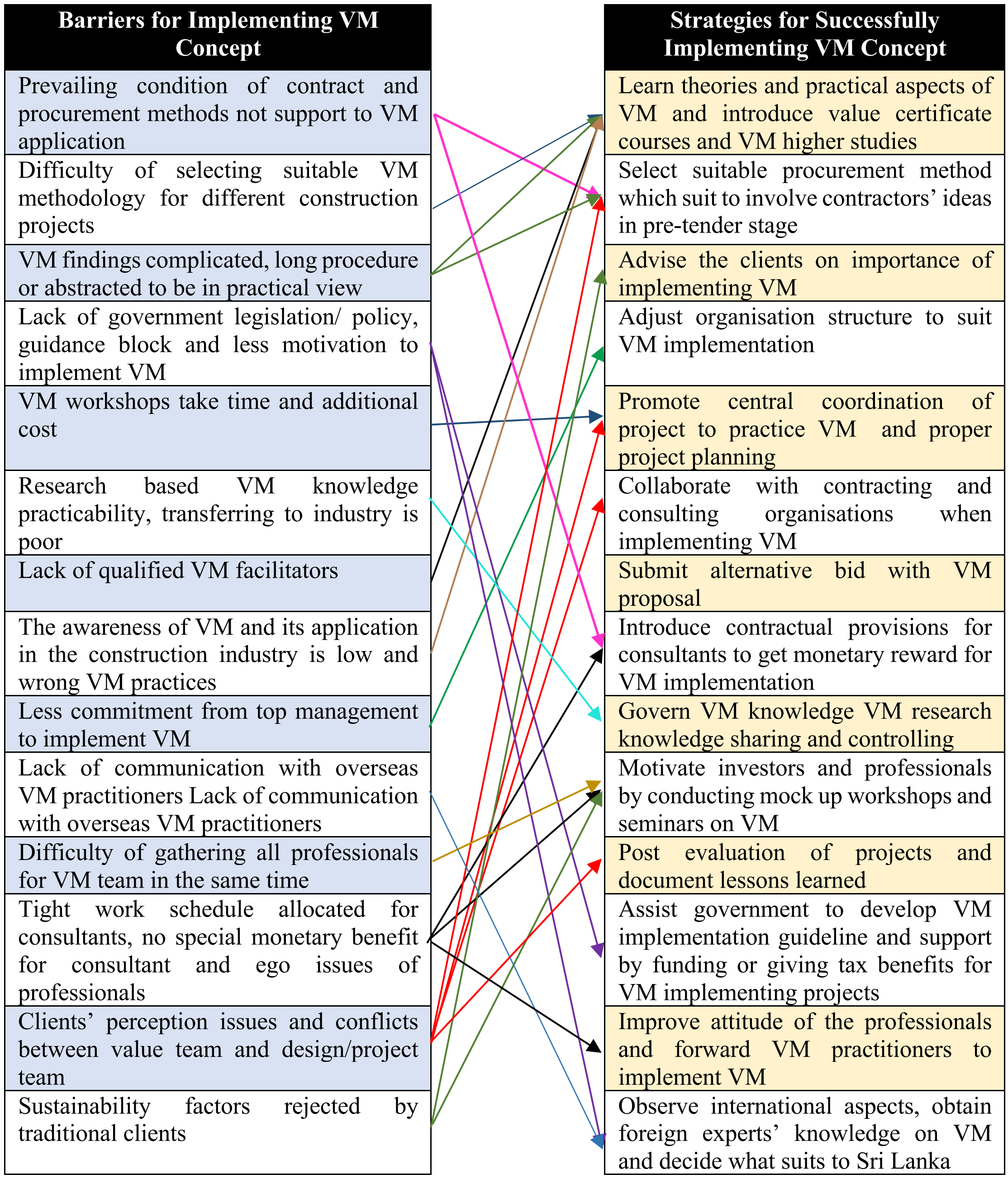

Figure 1: Strategies for bridging VM theory-practice gap

Findings indicated in Figure 1 reveals that there are number of barriers, which de-motivate proper VM implementation and lead to theory-practice gap in VM application in Sri Lankan construction industry. The study further identified tight work schedules and ego of professionals as key reasons that hamper the successful implementation of VM in construction projects. Hence, the implementation of VM in Sri Lankan construction industry is far from theoretical and standard VM practices.

The key strategies proposed to bridge the VM theory-practice gap in Figure 1 includes: (a) develop VM education process, (b) selection of suitable procurement method, (c) proper project planning, (d) motivate investors and professionals, (e) train VM facilitators and (f) govern VM knowledge sharing. Hence, the study makes recommendations for bridging VM theory-practice gap in order to deliver value for client's money.

5. DISCUSSION AND CONCLUSIONS

VM has been globally implemented to gain lot of savings and benefits. However, in Sri Lankan construction industry, it is evident that the application of VM is lacking. Bridging the theory-practice gap of VM derived as a requirement based on these circumstances which mainly contributes to economy of the country. VM is a value enhancement strategy. The case study findings also revealed that the projects have used VM to achieve different VM objectives, whilst delivering value for money. However, VM concept has not deeply rooted to the Sri Lankan construction industry and the VM teams mainly use it to reduce costs in construction projects.

The respondents highlighted that, if systematic VM process carried out, the outcome of VM implementation would be better than current situation. The other most prominent finding was although most popular VM job plan in the construction industry is SAVE 40-hour workshop, Sri Lankan construction industry more familiar with "contractors change proposal" than other methodologies. The reason for that is provided provision for it from the contractual arrangements such as FIDIC and Standard Bidding Document (SBD). However, findings revealed that there are number of theory-practice gaps in VM application in Sri Lankan construction industry, which de-motivates proper VM implementation. Due to these gaps, the implementation of VM in Sri Lankan construction sector is far from theoretical and standard VM practices.

The strategies proposed to bridge the VM theory-practice gap include train in-house VM facilitators, proper project planning, motivate investors, train Sri Lankan professionals by foreign experts and govern VM knowledge sharing. Hence, this study recommends that VM should be properly and systematically initiated in Sri Lankan construction industry by bridging existing gaps of theory-practice through the strategies in order to deliver value for client's money.

6. REFERENCES

Abidin, N. Z. and Pasquire, C. L., 2005. Delivering sustainability through value management: Concept and performance overview. *Engineering, Construction and Architectural Management*, 12(2), pp.168-180.

Abidin, N. Z. and Pasquire, C. L., 2007. Revolutionize value management: A mode towards sustainability. *International Journal of Project Management*, pp.275-282.

Aibinu, A. and Jagboro, G., 2002. The effects of construction delays on project delivery in Nigerian construction industry. *International Journal of Project Management*, 20(8), pp.593-599.

Bowen, P., Cattell, K., Edwards, P. and Jay, I., 2010. Value Management Practice by South African Quantity Surveyors. *Facilities*, 28(1/2), pp.46-63.

Cha, H. and O'Connor, J., 2006. Characteristics for Leveraging Value Management Processes on Capital Facility Projects. *Journal of Management in Engineering*, 22(3), pp.135-147.

Chartered Institute of Building Construction [CIOB], 2017. Value management in building design and construction. [Online] Available at: https://www.designingbuildings.co.uk/wiki/Value_management_in_building_design_and_construction [Accessed 17 December 2018].

Coetzee, C. E., 2009. *Value Management in the Construction Industry: What Does It Entail and is it A Worth Practice*. University of Pretori.

Ekanayake, A. C. and Sandanayake, Y. G., 2017. LiVE approach: lean integrated value engineering for construction industry. *Built Environment Project and Asset Management*, 7(5), pp.518-533.

Ellis, R. C. T., Wood, G. D. and Keel, D. A., 2005. Value management practices of leading UK cost consultants. *Construction Management and Economics*, 23(5), pp.483-493.

Gillier, T., Hooge, S. and Piat, G., 2015. Framing value management for creative projects: An expansive perspective. *International Journal of Project Management*, 33(4), pp.947-960.

Hayles, C., Graham, M. and Fong, P. S. W., 2010. Value management for sustainable decision making. *Municipal Engineer*, March, pp.43-60.

Hsieh, H. F. and Shannon, S. E., 2005. Three Approaches to Qualitative Content Analysis. *Qualitative Health Research Journal*, 15(9), pp.1277-1288.

Institute of Value Management Australia [IVMA], 2017. Institute of Value Management Australia. [Online] Available at: http://ivma.org.au/value-management/application-of-value-management [Accessed 3 January 2018].

Jaapar, A., Maznana, N. and Zawawia, M., 2012. *Implementation of Value Management in Public Projects*. pp.77-86.

Jaapar, A., Zawawi, M., Bari, N. and Ahmad, N., 2011. *Value Management in the Malaysian Construction Industry: Addressing a Theory and Practice Gap*. Famagusta, North Cyprus, pp.757-763.

Jaapur, A., Endut, I. R., Bari, N. and Takim, R., 2009. The Impact of Value Management Implementation in Malaysia. *Journal of Sustainable Development*, 2(2), pp.210-219.

Karim, S. B. A., 2016. *The Application of Value Management on Private Projects*. QS Link , pp.33-36.

Karunasena, G. and Gamage, O., 2011. *Value Achievement in Construction Industry*. Colombo, Department of Building Economics, Universityof Moratuwa, pp.152-161.

Kelly, J. and Male, S., 1993. *Value Management in Design and Construction: The Economic Management of Projects*. London: E and FN Spon, an imprint of Chapman and Hall.

Kelly, J., Male, S. and Graham, D., 2015. *Value Management of Construction Projects*. 2nd ed. West Sussex: John Wiley and Sons.

Kim, S., Lee, Y., Nguyen, V. and Luu, V., 2016. Barriers to Applying Value Management in the Vietnamese Construction Industry. *Journal of Construction in Developing Countries*, 21(2), pp.55-80.

Martinsuo, M. and Killen, C. P., 2014. Value Management in Project Portfolios: Identifying and Assessing Strategic Value. *Project Management Journal*, 45(5), pp.56-70.

Mat, M. M. C., 2014. *Value management - The way forward*, Institute of Value Management Malaysia.

Maznan, N. A., Bari, N. A. A. and Zawawi, M., 2012. *Value Management: Private Sector's Perception*. Bangkok, pp.383-391.

Oke, A. and Aigbavboa, C., 2017. *Barriers of Sustainable Value Management. In: Sustainable value management for construction projects*. pp.169-177.

Perera, S., Hayles, C. S. and Kerlin, S., 2011. An analysis of value management in practice: the case of Northern Ireland's construction industry. J*ournal of Financial Management of Property and Construction*, 16(2), pp.94-110.

Perera, S., Karunasena, G. and Selvadurai, K., 2003. Application of Value Management in Construction. *Built Environment Sri Lanka*, 4(1), pp.3-12.

Rameezdeen, R. and De Silva, S., 2002. Trends in construction procurement systems in Sri Lanka. *Built Environment Sri Lanka*, 2(2), pp.2-9.

SAVE Iinternational, 1998a. Function: definition and analysis. [Online] Available at: http://www.value-eng.org/pdf_docs/monographs/funcmono.pdf [Accessed 25 August 2018].

Shen, Q. and Liu, G., 2004. Applications of value management in the construction industry in China. Engineering, *Construction and Architectural Management*, 11(1), pp.9-19.

Shen, Q., Yu, A. and Chung, K., 2016. *VM Applications. In: Value Management in Construction and Real Estate*. New York: Routledge, pp.66-67.

Spaulding, W. M., Bridge, A. and Skitmore, M., 2005. The use of function analysis as the basis of value management in the Australian construction industry. *Construction Management and Economics*, 23(7), pp.723-731.

Toy, T., 1995. *Value of VM Facilitation*, The Hong Kong Institute of Value Management.

Yin, R. K., 2014. *Case study research: Design and methods*. 5th ed. CA: Sage Publications.

Azeem, A.H.A., Mallawarachi, H. and Geekiyanage, D., 2019. Building organisational capacities for effective e-waste management: A conceptual framework. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 158-167. DOI: doi.org/10.31705/WCS.2019.16. Available at: https://2019.ciobwcs.com/papers

BUILDING ORGANISATIONAL CAPACITIES FOR EFFECTIVE E-WASTE MANAGEMENT: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Globally, e-waste generation rises in parallel to the increased consumption of e-products. Management of this complex waste stream becomes a severe challenge, especially for developing countries. Sri Lanka also no exception to this problem due to the limited capacities of e-waste handling organisations in the country. Therefore, this study aims to develop a conceptual framework for effective e-waste management by integrating organisational capacities to improve the involvement of organisations for effective e-waste management. Initially, a comprehensive literature review was carried out on the state-of-art of the e-waste management, capacity buildings, and application of organisational capacities for e-waste management alike. The review of the literature revealed that there are eight dimensions to measure organisational capacities. They are mission and strategy, organisational structure, processes, human resources, financial resources, information resources, and infrastructure. The data collected from the literature review was manually analysed and finally, the conceptual framework was developed on organisational capacity buildings for effective e-waste management. The developed conceptual framework can be used as a guideline to implement organisational capacities for e-waste management. This framework will be a blueprint for individuals and organisations to incorporate dimensions of organisational capacity buildings to e-waste management by identifying the existing capacity gaps consequently, enhancing the organisational capacity for better managing the e-waste, especially in developing countries.

Keywords: *Capacity Buildings; Capacity Gaps; Developing Countries; E-Waste Management; Organisational Capacity.*

1. INTRODUCTION

Rapid development in the global economy, growing population, market penetration and exponential growth in technological innovation and product obsolescence fuelling the generation of the e-waste (Li *et al*., 2015). In worldwide, generation of e-waste has risen gradually together with an annual growth rate of 4-5%. The global e-waste generation of 41.8 million metric tonnes (MT) in 2014 represents the 1-3% of municipal waste, and it is expected to reach 50 million MT by 2018 (Wath *et al*., 2010). Furthermore, in developing countries, on average total e-waste generation represents 1% of total solid waste generation and it is forecasted to be increased by 2% annually (United Nations Environment Programme [UNEP], 2010). Indeed, developing countries' e-waste flow

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will likely to overtake the developed countries by 2030 (Li *et al*., 2015; Sthiannopkao and Wong, 2013;).

Similarly, Ratnayake *et al*. (2016) stated that the penetration of electrical and electronic equipment (e-products) market has considerably increased in Sri Lanka in recent decades. In line with that, management of the e-waste has become a critical concern in Sri Lanka to ensure that this e-waste does not dumb into landfills or watersides (Accounting and Financial Management Association [AFMA], 2015). Besides, most industrialised countries use advanced technologies, state of the art of facilities, and a high degree of mechanization for the management of e-waste (Li *et al*., 2015). Consequently, leading organisations have contributed to an upstream reduction of e-waste through product re-design and recyclable components (Nnorom and Osibanjo, 2008). However, Adediran and Abdulkarim (2012) argued that there are considerable capacities gaps in developing countries in the management of the e-waste in terms of policies, institutional framework, infrastructure, and amongst others. Sri Lanka is also no exception to these capacity gaps in the proper management of e-waste (Suraweera, 2016).

Therefore, addressing the limited capacities in organisations is a timely need to boost the organisations' in line with proper management of e-waste. This study is undertaken to integrate the organisational capacities into e-waste management and thereby to develop a conceptual framework to improve the organisational capacities for effective e-waste management, especially in developing countries.

2. RESEARCH METHODS

A comprehensive literature review was carried out to gain an in-depth understanding of the e-waste management, importance of managing e-waste, importance of enhancing organisational capacities building, which was discussed on both international and local context. This study was accomplished by referring the books, journal articles, conference proceedings, governments reports, and websites. A summary profile of literature sources referred to is presented in Table 1.

Table 1: The profile of literature sources referred for the study

Sources	**Focused Area**			**Quantity**		**Period of Publications**
	E-waste	**Capacity building**	**Both**	**No.**	**%**	
Journal Articles	18	22	07	47	70	2004 – 2017
Government Reports	03	07	-	10	15	1998 – 2017
Conference Papers	05	01	-	06	09	2003 – 2016
Books	01	02	-	03	05	1995 - 2015
Website	01	-	-	01	01	2017
Total	**28**	**32**	**07**	**67**	**100**	

Amongst, the majority (70%) of the literature sources are indexed journal articles which are published during the recent 20 years. Next, 10 number of government reports (15%) that are published in the global context and by the government of Sri Lanka were referred and most of the statistics about e-waste generation and control were extracted. Besides, six conference publications, three books on e-waste management and capacity buildings, and one website were reviewed for the collection of required data and to obtain knowledge for the development of the conceptual framework for building organisational capacities for effective e-waste management, particularly for developing countries.

3. LITERATURE REVIEW

3.1 CURRENT STATUS OF E-WASTE MANAGEMENT

Even though there is no common definition, proper definition and identification of categories of e-waste are critical for the sound management of e-waste. Therefore, the definition given in the directive of the 2002/96/EC on the waste of electrical and electronic equipment (WEEE) identified as broad and widely used definition around the globe. Accordingly, in this research, the e-waste is defined as *"Electrical and electronic equipment, all components, subassemblies and consumables which are part of the discarding product"* (EU, 1975 as cited in Ejiogu, 2013). Consequently, Garlapati (2016) stated that this e-waste stream is highly produced in developed countries, China is identified as the substantial contributor of e-waste that is of 12.2 million MT followed by the United States which about 11 million MT. Further to the author, similarly as of developed countries, the flow of e-waste is gradually increasing in developing countries. In India, e-waste is growing at a compounded annual growth rate of about 25 % and is estimated to generate 15 lakh MT of e-waste by 2015 (Garlapati, 2016).

Currently, in Sri Lanka, approximately 10,000 MT of non-white goods such as mobile phones and PCs, etc., are estimated to be generated annually (Central Environmental Authority [CEA], 2016). Further to report, amongst, only 8 % of e-waste is collected and exported to other countries. About 92% of goods are stored or disposed of in a haphazard manner (CEA, 2016). Further, usage of personal computers has increased from 1993 to 2000 and it is estimated to be 17.5 times per capita basis (Ministry of Environment and Natural Resources [MENR], 2008). Besides, the government of Sri Lanka has established 1005 telecentres throughout the island under the e-Sri Lanka initiative programme (Information and Communication Technology Agency [ICTA], 2017). It let to increasing of imports of information and communication technology (ICT) goods in the country while increasing the imports of ICT goods from 2.9 - 4.2 % within a period five years (World Bank, 2017). Therefore, CEA (2016) mentioned that with the growing penetration of electrical and electronic equipment, annual e-waste generation in the country is estimated at 20,000 MT and it is expected to reach about 43,000 MT per year in 2030. With this growing e-waste generation, the toxic substances in e-waste streams could have a serious risk to human health, leaches soil and contaminate the environment as there is no proper mechanism for its management (Begum, 2013).

Tran and Salhofer (2016) identified the stages involve in the e-waste management process from generation to final disposal which depicts in Figure 1. These subsequently connected steps of e-waste recycling are required to liberate the target materials and to further refine them separately (Baldé *et al*., 2015). Dutta and Goel (2017) insisted that effective and proper solutions are required for the proper management of e-waste.

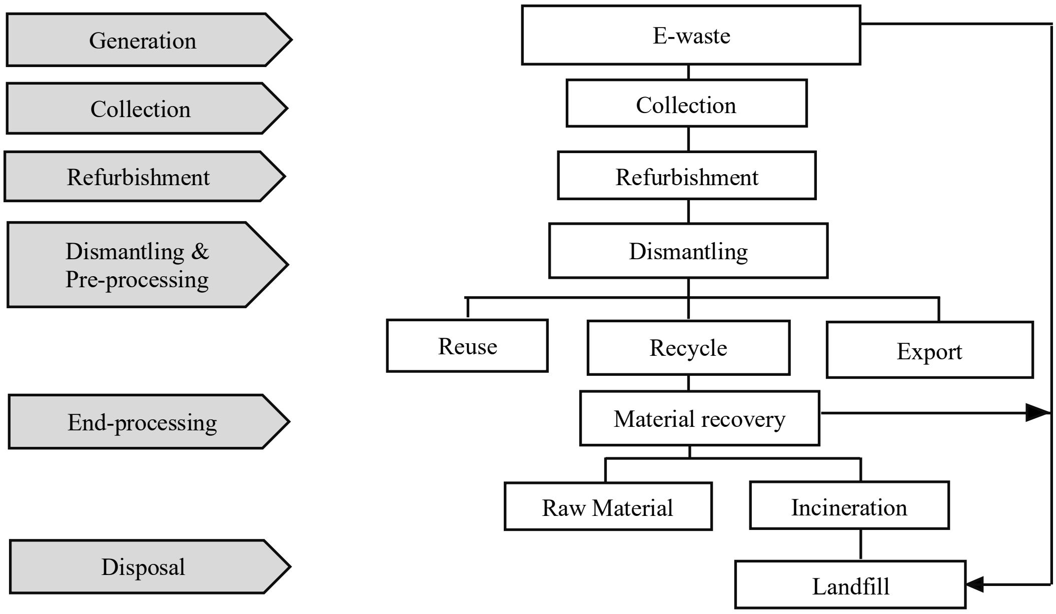

Figure 1: E-waste management process (Source: Adapted from Jang and Kim, 2010; Tran and Salhofer, 2016)

3.2 Capacity Needs for E-Waste Management

The rapid product obsolescence in the electronics industry has caused significant growth in global e-waste generation. Consequently, safer management of e-waste is becoming a major problem for many countries around the globe. Heeks *et al*. (2015) stated that developing countries, in particular, face challenges in managing the growing e-waste problem. For example, in Africa there are highly ineffective and inefficient infrastructure facilities for e-waste management, more precisely there is no well-established system for separation, sorting, storage, collection, transportation and disposal of e-waste (Bhutta *et al*., 2011). More importantly, there is an absence or ineffective enforcement of legislation related to e-waste management and disposal (Nnorom and Osibanjo, 2008). Therefore, leading multi-national companies fully adhered to the principle of developed countries where strict regulation are enforced, are being free from taking the fullest responsibility of product throughout its entire lifecycle in developing countries (Kibert, 2004).

It causes the obsolete or scrap of e-products not being collected for appropriate management in most developing countries (Nnorom and Osibanjo, 2008). Kalpana and Prabhavathi (2016) identified that absences of e-waste collection lead to store about 75% of the e-waste in unattended houses, offices, etc. Finally, the management of this e-waste is taking place through traditional methods of municipal solid waste management (MSW) namely landfilling or incineration (Nnorom and Osibanjo, 2008). Besides, Jadhav (2013) stated that probably the e-waste is given to the informal collectors who pay some amount to the consumer. Consequently, informal and inappropriate handling of e-waste causing serious environmental and human health issues. Accordingly, Adediran and Abdulkarim (2012) stated that no public awareness has been done by public and private sectors on the adverse effects of improper handling of e-waste. Moreover, consumers are not aware of the e-waste collection centres, rules and proper e-waste disposal practices (Sivathanu, 2016).

It is one of the examples of poor corporate social responsibility of electronic industries (Adediran and Abdulkarim, 2012). Furthermore, in most developed countries, consumer finance to recycle their e-waste (Li *et al*., 2015). Further to authors, it's regrettable; end-users in developing countries tend to sell their e-waste to the collectors who offer them better collection price. Therefore, organisations struggled in collecting funds, to invest in profitable improvements in e-waste recycling is emerged (Nnorom and Osibanjo, 2008).

Several initiatives have been undertaken in Sri Lanka to effectively manage the end of life of the electronic equipment (Suraweera, 2016). Subsequently, CEA has introduced the guidelines on the proper management of the e-waste (CEA, 2016). In addition to that, CEA has introduced the "National Corporate E-waste Management Program" with the participation of 19 private sector companies (CEA, 2016). Rodrigo (2013) mentioned that these companies accept to collect the respective end of life e-products through their designated service centres. However, evidence proved that these collaborative projects malfunction due to various reasons such as unavailability of any special strategies in the organisation for collection and it is not being implemented up to expected standards (Thavalingam and Karunasena, 2016). Ratnayake *et al*. (2016) further stated that most of the people are willing to support for the implementation of proper e-waste management in the urban area if they get enough support facilities for convenient and accessible e-waste collection centres. However, due to the absence of enough support facilities, these hazardous wastes are currently disposed of in roadsides, dump yards, stores and home gardens. Similarly, Ratnayake *et al*. (2016) specified that for example, 8 MT of e-waste accumulates for every two days within the urban area of the Gampaha district. Moreover, it is about 80 % of the household sector of the Jaffna district keeping their e-waste at home, similarly, all the public offices following the same act of keeping the e-waste in stores until they are auctioned (Kayathiri *et al*., 2014). Even though organisations used several strategies to create awareness among the public, it resulted in giving only short-term effects (Thavalingam and Karunasena, 2016). Authors further added that informal collectors engaged in the collection of e-waste using an unsophisticated technique to obtain precious metals from the e-waste have caused serious environmental and health issues. Furthermore, Mallawarachchi and Karunasena (2012) stressed that most organisations are at the basic stage of the e-waste management process and there is no special concern given to manage the e-waste. Further to the author, there is a lack of coordination between these government and private organisations in implementing the e-waste management procedures. Similarly, cooperation between formal and informal e-waste recycling companies is also in very minimal level in the country (CEA, 2016). Moreover, most organisations confronted with financial constraint in implementing the e-waste management process in organisations (Mallawarachchi and Karunasena, 2012). Due to the visible capacity gaps in the organisations, CEA (2016) has concluded that there was limited capacity in managing e-waste within the context of Sri Lanka.

Considering the challenges of managing the e-waste in developing countries, the electronic industries seemed to be not matured enough for managing the e-waste in these countries. Even though electronic industries cannot properly manage the e-waste, manufacturers of e-product are required to take the fullest responsibility for their products throughout its lifecycle (Ladou and Lovegrove, 2008). Therefore, Karunasena and Amaratunga (2015) stated that capacity building is necessary due to a lack of financial, institutional, technological and infrastructure capacities and access to knowledge to deal with risks and benefits. Therefore, it is necessary that existing capacities gaps in organisations need to be addressed to manage the rapid growth of the e-waste stream in the country. Accordingly, the concept of capacity building chosen to build the capacity of the organisations as a means to promote environmentally sound management of e-waste in Sri Lanka.

3.3 IMPORTANCE OF ORGANISATIONAL CAPACITY BUILDING FOR E-WASTE MANAGEMENT

The organisational capacity building focuses on the overall organisational performance and functioning capabilities as well as the ability of an organisation to adapt to change (Blokland *et al*., 2010). The organisational approach considers an entity, organisation or even a set of organisations as key to development (Lusthaus *et al*., 1995). Enemark and Williamson (2004) mentioned that an entity may be a formal organisation such as government or one of its departments or agencies, a private sector operation or an informal organisation such as community-based or volunteer organisation. The report of (UNDP, 1998) specified that traditional capacity development of the entity level focuses their development resources almost entirely on human resources, processes and organisational structures. The study further mentioned that, instead of focusing only in these areas, it should examine all dimensions of capacity at entity level including its interactions within the system, usually with other entities, stakeholders or clients, if the development initiatives to be successful.

It is due to that the organisational capacity building is complicated by multiplicity of environmental factors and also the organisations' function within the broad level, sometimes overlapping and often have complex contexts with laws, regulations, ordinances, policies and other government, community and donor priorities (US Agency for International Development [USAID], 2011). The context provides incentives to the organisations, which in turn stimulates them to act in certain manners, some incentives foster productivity, growth and capacity development, while others foster passivity, decline or even closer (Organisation for Economic Co-Operation and Development [OECD], 2006). Consequently, Table 2 provides detailed descriptions of dimensions of capacity at the organisational level which are used to measure the capacity of the organisation.

Table 2: Descriptions of dimensions at the organisational level

Dimensions at Organisational Level	Descriptions
Mission and Strategy	The strategy refers to all those activities that set the course for the organisation and help keep it on course in service of its mission. This includes role, mandate, the definition of services, clients or customer served, interactions within the broader system and stakeholder, the measures of performance and success, and the presence of core strategic management capacities
Organisational Structure	It includes organizational and management values, management style, and understanding organizational and managerial structures, designs, core competencies and standards within an entity or organization
Processes	It means supporting such functions as planning, client management, relationships with other entities, research or policy development, monitoring and evaluation, performance or quality management, financial and human resources management, etc. processes are central to improve capacities

Dimensions at Organisational Level	Descriptions
Human Resources	This is the most valuable resources in an organisation. Human resources management practices become vital in an organization's ability to achieve its goals. The study further added that the individual's goals apart from the organizational goals should be well defined and understandable and it would help to measure the performance of every one of an organization
Financial Resources	The financial resources include both operating and capital finance which are the part of the assets of the organization. Financial resources need to be managed to maximize the corporate value and to reduce the firm's financial risk
Information Resources	Identifying how the available information resources (all media, electronic and paper) are managed to support the mission and strategies of the entity
Infrastructure	It includes the assessment of existing infrastructures in terms of physical assets such as property, building, computer system and telecommunication infrastructure, productive work environments

Source: Adapted from Enemark and Williamson (2004); Imbaruddin (2005); Lusthaus *et al.* (1995); Siano *et al.* (2010); UNDP (1998)

3.4 THE CONCEPTUAL FRAMEWORK FOR BUILDING ORGANISATIONAL CAPACITIES FOR E-WASTE MANAGEMENT

The framework exhibits the organisational level capacity dimensions for e-waste management, which facilitates a basis to investigate the existing organisational capacities and gaps of the capacities for e-waste management. The developed conceptual framework is illustrated in Figure 2.

In the developed framework, the organisational capacity can be assessed under eight capacity dimensions specified by the UNDP, namely, mission and strategy, organisational structure, processes, human resources, financial resources, information resources, infrastructure resources. In a different viewpoint, the identified capacity gaps in organisational buildings can be eliminated and/or minimised by the integration of identified strategies for improvement. Initially, the organisational mission and strategies need to revise incorporating potential e-waste management policy, activities and an appropriate financial plan needs to be formed. Next, a responsible party/authority towards the e-waste management need to be appointed and placed within the organisational structure. It is essential to implement the required processes to improve the current management of e-waste and minimise the existing capacity gaps. It means supporting such functions as planning, client management, relationships with other entities, research or policy development, monitoring and evaluation, performance or quality management, financial and human resources management, etc. It is vital to allocate necessary and sufficient amount of human and financial resources to support the implementation of the set process towards effective e-waste management. As the continual improvement of the process, it is required to observe and evaluate the performance of allocated resources and infrastructure to know how effectively they have achieved the set outcomes. Finally, the appropriate changes and possible improvements can be done to further improve improved e-waste management.

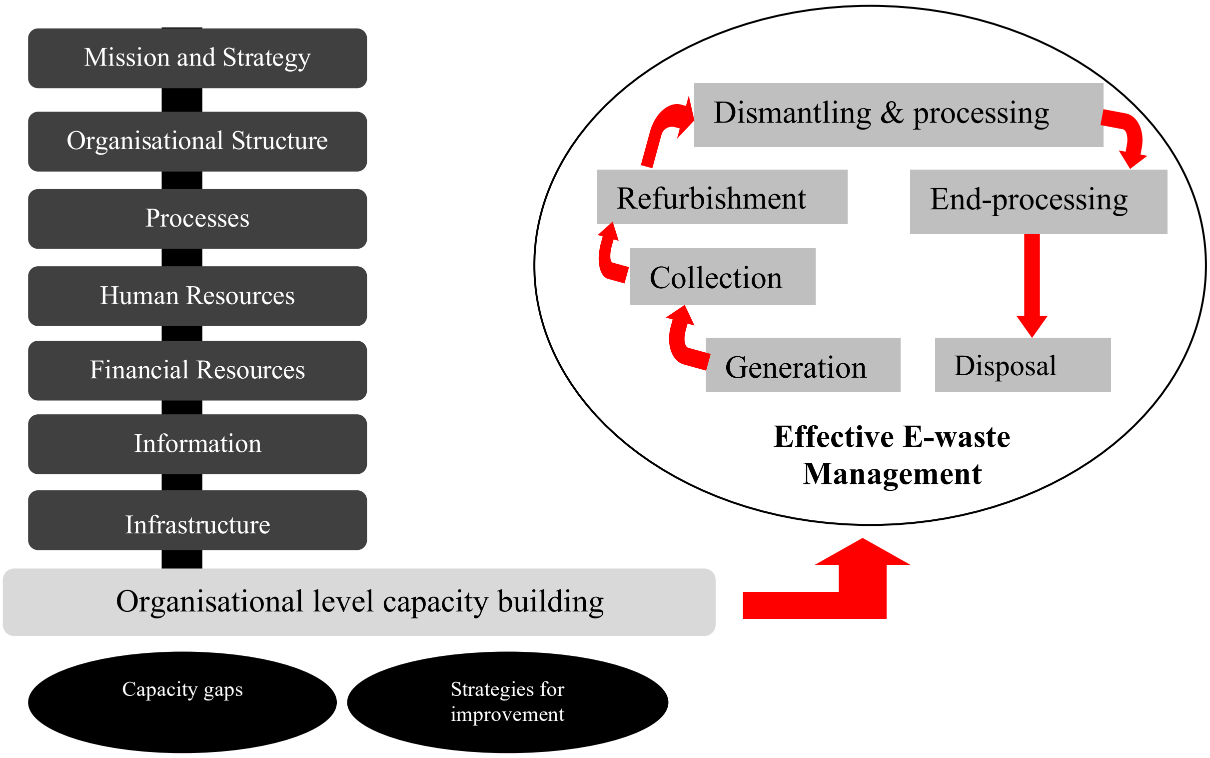

Figure 2: The conceptual framework for effective e-waste management

4. CONCLUSIONS

A result of the comprehensive review of the literature suggests that ever-increasing e-waste that has challenged its proper management in developed countries has now extended to developing countries like Sri Lanka. However, it is found that these developing countries are far less having the necessary state of the art of facilities, infrastructure, poor corporate social responsibility of electronic manufacturing industry and relevant legislation which are the basic requirement to manage the e-waste, compared to developed countries. In Sri Lanka, though the government has introduced a national policy on e-waste management together with several other projects collaborated with private sectors, which aim to manage e-waste, still the crisis has not been reduced to the targeted level. These challenges are required to be addressed for the proper management of e-waste. This brought the study to focus on applying the concept of the capacity building into e-waste management which then helps electronic manufacturing organisations to enhance its capacities to break the challenges evolving of ever-increasing e-waste by eliminating the issues which are prevailing as barriers for proper e-waste management. Therefore, this study developed a conceptual framework that applying capacity-building concept for effective e-waste management. The developed framework is a unique one that is the first and foremost, integrate the capacity-building concept to e-waste management, though there are several capacity-building frameworks exist in different disciplines.

However, the scope of the study was limited only to organisation level capacity among the three levels of capacities. Besides, among the different types of solid waste, it only focuses on e-waste and a special emphasis was given on e-waste management practices and involvement of organisational capacities in e-waste management in developing states.

Consequently, it necessitates that these capacities gaps in an organisation need to be addressed for the effective management of e-waste. Therefore, future research can be taken to enhance the organisational capacities for the proper management of e-waste in Sri Lanka.

5. REFERENCES

AFMA. (2015). *E-waste management in Sri Lanka.* (A. Gunarathne, Ed.) Nugegoda: University of Sri Jayewardenepura.

Adediran, Y. and Abdulkarim, A., 2012. Challenges of electronic waste management in Nigeria. *International Journal of Advances in Engineering & Technology*, 4(1), pp.640-648.

Baldé, C.P., Wang, F., Kuehr, R. and Huisman, J., 2015. *The global e-waste monitor–2014*. Bonn, Germany: United Nations University, IAS–SCYCLE.

Begum, K.J., 2013. Electronic Waste (E-Waste) Management in India: A Review. *IOSR Journal of Humanities and Social Science*, 10(4), pp.46-57.

Bhutta, M.K., Omar, A. and Yang, X. (2011). Electronic Waste: A Growing Concern in Today's Environment. *Economics Research International*, pp.1-9.

Blokland, M., Alaerts, G., Kaspersma, J. and Hare, M., 2010. *Capacity development for improved water management*. CRC Press.

CEA, 2016. *Status Report on Electrical and Electronic Waste Management in Sri Lanka*. Battaramulla: Ministry of Mahaweli Development and Environment.

Dutta, D. and Goel, S., 2017. Electronic Waste (E-Waste) Generation and Management. *In Advances in Solid and Hazardous Waste Management*, pp.249-266. Springer, Cham.

Ejiogu, A.R. (2013). E-waste economics: a Nigerian perspective. *Management of Environmental Quality: An International Journal*, 24(2), pp.199-213.

Enemark, S. and Williamson, I. 2004. Capacity building in land administration - a conceptual approach. *Survey Review*, 37(294), pp.639-650.

Garlapati, V.K. (2016). E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. *Renewable and Sustainable Energy Reviews*, 54, 874-881.

Heeks, R., Subramanian, L. and Jones, C., 2015. Understanding e-Waste Management in Developing Countries: Strategies, Determinants, and Policy Implications in the Indian ICT Sector. *Information Technology for Development*, 21(4), pp.653-667.

ICTA, 2017. Information and Communication Technology Agency of Sri Lanka. Available from: https://www.icta.lk/projects/nenasala-project-national-telecenter-project/# [Accessed 22 July 2017].

Imbaruddin, A., 2005. Institutional capacity: an analytical framework. *Journal Administration Public*, 1(1), pp.1-18.

Jadhav, M.S., 2013. Electronic waste: a growing concern in today's environmental sustainability. *International Journal of Social Science & Interdisciplinary Research*, 2(2), pp.139-147.

Jang, Y.C. and Kim, M., 2010. Management of used & end-of-life mobile phones in Korea: A review. *Resources, Conservation and Recycling*, 55, pp.11-19.

Kalpana, B. and Prabhavathi, M., 2016. E-waste management. International Journal of Innovative *Research in Information Security*, 3(9), pp.26-28.

Karunasena, G. and Amaratunga, D., 2015. Capacity gaps in post-disaster construction & demolition waste management. *Engineering, Construction and Architectural Management*, 22(4), pp.446-466.

Kibert, N.C., 2004. Extended producer responsibility: a tool for achieving sustainable development. *Journal of Land Use & Environmental Law*, 19(2), pp.503-523.

Ladou, J. and Lovegrove, S., 2008. Export of Electronics Equipment Waste. *International Journal of Occupational and Environmental Health*, 14(1), pp.1-10.

Li, J., Zeng, X. and Stevels, A., 2015. Eco-design in Consumer Electronics: Past, Present, and Future. *Critical Reviews in Environmental Science and Technology*, 45(8), pp.840-860.

Lusthaus, C., Anderson, G. and Murphy, E., 1995. *Institutional assessment: A Framework for Strengthening Organisational Capacity for IDRC'S Research Partners*. Ottawa, ON, Canada: International Development Research Centre.

Mallawarachchi, H. and Karunasena, G., 2012. Electronic and electrical waste management in Sri Lanka: Suggestions for national policy enhancements. *Resources, Conservation and Recycling*, 68, pp.44-53.

MENR, 2008. *The report of the outcome of the study on "Development of a National Implementation Plan for Electrical and Electronic Waste Management in Sri Lanka"*. Ministry of Environment and Natural Resources.

Nnorom, I. and Osibanjo, O., 2008. Overview of electronic waste (e-waste) management practices and legislations, and their poor application in the developing countries. *Resources, Conservation and Recycling*, 52, pp.843-858.

OECD, 2006. *The Challenge of capacity development: working towards good practice*. Paris: Organisation for economic co-operation and development.

Ratnayake, D., Kannangara, S., Marasinghe, M., Rajamanthre, K., Abeywardhene, D., Peiris, N. and Miguntanna, N., 2016. Investigation of public attentiveness, attitude and practice on e-waste management in urban and rural communities in Sri Lanka. In *6th International Research Symposium on Engineering Advancements*. Malabe, pp.69-74.

Rodrigo, C., 2013. Utility Vs. Environment: Sri Lanka's Policy Outlook on Managing "E-Waste. Available from: http://www.ips.lk/talkingeconomics/2013/06/05/utility-vs-environment-sri-lankas-policy-outlook-on-managing-waste-electrical-and-electronic-equipment/ [Accessed 15 May 2018].

Siano, A., Kitchen, P.J. and Confetto, M.G., 2010. Financial resources and corporate reputation: Toward common management principles for managing corporate reputation. *Corporate Communications: An International Journal*, 15(1), pp.62-82.

Sivathanu, B., 2016. User's perspective: knowledge and attitude towards e-waste. *International Journal of Applied Environmental Science*s, 11(2), pp.413-423.

Sthiannopkao, S. and Wong, M.H., 2013. Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. *Science of the Total Environment*, 463, pp.1147-1153.

Suraweera, I., 2016. E-waste issues in Sri Lanka and the Basel Convention. *Reviews on Environmental Health*, 31(1), pp.141-144.

Thavalingam, V. and Karunasena, G., 2016. Mobile phone waste management in developing countries: A case of Sri Lanka. *Resources, Conservation and Recycling*, 109, pp.34-43.

Tran, C.D. and Salhofer, S.P., 2016. Analysis of recycling structures for e-waste in Vietnam. *Journal of Material Cycles and Waste Management*, 20(1), pp.110-126.

UNDP, 1998. Capacity assessment and development In a Systems and Strategic Management Context. *Technical Advisory Paper No. 3*, Management Development and Governance Division, Bureau for Development Policy. Available from: https://www.cbd.int/doc/pa/tools/Capacity%20assessment%20and%20development.pdf [Accessed 21 February 2018].

UNEP, 2010. A Report - Recycling – from E-Waste to Resources. United Nations Environment Programme. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/21767/UNEP%20GPA%20IGR4-2%20-%20Progress%20report%2014%20September.4.2.pdf?sequence=1&isAllowed=y [Accessed 16 March 2018]

USAID, 2011. Organisational Capacity Building Framework: A Foundation for Stronger, More Sustainable HIV/AIDS Programs, Organisations & Networks. Washington, DC.: AIDSTAR-Two Project. Available from: https://www.msh.org/sites/msh.org/files/as2_technical_brief_2_final.pdf [Accessed 25 February 2018].

Wath, S.B., Vaidya, A.N., Dutt, P.S. and Chakrabarti, T, 2010. A roadmap for development of sustainable E-waste management system in India. *The Science of The Total Environment*, 409(1), pp.19-32.

World Bank, 2017. World Development Indicators 2017. Washington, DC: World Bank. Available from: https://openknowledge.worldbank.org/handle/10986/26447 [Accessed 28 November 2017].

Rizvi, F.S. and Somachandra, W.D.I.V., 2019. Client's contribution to achieve sustainability through corporate social responsibility in the Sri Lankan construction industry. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 168-178. DOI: doi.org/10.31705/WCS.2019.17. Available at: https://2019.ciobwcs.com/papers

CLIENT'S CONTRIBUTION TO ACHIEVE SUSTAINABILITY THROUGH CORPORATE SOCIAL RESPONSIBILITY IN THE SRI LANKAN CONSTRUCTION INDUSTRY

F.S. Rizvi[1] and W.D.I.V. Somachandra[2]

ABSTRACT

The Sri Lankan construction industry's impact on the environment, social and economy is inevitable; emphasising the need to adopt sustainability. Sustainability is distinguished in order to avoid depletion of natural resources as well as to maintain the ecological balance. Sustainability could result in a corporate level, based on construction business organisations further illustrating the concept of corporate social responsibility (CSR). CSR focuses on impact by organisations concerning the triple bottom line. CSR is identified as a path to achieve corporate sustainability. Stakeholders' participation is crucial to incorporate in a sustainable development plan which facilitates the identification of the clients who play a prominent role. This research followed a qualitative study by interviewing clients selected through snowball sampling in the Sri Lankan construction industry. Phenomenology was the approach followed for this research and bracketing was used as a method of analysis. Results of the research identified categories to achieve sustainability through CSR in the perception of clients as: cost constraint, government regulatory approach, consultants' intervention, client's apprehension on sustainability and their attitude on social and environmental aspects, thereby paving the path to develop recommendations.

Keywords: *Client; Construction Industry; Corporate Social Responsibility (CSR); Sustainability; Sri Lanka.*

1. INTRODUCTION

The construction industry develops physical assets that are man-made capitals (Spence and Mulligan, 1995). Clients, architects, engineering consultants, contractors and suppliers conduct construction businesses (Shen *et al*., 2010); that delivers services and supplies resources for the construction industry. Construction businesses involve stakeholders referred to as constituents (Kakabadse *et al*., 2005). Nevertheless, the construction industry is renowned for destructing the environment, negatively impacting communities, exploiting workers, natural resources, corrupt practices, and failure in health and safety measures (Huang and Lien, 2012; Murray and Dainty, 2009; Spence and Mulligan, 1995). Respectively, Barthorpe (2010) accuses the construction industry for having little concern towards the environment, for being thoughtless and

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unsympathetic towards the society and for provoking its clients. The Sri Lankan construction industry is ranked as the fourth highest sector contributing to the economy (De Silva *et al*., 2008). Further, the Department of Census and Statistics of Sri Lanka (2017) represented the construction industry to be securing the fourth place for its employment population; creating an impact on the social perspective by generating opportunities for the labour force. Moreover, concerning the environmental perspective in Sri Lanka, the construction industry is yet to address the burdens caused by construction materials consumed for building construction (Abeysundara *et al*., 2009).

Therefore, as discussed above, the Sri Lankan construction industry impacts on the environment, social and economy indicating an interwoven relationship approaching to the concept of sustainability. Berger *et al*. (2007) describes the integration of environmental, economic and social concerns to an organisation's operations, strategy, decision-making and culture by referring to the term 'corporate social responsibility' (CSR). Furthermore, although O'Connor *et al*. (2015) stated that stakeholders including the clients are concerned about sustainability, Serpell *et al*., (2012) conversely concluded that engineers and architects were the most aware on sustainability whereas owners (client) and developers were not as conscious. However, as clients play a central role in the construction industry (Khalfan *et al*., 2005), they should demand for improved performance from construction industry players (Ling *et al*., 2005). From the majority viewpoint, "client is the key driver towards sustainable construction"; however, a doubt arises if the clients 'know enough to brief effectively'; quotes Pitt *et al*. (2009). Thus, there remains a challenge to examine the gap between the client's extent of awareness and incentives towards achieving sustainability through CSR in the Sri Lankan construction industry.

This research aims to examine the client's contribution towards attaining sustainability through CSR in the Sri Lankan construction industry. The paper first goes on to identify the concept of sustainability and its' relationship with CSR. It then identifies the clients' responsibility to achieve sustainability in the construction industry and analyses the Sri Lankan client's contribution to promote CSR. Finally, concluding and providing recommendations to improve client's influence to achieve sustainability through CSR in the Sri Lankan construction industry.

2. LITERATURE REVIEW

As indicated in the introduction, the construction industry significantly impacts on the environment, social and economy; highlighting the prominence to adopt sustainability. Sustainability is implied by the ability of an organisation to operate while maintaining a harmonious balance between the economic, social and environmental values (Herremans and Reid, 2002). Organisations pursue sustainability with the aim of enhancing business value (Presley and Meade, 2010). Corporate is defined as a group of organisations or business entities. Considering the terms; Dyllick and Hockerts (2002) distinguishes corporate sustainability as the ability of organisations to meet the needs of their direct and indirect stakeholders, without compromising on the needs of prospective stakeholders; aiming for this goal, organisations should effectively contribute to sustainability in the political domain while growing and maintaining their environmental, social, and economic capital base.

The concept of CSR in business operations emerged and was universally acknowledged as "a path to achieve corporate sustainability" (Somachandra, 2016). CSR is a concept in which a business organisation is responsible for the influence of its corporate activities concerning the interaction with stakeholders and the environment (Murray and Dainty, 2009). Additionally, Carroll (1991) identifies philanthropic, ethical, legal and economic responsibilities in a pyramid forming CSR. Furthermore, Jones *et al*. (2006) debate as to whether organizations implementing CSR do so as a philanthropic gesture as opposed to applying it to the core business process. However, pursuing CSR is critical to achieve sustainable construction (Shen *et al*., 2010). Ebner and Baumgartner (2006) explain that CSR is the social dimension of sustainable development; on the other hand, the authors further cite that sustainable development is a source for CSR. CSR is identified as sustainable development in a corporate level while it maintains a strong relationship between the concepts possessing significant interdependencies. Accordingly, it is acknowledged that sustainability should be implemented in the business process, which derives corporate sustainability, being used as a path leading to the concept of CSR. Instigating the CSR concept in an extended corporate level will subsequently inherit corporate sustainability and contribute to related construction practices, which along with corporate sustainability will eventually lead to sustenance in the construction industry (Ebner and Baumgartner, 2006).

Stakeholder participation is a critical factor to be incorporated in the sustainable development plan where they would be in a position to influence an organisation's operations, objectives, progress and persistence (Bal *et al*., 2013). The client is the sole initiator who engages in a project from the inception to the completion stage (Zhao *et al*., 2012). Hence, the prominence of clients in the construction industry could not be exaggerated (Kometa *et al*., 1994). Client should precisely specify and define the objectives of projects as it could contribute as a base to assess project performance (Lim and Ling, 2002). This implies the prominent role entrusted to a client in terms of their contribution. The commitment of the client to the project priorities are namely; establishing the budget, formulating schedules and technical performance milestones, which are identified as project management characteristics related to distinguished success (Lim and Ling, 2002). Further, the authors argued that it is the clients' responsibility to make a reasonable effort in clearly defining and devising the project. Moreover, it was argued that generally project teams are prone to commence developing the project with the assumption that the client has already acknowledged the specific objectives and the most effective ways to achieve them. In such instances, authors infer that it is the clients' responsibility to make an effort to determine concerns rather than the project team making the clients aware. However, Pitt *et al*. (2009) questioned the client awareness to brief effectively in driving towards sustainability. Thus, making an effort to enhance consciousness is essential in order to eliminate the perception of financial decision-making, which will have the knock on effect of minimising the impact on the environment, social and economy by clients. Effective involvement of stakeholders including clients, who engage by extending and sharing their support and participating cohesively, will significantly affect the planning and development of innovative business solutions. Moreover, Ayuso *et al*. (2011) discovered that the knowledge obtained by the involvement of stakeholders has a co-relation to an organisation's sustainable orientation. The client plays a primary role of encouraging the implementation of sustainable construction performances (Serpell *et al*., 2012). Lim and Ling (2002) cited that generally clients have seven primary needs in the construction industry, which are maintenance cost, flexibility, time, function, economy, safety and quality. However, it is disappointing to discern that the client needs did not factor the provisions for the environmental impact and a reflection of the social setting, which are substantial components towards attaining sustainability. Encouraging clients to adopt sustainability by introducing incentives, gathering and promoting proof of the business case, using fiscal and regulatory framework and encouraging companies to promote sustainability driven performances are best practices to promote sustainability according to Pitt *et al*. (2009). Furthermore, the researchers recognised the client as the most important individual to define sustainable construction practices while ranking the architects as the second most important variable. Hence, this examination focuses on the clients' contribution to achieve sustainability through the path of CSR in the Sri Lankan construction industry.

3. METHODOLOGY

Collecting data for the research commences once the research problem is identified, aim and objectives are defined (Doody and Bailey, 2016; Kothari, 2004). Primary and secondary data are two types of data. Primary data is original data that is collected and secondary data is information that has already been processed (Kothari, 2004). This research is designated by achieving initial objectives through the literature review, which focussed on collecting secondary data. In addition, the final two objectives were achieved through primary data. Dörnyei (2007) categorizes three ways to collect primary data, which are qualitative, quantitative, and a mix-method. Qualitative data deals with non-numerical data that explore and define the nature, and quality of how people understand, react and experience (Alshenqeeti, 2014), this justifies that a qualitative approach is appropriate for this research. The reason for selecting an approach of this nature arises as the final two objectives focuses on the perspective of Sri Lankan clients and as this research requires an inspectional and investigative study.

Among five qualitative designs identified by Creswell *et al*., (2007) phenomenology is best suited to this research as the author discusses characteristics, which correspond with this research. One such identified characteristic applicable in the research context is disciplined background focusing on understanding the experience of a respondent about a phenomenon. This research design is followed for this study as it focused on extracting what clients have in common subjected to them experiencing a phenomenon (Creswell *et al*., 2007). Moreover, Dörnyei (2007) exclaims; qualitative data are typically gathered conducting interviews and questionnaires. However, interviews are identified as a powerful source that would elicit the data narrated. This enables a researcher to analyse in great depth concerning the public view by investigation (Dörnyei, 2007). Thus, interviews were adopted as a strategy of inquiry to understand, investigate and identify the clients' current practice and view on adopting business process related CSR in the Sri Lankan construction industry. Polkinghorne (1989) evaluated that the recommended sample size to interview for phenomenology is 5 to 25 participants in a similar experience background. Thus, thirteen clients from the Sri Lankan construction industry involved in building construction were selected based on snowball sampling for this research and were allocated reference codes as 'INT' with a specific number assigned to each client. When considering the nature of the projects that clients were involved in, nearly 54% of same were developing commercial buildings, 31% were into residential building and the remainder were involved in a development mix. In addition, bracketing was used as an analysis method for this research as, bracketing is the process of recognizing a phenomenon followed by data collection from individuals who experience the phenomenon, further analysing the data and extracting the most significant quotes which then leads to classifying same into themes (Creswell *et al*., 2007; Lester, 1999).

4. RESULTS AND DISCUSSION

This research mainly focuses on clients' practices in the business process related to CSR. Results of this research indicated many classifications of the clients' contribution to promote CSR in the business process to facilitate sustainability; extracted through the interviews conducted to review the client's practices in-order to achieve sustainability through the fundamentals of CSR. Subsequently, five major categories were recognised, that are also identified as factors affecting the client to achieve sustainability in the construction industry through CSR. Such extracted categories are discussed below as referenced from the clients themselves.

4.1 COST CONSTRAINT

Cost is one of the most significant constraints identified by the results of this research. Cost could further be classified as initial cost concern, cost consciousness and economical. All respondents explicitly stated that their main concern was the cost, even though they are aware of sustainability-oriented benefits. INT-10 respondent exclaimed, *"Trying to maintain sustainability but focusing on initial cost"*.

This clearly reveals the primary concern of a client. All clients explicitly stated that cost is their main concern, as their primary objective is to gain profit and were not willing to wait for the payback period. Furthermore, respondent INT-12 stated: *"What happened is, it's still not that much of economical know (sustainability), still it's the cost"*. Further to that, INT-11 claimed that: *"Environmentally friendly option was considered but we saw the cost to be economised and we mainly followed the UDA Concept"*.

It is not always about reducing the cost, but it rather reflects clients' knowledge and understanding mainly acquired through experience. Respondent INT-11 who occupies the building, viewed cost to be economised during construction phase but overlooked the operational phase in this regard. This reveals a lack of integrity between phases when making decisions by being cost conscious. Moreover, according to INT-5: *"As middle rise property developers, we are a little afraid with regards to the initial cost. Otherwise we are ready to implement (Sustainability)"*.

This clarifies that initial cost is the prime point for residential property developers, further illustrating the fear to implement it, as they may not receive an anticipated profit level. The cost constraint category verifies the impact created on client perspectives.

4.2 GOVERNMENT REGULATORY APPROACH

The second vital category is the government's regulatory approach. While conducting interviews, it was clearly identified from the sample that most of the clients' main objective is to acquire government approval, which seemed to be the only reason to adopt sustainable measures. When inquired whether the consultants introduced sustainable measures; INT-2 confessed that:

> *"Yeah actually, now; environmental thing of-course they discussed because we have to get the approval from ministry of environment & according to the UDA approval. So, all those things have to be taken into consideration"*.

This implies the significance of a regulatory approach in a client's mindset as further stated by INT-12; *"Generally, we stick to the regulations. Whatever regulations enforced by the Government"*. Hence, government regulations reveal the effect on a client's approach to implement sustainable measures or which gives an extra mile of motivation to follow such concepts.

4.3 CONSULTANTS' INTERVENTION

Clients appoint a specialised agent as, engineering consultant or architects for supervision and monitoring of the construction work effectively on their behalf as majority of clients do not have confidence that the outcome will meet all expected specifications, and adhere to quality standards in the construction industry (Reve and Levitt, 1984). Although this is the case, some interviewees seem to feel that some consultants presently do not fulfil their obligations towards clients with respondent INT-9 exclaiming:

> *"The architect comes to site only once. During the beginning of the project they always come and try to impress us (client). But, after that they send juniors who have no idea. We have to call them and go behind them. It is very difficult to work with them".*

Moreover, it was understood that the consultants were not approaching with sufficient information to convince the client to implement the sustainable concepts according to INT-11:

> *"If someone can show with facts and figures the benefit of using such concepts then it's easy to make a decision. There is a huge problem in convincing. Can do marketing but it's not practical. Say if we think we do a green concept building, we have to consider the maintenance; the practical issues are a concern in a country like Sri Lanka. There is no proper discipline; for a simple example, people do not even segregate the garbage properly. The consultants support is very important, but the contractor's workmanship is also important".*

Furthermore, the interviewee INT-3 stated that:

> *"Most of his (Consultants) suggestions were attached mostly with architectural view but also energy saving and sometimes, energy saving when you see the cost then economical, but mostly architectural view I can say 60-70%. Because, they (architects) want to develop their image. He doesn't care about the cost frankly saying".*

This emphasises the huge gap in the interpersonal relationship between the clients and consultants sourced by communication and management constraints, extent of persuasiveness on encouraging the client to adopt good approaches for the project and poor collaboration, instead focusing on their personal intent. Through the sample, it was understood that the consultants mainly focus on aesthetic aspects and not catering to the benefit of the clients although they are hired for it.

4.4 CLIENTS' APPREHENSION ON SUSTAINABILITY

Almost all clients in the sample accepted that they were aware on benefits of sustainability concept. Nevertheless, according to INT-12, residential building developers who intended to sell units of their development viewed implementation of sustainability, as a constraint to obtain profit as earning profit was their main objective. This further implied a lack of social concern, as they did not consider on intergenerational relationship.

> *"Since our target is to sell; we are planning to sell know, so our prime target is the cost and to complete the job. Not sustainability. (What do you think about the green concept?*

> *Any involvement, interest or idea?) (Smiling sarcastically) for the time being No. for the project I don't think it's possible; with the project and cost. (What are the reasons you see it's not possible) suppose if we are using... basic example solar. That cost will directly go to the buyers know, so with the competitive environment you can't be in the market. That is the thing."*

However, another responded recognised as INT-13 saw sustainability as a marketing tool.

> *"...So let's say we design a sustainable building, so called green building so we can, as a developer use it as a marketing tool you know. In the long run it will be beneficial to the occupants. So in that case we can use it as a marketing tool".*

According to INT-12 and INT-13 respondents' quotes, it signifies the influence a client's viewpoint could lead to promoting CSR in order to achieve sustainability while still fulfilling their objectives. Therefore, the client's perception on sustainability creates a benchmark on contributing to promote CSR.

4.5 CLIENT ATTITUDE ON SOCIAL AND ENVIRONMENTAL ASPECTS

Client inconsiderateness and ignorance portrays a negative attitude towards the social and environmental concerns. The social aspect was identified by inquiring their thoughts on labourers working at their site while the environmental factor was assessed by inquiring on measures taken to preserve a balance between the construction and environment with regard to waste management, noise pollution and gas emission. Correspondingly, INT-8 declares:

> *"Instructions were given to follow safety standard. I go and look in and see as if anything happens to the workers the company name will be ruined. They need only money; No education".*

Sadly, this is the attitude of some clients towards social. Further, INT-12 states:

> *"To be honest we don't have enough skilled labours in Sri Lanka. I think the main issue is all the guys are driving tuk tuks now, so we have a huge problem with skilled labourers.... All together, we have about 400 labourers. Out of them 60 are foreign labours. The contractor will provide accommodation, food, and stuff. We don't get involved and look in that".*

The statement of this respondent enlightens social concern as well as the economical concern, as employing foreign labourers will eventually affect the economy of the country. However, as clients do not look into the wellbeing of their labourers and their attitude in this regard, it could influence the decrease in the quota of local labourers.

With respect to the environmental consideration, INT-2 pronounces that:

> *"Waste of course at the moment they are…(sighing) the contractor is looking after it. I have no involvement so sometimes they are not.... Day to day waste they use to burn; that is not good actually. But I didn't tell anything. Other thing is whatever the excess they have to send it out of the site, so that was the agreement".*

Construction waste is hazardous and emissions from burning the waste can harm the environment as well as neighbouring surroundings. Clients lacking such a critical awareness with respect to the social, environmental and economic aspects, reflects the poor attitude pertaining to the sustainability in the construction industry.

5. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the construction industry is still in the process of achieving sustainability through client intervention particularly with regard to the business processes related CSR. It was extracted from the study that the clients in the construction industry of Sri Lanka are primarily focusing on cost contrary to quality and durability of the outcome. Further, it was acknowledged from the analysis that clients who intended to sell their properties highly prioritized initial cost while clients who were to occupy the development considered sustainable approaches and quality to a certain extent based on their financial capacity. However, the client is not always at fault since it is not realistic to blindly invest money on a concept that they are clearly not aware of and have no considerable involvement. Hence, it was examined through investigation that consultants had to play a significant role in educating and convincing clients on such implementations. The clients revealed that they needed a proper presentation with reference to facts and figures in order to invest on any kind of approach that isn't conventional. Moreover, it was clarified that even the clients preferred short-term gains with contrast to long-term benefits.

Although it is practically not possible for a client to disregard cost and concentrate on sustainable approaches, it is recommended to absorb sustainability through CSR considering it as a moral obligation for inter-generational contemplation. It is not always expensive to be sustainable; designing wisely and conducting the business process in an ethical manner is a means of attaining stipulated goals. Fiscal and regulatory framework is a great source to encourage sustainability to be embraced by organisations and subsequently attempting to convince the client by emphasizing the merits and future potential for prospects.

Additionally, it was observed that the clients' main intention to initiate sustainable measures were to obtain government approvals and permits. This implies the importance and influence the government could impact. Thus, it is recommended to give concession or recognition to the clients who implement sustainability in their business process, which would further motivate other clients to embrace such concepts.

Further, the consultant's correspondence with the clients was identified to be a crucial factor in plotting the latter as a crucial avenue to promote CSR and achieve sustainability in the construction industry. It was clarified that the green concept is not practical in the view of the clients, but the actual reason identified is the poor persuasiveness by consultants. Therefore, it is proposed that clients should play a primary role in scanning and selecting a consultant renowned for enforcing a sustainable business process in the construction industry. This highlights the necessity to assess and evaluate the consultants based on a wide perception considering their ability to develop a cooperative project environment while establishing means to resolve conflicts and solve problems.

Majority of the clients appraised were involved in commercial and residential building construction and thus if those clients do not make an attempt to contribute on sustainability consistently, this would remain merely an illusion with respect to the low-profile clients. It is suggested that if developers intend to sell their building and/or apartments, they must determine the selling cost by computing a figure inclusive of the cost for sustainable variables by acknowledging and educating the buyers on the benefits of sustainability in terms of the operational phase, maintenance, durability, intergenerational consideration and convincing same subsequently. This is defined as ethical trading where the client determines the added market value for sustainability concept and emphasise the advantages to convince customers on better quality via ethical purchasing. This is recommended to be implemented by providing weight to the business' core values with regard to its brand. Therefore, CSR shouldn't be simply an extension to the core business, but rather it should be a pivotal part of the business process.

Likewise, it was clarified through the study that if the clients are more considerate on the well-being of the labourers working at site and should the government introduce more benefits as well as providing encouragement and motivation, it will undoubtedly lead to a positive impact on the social and economic forces of sustainability. It was identified that the path for clients to promote CSR to achieve sustainability is through creating awareness, interest, their financial capability, experience, intergenerational concern and knowledge. Moreover, it is recommended to enact strict regulations to conserve the environment and its natural atmosphere by preventing the construction industry and its stakeholders from inflicting damage either in an upright or a commanding manner.

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7. REFERENCES

Abeysundara, U. G. Y., Babel, S., and Gheewala, S., 2009. A matrix in life cycle perspective for selecting sustainable materials for buildings in Sri Lanka. *Building and Environment*, 44(5), pp.997–1004.

Alshenqeeti, H., 2014. Interviewing as a data collection method: A critical review. *English Linguistics Research*, 3(1), p.39.

Ayuso, S., Ángel Rodríguez, M., García-Castro, R. and Ángel Ariño, M., 2011. Does stakeholder engagement promote sustainable innovation orientation?. *Industrial Management & Data Systems*, 111(9), pp.1399-1417.

Bal, M., Bryde, D., Fearon, D. and Ochieng, E., 2013. Stakeholder engagement: Achieving sustainability in the construction sector. *Sustainability*, 5(2), pp.695-710.

Barthorpe, S., 2010. Implementing corporate social responsibility in the UK construction industry. *Property Management*, 28(1), pp.4-17.

Berger, I. E., Cunningham, P. H., and Drumwright, M. E., 2007. Mainstreaming corporate social responsibility: Developing markets for virtue. *California Management Review*, 49(4), pp.132–160.

Carroll, A.B., 1991. The pyramid of corporate social responsibility: Toward the moral management of organisational stakeholders. *Business Horizons*, 34(4), pp.39-48.

Creswell, J.W., Hanson, W.E., Clark Plano, V.L. and Morales, A., 2007. Qualitative research designs: Selection and implementation. *The Counselling Psychologist*, 35(2), pp.236-264.

Department of Census and Statistics, 2017. Sri Lanka Labour Force Survey - Annual Report 2017 [online]. Available from: http://www.statistics.gov.lk/samplesurvey/LFS_Annual%20Report_2017_version2.pdf [Accessed 15 January 2019].

De Silva, N., Rajakaruna, R.W.D.W.C.A.B. and Bandara, K.A.T.N., 2008. Challenges faced by the construction industry in Sri Lanka: perspective of clients and contractors. *Building Resilience*, pp.158-169.

Doody, O. and Bailey M. E (2016) Setting a research question, aim and objective. *Nurse Researcher*. 23(4), pp.19-23.

Dörnyei, Z., 2007. *Research methods in applied linguistics: Quantitative, qualitative, and mixed methodologies*. Oxford: Oxford University Press.

Dyllick, T. and Hockerts, K., 2002. Beyond the business case for corporate sustainability. *Business Strategy and the Environment*, 11(2), pp.130-141.

Ebner, D. and Baumgartner, R.J., 2006. The relationship between sustainable development and corporate social responsibility. *Corporate Responsibility Research Conference*, 4(5.9), Queens University, Belfast Dublin.

Herremans, I.M. and Reid, R.E., 2002. Developing awareness of the sustainability concept. *The Journal of Environmental Education,* 34(1), pp.16-20.

Huang, C.F. and Lien, H.C., 2012. An empirical analysis of the influences of corporate social responsibility on organisational performance of Taiwan's construction industry: using corporate image as a mediator. *Construction Management and Economics*, 30(4), pp.263-275.

Jones, P., Comfort, D. and Hillier, D., 2006. Corporate social responsibility and the UK construction industry. *Journal of Corporate Real Estate*, 8(3), pp.134-150.

Kakabadse, N.K., Rozuel, C. and Lee-Davies, L., 2005. Corporate social responsibility and stakeholder approach: a conceptual review. *International Journal of Business Governance and Ethics*, 1(4), pp.277-302.

Khalfan, M.M., McDermott, P., Vrijhoef, R. and Asad, S., 2005. The effect of procurement on the integration of the supply chain within the construction industry. *Proceedings CIB Combining Forces*, *1*, pp.14-25.

Kometa, S.T., Olomolaiye, P.O. and Harris, F.C., 1994. Attributes of UK construction clients influencing project consultants' performance. *Construction Management and Economics*, 12(5), pp.433-443.

Kothari, C.R., 2004. *Research Methodology Methods and Techniques*. 2nd ed. New Delhi: New Age International Publishers.

Lester, S., 1999. *An introduction to phenomenological research*. Taunton UK, Stan Lester Developments.

Lim, E.H. and Ling, F.Y.Y., 2002. Model for predicting clients' contribution to project success. *Engineering, Construction and Architectural Management*, 9(5/6), pp.388-395.

Ling, F.Y.Y., Ofori, G. and Dulaimi, M.F., 2005. Targeting constraints and improving performance in Singapore construction. *Combining Forces Advancing: Facilities Management and Construction through Innovation Series*, *1*, pp.61-72.

Murray, M. and Dainty, A., 2009. *Corporate social responsibility in the construction industry*. Abington: Taylor & Francis.

O'Connor, J.T., Torres, N. and Woo, J., 2015. Overview of construction sustainability research products. *5th International/11th Construction Specialty Conference*, pp.134:1–134:10.

Pitt, M., Tucker, M., Riley, M. and Longden, J., 2009. Towards sustainable construction: promotion and best practices. *Construction innovation*, 9(2), pp.201-224.

Polkinghorne, D. E., 1989. Phenomenological Research Methods. *Existential-Phenomenological Perspectives in Psychology*, pp.41–60.

Presley, A. and Meade, L., 2010. Benchmarking for sustainability: an application to the sustainable construction industry. *Benchmarking: An International Journal*, 17(3), pp.435-451.

Reve, T. and Levitt, R.E., 1984. Organisation and governance in construction. *International Journal of Project Management*, 2(1), pp.17-25.

Serpell, A., Kort, J. and Vera, S., 2012. Awareness, actions, drivers and barriers of sustainable construction in Chile. *Technological and Economic Development of Economy*, 19(2), pp.272-288.

Shen, L.Y., Tam, V.W., Tam, L. and Ji, Y.B., 2010. Project feasibility study: the key to successful implementation of sustainable and socially responsible construction management practice. *Journal of Cleaner Production,* 18(3), pp.254-259.

Somachandra, W.D.I.V., 2016. Critical Factors of Corporate Social Responsibility (CSR) in Sri Lankan Construction Industry. In *Proceedings of 7th International Conference on Sustainable Built Environment 2016 (ICSBE)*, Kandy, Sri Lanka, December 16-18, 2016. Department of Civil Engineering, University of Peradeniya, pp.01-09.

Spence, R. and Mulligan, H., 1995. Sustainable development and the construction industry. *Habitat International,* 19(3), pp.279-292.

Zhao, Z.Y., Zhao, X.J., Davidson, K. and Zuo, J., 2012. A corporate social responsibility indicator system for construction enterprises. *Journal of Cleaner Production*, 29, pp.277-289.

Abeykoon, M.M.G.D., Zainudeen, N., Perera, C.S.R. and Madhuwanthi, H.A.S., 2019. Client's impact to the schedule delays in road projects: Contractor's perspective. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 179-188. DOI: doi.org/10.31705/WCS.2019.18. Available at: https://2019.ciobwcs.com/papers

CLIENT'S IMPACT TO THE SCHEDULE DELAYS IN ROAD PROJECTS: CONTRACTOR'S PERSPECTIVE

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ABSTRACT

The problem of schedule delay is a frequent and regular phenomenon in the construction projects. Road construction of Sri Lanka is no exception. Client as a key project participant has a control on duration of construction phases. This makes client a casual cause for schedule delay. However, contractor also is a major suffering party due to unprecedented delays. Therefore, this research is aimed at investigating the contractor's perspective of client's impact to the schedule delay in rehabilitation and widening road projects (RWRP) in Sri Lanka. Initially, a comprehensive literature review aided to identify types and effects of delay in road construction projects. Further, identified literature was refined in the sense of Sri Lankan context through three number of preliminary interviews. Next, six cases were selected considering RWRPs in Sri Lanka and steered a document review to investigate the influence of the involvement of the client for delays. Then, a questionnaire survey was carried out to examine the significance of client's causes for delay on contractor's perspective and to identify the client's best practices including suggestions to minimize the delays in RWRPs in Sri Lanka. The analysed data confirmed that delayed interim payments to the contractors due to monetary difficulties of the client, change orders by the client throughout the construction period, delay in land acquisition and delay in handing over the site for construction work as key client causative factors. This study request client to adhere with the identified best practices to mitigate schedule delays in RWRP in Sri Lanka.

Keywords: *Client Initiated Delays; Rehabilitation and Widening Road Projects; Schedule Delays.*

1. INTRODUCTION

In an economy, the construction industry can be recognized as one of the key sectors which majorly impacts on the economic development (Divya and Ramya, 2015). Similarly, Tolera (2013) declared the construction industry as a vital subsector of a country's economy. This close relationship with the economy has led many countries to emphasis on ascertaining the strategies to improve the performance of the construction industry (Toor and Ofori, 2010) and to develop large-scale infrastructure projects including roadways, power plants, bridges, seaports, dams, airports, and telecommunications networks (Chen, 2004).

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However, the construction industry has to deal with cost, time and quality factors to develop and to become successful (Kesavan *et al*., 2015; Mahamid, 2017). Further, Ngacho and Das (2014) stated that time is the most significant measure among other key performance indicators of the construction projects. Importantly, Tafazzoli and Shrestha (2017) highlighted that completion of the construction projects within the scheduled time as a cause for efficiency.

Therefore, time is a noticeable element that needs a proper research effort in the construction industry. Numerous researches had been carried out to find the causes for delays in the construction projects in the Sri Lankan and global context. However, only a few researches have been carried out to identify the delay factors in terms of rehabilitation and widening road projects in Sri Lanka. Even though the delays are unavoidable in road construction projects, minimizing delays has become a primary responsibility of project participants (Ekanayake and Perera, 2016). However, influence of the client as a project participant has gain a minimal research attention. Hence, considering the link of the clients to the time factor in a project this research focuses on client initiated delays, in road rehabilitation projects in Sri Lanka considering the perspective of the contractor.

2. LITERATURE REVIEW

Involvement of many parties including clients, contractors, consultants, regulators, and other stakeholders in the construction sector has created a complexity (Gajare and Attarde, 2014). Moreover, the numerous activities and their interrelationships that require different specialized knowledge complicate construction project (Acıkara *et al*., 2017). Beyond this complex nature, construction projects accomplish their main goals through managing the works within planned time, cost and quality (Kesavan *et al*., 2015; Malkanthi *et al*., 2017). Therefore, all the project participants are in the objective of effective time management (Idiake *et al*., 2015).

2.1 DELAYS IN CONSTRUCTION PROJECTS

Delay is a very frequent and non-prearranged phenomenon almost associated with ongoing construction projects (Daba and Pitroda, 2018). Assaf and Al-Hejji (2006), defined a delay in construction as an overrun of the completion time beyond the completion date specified in the contract document or the date which the parties agreed to deliver the project. According to Hamzah *et al*. (2011), ongoing progress of a project which is insufficient to complete the project within construction program is a situation of a delay.

2.2 CAUSATIVE FACTORS FOR DELAYS

Construction delays are caused by numerous factors (Fugar and Agyakwah-Baah, 2010). Identifying and understanding the delay factors enable clients and contractors to mitigate the effect of the delays on their projects (Hussain *et al*., 2018). In the view of Ahmed *et al*. (2003), possible causative factors for delay can be categorized as contractor's responsibility, consultant's responsibility, client's responsibility and external factors. Meanwhile, Kesavan *et al*. (2015) increased number of categories up to seven categories as client related factors, contractor related, consultant related, labour related, material related, equipment related and external factors. In the study carried out by Assaf and Al-Hejji (2006), external factors category was replaced by project related and design related factors. Moreover, Sambasivan and Soon (2007) added contract relationship related and contract related categories to the category list. Table 1 shows the categories and causative factors for delays identified through literature.

Table 1: Categories and causative factors for delays

Category	Factor	
Client related	1. Delayed interim payments to the contractors due to monetary difficulties of the client 2. Client's interference to the work 3. Unreasonable time consuming for the decision making process by the client 4. Inadequate project feasibility study 5. Poor arrangements of project co-ordination and communication by the client with other project participants 6. Irrational project duration 7. Project postpone by the client 8. Delaying in approving sample materials 9. Indefinite scope of work 10. Change orders (Variations) by the client throughout the construction period 11. Delaying in approving documents by the client 12. Frequent design changes 13. Award the project to lowest bid	14. Project scope modification (Change specification and replace or add new works to the scope) 15. Inadequate clients' supervisors 16. Contract modifications 17. Errors and mistakes in drawings 18. Delay project due to delaying of land acquisition 19. Delaying of providing work permits (Should be obtained and provide by the Client) 20. Suspension of the project by the client 21. Delaying of hand over the site for construction work (Giving possession of site to the contractor) 22. Conflicts between joint-ownership of the project by different state authorities' 23. Clients' site clearance infirmities 24. Additional work
Contractor related	1. Insufficient contractors' experience 2. Contractors' financial and cash flow difficulties 3. Incorrect construction methods 4. Defective works and reworks 5. Poor site management and performance 6. Unproductive project planning and scheduling 7. Rework for correcting of errors and inacceptable work 8. Poor communication and coordination of contractor with other parties	9. Conflicts between contractor and other construction parties 10. Poor resource management 11. Poor qualifications of the contractors' site supervisors 12. Delay in commencement 13. Construction mistakes 14. Lack of high-technology equipment 15. Delay in the sub-contractor's 16. Delays in site mobilization

Consultant related	1. Changes in specifications; 2. Poor experience of consultant 3. Late in approving of completed work 4. Poor supervision and late testing 5. Poor communication and coordination of consultant with other parties 6. Inflexibility of consultant 7. Incapable inspectors 8. Insufficient inspectors 9. Delay in preparation of drawings	10. Changes in specifications of materials 11. Slow response to the contractor inquiries 12. Delay in approving changes in the work scope 13. Discrepancies in design documents 14. Un-use of advanced engineering design software 15. Absence of engineer's site staff
Design related	1. Late design works 2. Inappropriate design 3. Mistakes in design	4. Insufficient data collection before design 5. Designers' poor experience and capability
Material related	1. Late delivery of materials 2. Shortage of construction materials	3. Changes in types of material during construction 4. Low quality raw materials
Labor related	1. Low productivity 2. Less motivation 3. Unqualified workers 4. Discipline problem, labor accidents and injuries	5. Low level of operator's skill 6. Insufficient laborers 7. Personal conflicts among laborers and management team
External	1. Adverse weather condition 2. Force majeure 3. Corruption 4. Effect of social, cultural and political factors 5. Policy of government 6. Unavailability of utilities at site 7. Exchange rate fluctuation 8. Monopoly 9. Natural disaster 10. Unforeseen ground condition	11. Delay in obtaining permits from authorities 12. Traffic control and restriction at job site 13. Accidents at construction 14. Project size and location 15. Delay in providing services from utilities 16. Changes in laws and regulations 17. External work due to utilities and public services

Sources: Al-Hazim and Salem (2015); Assaf and Al-Hejji (2006); Alinaitwe *et al*., (2013); Divya and Ramya (2015); Gebrehiwet and Luo (2017); Hussain *et al*., (2018); Kaliba *et al*., (2009); Kesavan *et al*., (2015); Luu *et al*., (2009); Mahamid (2017); Ravisankar *et al*., (2014)

3. RESEARCH METHODOLOGY

A comprehensive literature survey was carried out in order to explore the existing theories and researches on influence of parties causing delays in road constructions project and on causative factors for delays. Further, for the purpose of investigating the applicability of literature findings to Sri Lankan context, preliminary interviews were carried out with three experts (Interviewee A (I-A), Interviewee B (I-B) and Interviewee C (I-C)) with 20 or more than 20 years of working experience in road sector. The research approach was based on the research problem. This research was focused to find out client's causes for delays and identify the suggestions along with the client's best practices to minimize delay. Accordingly, this research was based on both quantitative and qualitative aspects. Therefore, for this research a mixed approach was adopted.

According to Zainal (2007) an ability to examine the data in a close proximity is given to the researcher when using case study as a data collection technique. Therefore, after preliminary interviews this study used 6 in-depth case studies to investigate the influence of the involvement of the client for delays. Then, to achieve a generalised opinion from different respondents within a shorter period the study selected questionnaire survey to examine the significance of client's causes for delay and to identify the suggestions and client's best practices to minimize delay. For the Questionnaire survey 20 respondents were selected within cases and another 24 respondents were selected from outside the cases and was analysed through Relative Importance Index (RII) ranking method.

4. RESEARCH FINDINGS AND DISCUSSION

In the preliminary interviews, two of the three interviewees agreed that the four types of delay specified in the literature are applicable to the road rehabilitation and widening projects in Sri Lanka. However, I-A in his comment he argued "for excusable compensable delays contractor is entitled to both EOT and additional money as the compensation, but in Sri Lanka the government being the client only allow contractor the EOT". Interviewee further added, *"therefore, it is better to use the delay type as 'excusable-compensable but not complied' instead of 'excusable-compensable' type"*. Confirming the literature findings all the interviewees identified non-excusable delays as contractor initiated delays. Further, almost all the respondents emphasized that in non-excusable delays the contractor does not have any right to claim EOT or additional money since there was no fault with the client or client's representatives. Besides, I-C and I-B argued that the contractor does not cause most of the delay events in RWRP in Sri Lanka and that they are caused mainly by the client or due to events beyond the control of both parties.

4.1 FINDINGS OF THE CASE STUDY

Under the case study, primarily data were collected through the documents and where there is no clear information project staff were asked for clarifications. So, three ongoing RWRPs and three completed projects (within five years) were selected for the in-depth study. A brief description about selected cases are given in Table 2.

Table 2: Profile of the cases

	Case A	Case B	Case C	Case D	Case E	Case F
Contract Sum (Rs.)	6.9 Bn	721 Mn	885 Mn	1020 Mn	2976 Mn	924 Mn
Form of Contract	SBD/02	SBD/02	SBD/02	SBD/02	SBD/02	SBD/02
Current status of the project	Ongoing	Completed on 02/10/2015	Completed on 15/09/2015	Completed on 05/10/2015	Ongoing	Ongoing

	Case A	Case B	Case C	Case D	Case E	Case F
Road Length	23 km	12.8 km	15.5 km	15.845 km	29 km	13.598 km
Road Grade	A	B	B	B	B	B
Contractor's CIDA Grade	CS2	CS2	CS2	CS2	CS2	CS2
Original Commencement Date	6-Sep-13	28-Aug-13	28-Aug-13	28-Aug-13	3-Jan-17	3-Jan-17
Original Completion Date	6-Mar-15	25-Apr-15	25-Apr-15	25-Apr-15	3-Jan-19	3-Jul-18
Original Duration of The Project	546 Days	605 Days	605 Days	605 Days	730 Days	546 Days
Revised Completion Date	31-Mar-18	24-Nov-15	16-Sep-15	05-Oct-15	17-Mar-19	19-Sep-18
No of Days Delay	1122 Days	213 Days	144 Days	163 Days	73 Days	78 Days

Eight factor categories were identified as the delay causes under six cases. Summary of identified delay causes through the case studies are summarised in Table 3.

Table 3: Summary of identified delay causes

Case / Factor	Case A	Case B	Case C	Case D	Case E	Case F
1. Delay project due to delaying of land acquisition	✓		✓	✓		✓
2. Delaying of hand over the site for construction work (Giving possession of site to the contractor)	✓		✓	✓		✓
3. Utility relocation delay (Electricity posts, water lines, Telecom posts and underground services)	✓	✓	✓		✓	✓
4. Change orders (Variations) by the client throughout the construction period		✓	✓		✓	
5. Delaying of issue drawing (Delay of obtaining approvals for drawings)			✓	✓		✓
6. Unavailability of borrowed soil					✓	✓
7. Adverse weather condition	✓		✓	✓		
8. Increase in measured quantity		✓		✓		

According to Table 3, utility relocation delay (electricity posts, water lines, telecom posts and underground services) has occurred significantly in almost all the cases except for case D. Four projects out of six have identified 'delay in project due to delay in land acquisition and 'delay in handing over of the site for construction work (giving possession of site to the contractor)' as delay events faced by the projects. Moreover, change orders (Variations), delay in issuance of drawing (delay in obtaining approvals for drawings) and adverse weather condition were the delay events in three projects out of six. Moreover, five out of eight identified factors from the case studies have originated from the client. Further, there were at least two or more than two delay events which were caused by the client in each case. As a summary, client's contribution for delay in the selected projects in terms of percentages is portrayed in Table 4.

Table 4: Involvement of the client for delays in Sri Lankan RWRP

	Total project delay (Days, K)	Client driven delay (Days, L)	Percentage of client-initiated delays
Case A	1162	1118	96%
Case B	213	121	57%
Case C	144	134	93%
Case D	163	86	53%
Case E	73	43	59%
Case F	78	48	62%

According to Table 4, in all projects more than 50% of the total delay were caused due to the involvement of the client. Therefore, in all the six RWRPs, half of the reasons to delay the projects were originated and caused from the client. Among the cases, case A is dominant as it was affected by client caused delays by 96% of the total project delay followed by the case C with a 93% accruing from client. As a conclusion, the mean value of client-initiated/caused delay is 70%. However, a significant level of dispersion can be observed.

4.2 FINDINGS OF THE QUESTIONNAIRE SURVEY

Thirty-four professionals responded out of forty-four distributed questionnaires, which yield 77% rate of response. Respondents included 44% of quantity surveyors, 21% of assistant quantity surveyors, 26% of site engineers and 9% of project managers.

Twenty-five client initiated delay factors identified through the literature were confirmed to Sri Lankan RWRP through the preliminary interviews. Then, later part of the questionnaire was structured to rank the client-initiated delay factors. Therefore, the respondents were requested to mark the significance of client delay factors in the Sri Lankan RWRP using a likert scale of 1-5(1= Very Low (VL), 2= Low(L), 3= Medium(M), 4= High(H), and 5= Very High(VH)) RII was calculated separately for each factor based on the significance marked by the respondents. Accordingly, the factors were ranked considering the RII values. Summarized findings are illustrated in Table 5.

As per the calculated RII values and the ranks given to the client initiated delay factors, top four most significant (equal or more than 80% of RII) client initiated delay factors in the Sri Lankan RWRPs are delayed interim payments to the contractors due to monetary difficulties of the client, change orders (variations) by the client throughout the construction period, utility relocation delay (electricity posts, water lines, telecom posts and underground services), delay in of land acquisition followed by changes made to the drawings (issuance of revised drawings while construction is going on) delay in handing over the site for construction work and delay in issuance of drawing with having more than RII value of 75%.

Table 5: RII values of Client initiated delay factors

Client initiated delay factors	**Responses (%)**						**RII Value as %**	**Rank**
	VH **5**	**H** **4**	**M** **3**	**L** **2**	**VL** **1**			
Delayed interim payments to the contractors due to monetary difficulties of the client	76	12	9	3	0	0.924	92%	**1**
Change orders (Variations) by the client throughout the construction period	65	24	6	6	0	0.894	89%	**2**
Utility relocation delay	41	35	9	15	0	0.806	81%	**3**
Delay project due to delaying of land acquisition	32	41	24	0	3	0.800	80%	**4**
Changes made to the drawings	29	44	18	3	6	0.776	78%	**5**
Delaying of hand over the site for construction work	32	32	24	12	0	0.771	77%	**6**
Delaying of issuing drawing	32	32	24	9	3	0.765	77%	**7**
Irrational project duration	32	29	26	9	3	0.759	76%	**8**
Government changes and Government policy changes	38	24	21	12	6	0.753	75%	**9**
Attitudes of the Client and Clients' staff	29	24	41	3	3	0.747	75%	**10**

Accordingly, to avoid and minimize the aforementioned implications client needs to adhere with best practices. Therefore, last section of the questionnaire was structured as an open-ended question with the aim of identifying the client's best practices and suggestions to minimize the delay in projects. However, seven suggestions frequently proposed by the respondents were proper planning from feasibility stage to final stage, timely payments to facilitate contractor's cash flow, client should finalize the design prior to begin construction client should assist the utility relocation process, handing over the site for construction work as per the program, client should assist the land acquisition process in accordance with the land acquisition schedule, provide necessary drawings, instructions, permits on time.

5. CONCLUSIONS

Client related factors, material related factors and external factors are the highly significant factor categories cause for delay in RWRP in Sri Lanka. Client related factors with a RII value of 0.924 has become the most significant delay category in RWRP in Sri Lanka over other factor categories. More than 50% of the total delay in Sri Lankan RWRPs were resulted due to the client driven factors with the mean value of client initiated/caused delay of 70% and a standard deviation of 17.54. In Sri Lankan context, twenty-five Client-initiated delay factors could be identified related to RWRP. Moreover, top four most significant client-initiated delay factors in the Sri Lankan RWRPs are delayed interim payments to the contractors due to monetary difficulties of the client, variations by the client, utility relocation delay, and delay in of land acquisition followed by changes made to the drawings.

As an outcome of the data analysis of three different forms; preliminary interviews, case studies and questionnaire survey, it is clearly remarked that planning, timely payments, land acquisitions, utility relocation, compliance with programme and timely provision of drawings as significant practices with high impact to reduce client-initiated delays.

6. REFERENCES

Acıkara, T., Kazaz, A., and Ulubeyli, S., 2017. Evaluations of construction project participants' attitudes toward quality management in Turkey. *Procedia Engineering, 196*(1), pp.203-210.

Ahmed, S., Azhar, S., Kappagantula, P., and Gollapudi, D., 2003. Delays in construction: A brief study of the Florida construction industry. *39th Annual Conference of the Associated Schools of Construction*, pp.257-266

Al-Hazim, N., and Salem, Z.A., 2015. Delay and cost overrun in road construction projects in Jordan. *International Journal of Engineering and Technology, 4*(2), pp.288-293.

Alinaitwe, H., Apolot, R., and Tindiwensi, D., 2013. Investigation into the causes of delays and cost overruns in Uganda's public sector construction projects. *Journal of Construction in Developing Countries, 18*(2), pp.33–47.

Assaf, S.A., and Al-Hejji, S., 2006. Causes of delay in large construction projects. *International Journal of Project Management, 24*(4), pp.349-357.

Chen, A.H., 2004. *Rethinking infrastructure project finance.* Thesis (PhD). Southern Methodist University.

Daba, D.D., and Pitroda, J., 2018. A critical literature review on main cause of delay in construction projects. *International Research Journal of Engineering and Technology, 5*(1), pp.612-615.

Divya, R., and Ramya, S., 2015. Causes, effects and minimization of delays in construction projects. *National Conference on Research Advances in Communication, Computation, Electrical Science and Structures.* pp.47-53

Ekanayake, E.M.K., and Perea, B.A.K.S., 2016. Appropriate delay analysis techniques to analyse delays in road construction projects in Sri Lanka. *Built Environment Project and Asset Management, 6(*5), pp.521-534.

Fugar, F.D., and Agyakwah-Baah, A.B., 2010. Delays in building construction projects in Ghana. *Australasian Journal of Construction Economics and Building, 10*(1), pp.103-116.

Gajare, Y., and Attarde, P., 2014. Analysis of delay causes in residential construction projects. *International Journal of Latest Technology in Engineering, Management and Applied Science, 3*(12), pp.34-37.

Gebrehiwet, T., and Luo, H., 2017. Analysis of delay impact on construction project based on RII and correlation coefficient: Empirical study. *Procedia Engineering, 196*(1), pp.366-374.

Hamzah, N., Khoiry, M., Arshad, I., Tawil, N., and Ani, A. I., 2011. Cause of construction delay - theoretical framework. *Procedia Engineering, 20*(1), pp.490-495.

Hussain, S., Zhu, F., Ali, Z., Aslam, H.D., and Hussain, A., 2018. Critical delaying factors: Public sector building projects in Gilgit-Baltistan, Pakistan. *Buildings, 8*(1), pp.48-64.

Idiake, J.E., Oke, A.A., and Shittu, A.A., 2015. Analysis of cost and quality relationship of private building projects in Abuja, Nigeria. *International Journal of Construction Engineering and Management, 4*(2), pp.35-43.

Kaliba, C., Muya, M., and Mumba, K., 2009. Cost escalation and schedule delays in road construction projects in Zambia. *International Journal of Project Management, 27*(1), pp.522-531.

Kesavan, M., Gobidan, N., and Dissanayake, P., 2015. Analysis of factors contributing civil engineering project delays in Sri Lanka. *6th International Conference on Structural Engineering and Construction Management 2015*, Kandy 11-13 December 20015. pp.40-46.

Luu, V.T., Kim, S.Y., Tuan, N.V., and Ogunlana, S., 2009. Quantifying schedule risk in construction projects using bayesian belief networks. *International Journal of Project Management, 27*, pp.39-50.

Mahamid, I., 2017. Analysis of schedule deviations in road construction projects and the effects of project physical physical characteristics. *Journal of Financial Management of Property and Construction, 22*(2), pp.192-210.

Malkanthi, S.N., Premalal, A.G., and Mudalige, R., 2017. Impact of cost control techniques on cost overruns in construction projects. *Engineer: Journal of the Institution of Engineers, Sri Lanka, 50*(4), pp.53-60.

Ngacho, C., and Das, D., 2014. A performance evaluation framework of development projects: An empirical study of constituency development fund (CDF) construction projects in Kenya. *International Journal of Project Management, 32*(3), pp.492-507.

Ravisankar, K., AnandaKumar, S., and Krishnamoorthy, V., 2014. Study on the quantification of delay factors in construction industry. *International Journal of Emerging Technology and Advanced Engineering, 4*(1), pp.105-113.

Sambasivan, M., and Soon, Y.W., 2007. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management, 25*(5), pp.517–526.

Tafazzoli, M., and Shrestha, P.P., 2017. Investigating causes of delay in U.S. construction projects. *53rd ASC Annual International Conference Proceedings*, pp.611-621

Tolera, H., 2013. A socio-economic linkage of urban informal sector to formal and other informal sectors in Hawassa town: Intensifying growth from the street. *Science, Technology and Arts Research Journal, 2*(1), pp.95-102.

Toor, S., and Ofori, G., 2010. Positive psychological capital as a source of sustainable competitive advantage for organizations. *Journal of Construction Engineering and Management, 136*(3), pp.341-352.

Zainal, Z., 2007. Case study as a research method. *The Asian Journal of Humanities, 9*(1), pp.1-6.

Deniyage, C.J. and Palliyaguru, R., 2019. Conceptual framework for effective implementation of 'Project Management Institute's Standard for Earned Value Management' in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 189-199. DOI: doi.org/10.31705/WCS.2019.19. Available at: https://2019.ciobwcs.com/papers

CONCEPTUAL FRAMEWORK FOR EFFECTIVE IMPLEMENTATION OF 'PROJECT MANAGEMENT INSTITUTE'S STANDARD FOR EARNED VALUE MANAGEMENT' IN SRI LANKA

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ABSTRACT

Successful accomplishment of a project requires effective management of its performance. The performance of the most construction projects is tracked utilizing planned cost vs. actual cost measures only. Earned Value Management (EVM) technique came into existence as an effective performance measurement and a feedback tool for managing projects by emphasizing more on the Earned Value (EV) of projects. Regardless of the immense benefits of EVM, there are significant deficiencies in the process of implementation of the EVM technique in Sri Lanka. Therefore, this study aims to develop a conceptual framework for effective implementation of EVM in the Sri Lankan construction industry with specific reference to the Project Management Institute's (PMI's) standard for EVM. A qualitative research approach was used to accomplish the aim of the study. The empirical findings were analyzed using the manual content analysis technique to determine the degree of implementation of the PMI's standard for EVM in Sri Lanka. The deficiency of professionals and inadequate conceptual knowledge were identified as the most critical barriers associated with the implementation process of the EVM technique. Allocating a separate team to execute the EVM technique, arranging short courses on EVM, developing a standard master format for project performance measurement are the measures that this study recommends promoting the adoption of the EVM technique in the Sri Lankan construction industry.

Keywords: *Earned Value Management; Performance Measurement; Project Management Institute; Standard.*

1. INTRODUCTION

Criteria of the construction project's success have constantly enriched in project management context (Chan and Chan, 2004). Thus, the performance of a construction project has been judged using different traditional approaches to get a better picture of the project's status (Khan *et al*., 2011). However, those Project Management tools did not withstand the expected level (Soloman, 2002). As a result of the multidisciplinary effort of researchers, EVM emerged as a useful Project Management tool (Bhosekar and Vyas,

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2012). EVM is a technique that can be applied to the management of all capital projects, in any industry, while employing any contracting approach (Fleming and Koppelman, 2002). With the adaptation of EVM to construction project management, the project team can modify the cash flow, update financial reports, figure out the schedule status of a project, capture work progress against the baseline and evaluate the health of the project along with its life cycle in a timely manner (Kim *et al*., 2003).

Sri Lankan construction industry is well in need of a well-known and established performance monitoring technique for the development of the sector and its better performance (Ekanayake *et al*., 2018). This research aims to develop a conceptual framework for effective implementation of the EVM technique in the Sri Lankan construction industry, with specific reference to the PMI's standard for EVM. EVM, which is a new performance measurement technique, was initially developed in the United States, and it has been minimally addressed in the literature of the Sri Lankan context (Hettipathirana and Karunasena, 2014). However, a few researchers had studied the feasibility of adopting a standard for the implementation of EVM in the Sri Lankan construction industry (e.g. Nimashanie and Perera, 2013; Wickramasooriya *et al*., 2017). As far as the Sri Lankan context is concerned, the potential impediments and solutions to such matters during the implementation of the PMI's standard have not been explicitly addressed. Thus, there is a research gap towards developing a conceptual framework for effective implementation of the EVM technique considering the adaptability of the PMI's standard for EVM in the Sri Lankan context. The potential of applying the PMI's standard for EVM in achieving construction project success could grow once a conceptual framework is established concerning the deficits mentioned above. When considering to implement the EVM technique within the Sri Lankan context by adopting the PMI's standard, the following constituents were identified as crucial to be investigated: (1) the contemporary practices of performance measurement in Sri Lanka; (2) the degree of implementation of the PMI's standard in local construction firms; (3) challenges that can be anticipated; and (4) the potential solutions to successfully address those challenges through the PMI's standard for EVM.

2. LITERATURE REVIEW

2.1 THE PMI'S STANDARD FOR EVM

As a performance measurement methodology, EVM adds some critical practices to the project management process. These practices occur primarily in the areas of project planning and control and are related to the goal of measuring, analyzing, forecasting, and reporting cost and schedule performance data for evaluation and action by workers, managers, and other key stakeholders (PMI, 2005). EVM synthesizes best results in initiating, planning, executing, monitoring and controlling phases in the project by breaking down work packages, developing proper performance baselines and incorporating those to review in a systematic manner (Willems and Vanhoucke, 2015). Clear project scope is required with a project budget and a project schedule to implement EVM concepts. The project budget must reflect all planned costs incurred by the activities of which the project consists (Buyse and Vandenbussche, 2010). EV measuring techniques must be established for each type of event before carrying out project monitoring work (Dissanayake, 2010). In the project execution process, EVM requires that physical work progress be assessed and budgetary EV be credited as prescribed in the project management plan (PMI, 2005). The significant steps of the PMI's standard for EVM can be summarized as follows.

I. Establish a Performance Measurement Baseline (PMB)

1. Decompose work scope to a manageable level
2. Assign unambiguous management responsibility
3. Develop a time-phased budget for each work task
4. Select EV measurement techniques for all functions
5. Maintain the integrity of PMB throughout the project

II. Measure and analyze performance against the baseline

6. Record resources usage during project execution
7. Objectively measure the physical work progress
8. Credit EV according to EV techniques
9. Analyze and forecast cost/schedule performance
10. Report performance problems and/or take actions

2.2 THE CONTEMPORARY PRACTICES OF PERFORMANCE MEASUREMENT APPLICATION IN SRI LANKA

In the Sri Lankan construction industry, there is a strong need for a globally established performance monitoring technique for the development and better performance of the sector (Nimashanie and Perera, 2013). Unfortunately, there is no specific method that has been identified so far as well. Performance evaluation in the construction industry is thus carried out using the results of diverse applications such as S curves, Gantt charts, Cash flow statements, and EVM (Wickramasooriya *et al*., 2017). Hence, no established or recognized standard is available for project performance evaluation in Sri Lanka, the success or failure of the projects often depends on rather traditional methods, which are disadvantageous as well as obsolete compared to EVM (Hettipathirana and Karunasena, 2014). Regrettably, in the Sri Lankan context, EVM had not gained any attention or importance otherwise (Ekanayake *et al*., 2018). Thus, it can be concluded that the management and control of cost and schedule are in the primary stage in Sri Lanka (Bowen *et al*., 2012). Despite all the held facts, the existing literature on EVM is also minimal concerning the Sri Lankan context. Ekanayake *et al*. (2018) had solitarily conversed some general barriers in implementing EVM concepts in Sri Lanka as stipulated in Table 1.

Table 1: Obstacles in implementing EVM in Sri Lanka

Barriers	Status
EVM performance	EVM covers a large area with limitations within Sri Lankan projects, and Employees are not interested in doing additional work as well.
The struggle of Employees	Lack of hard bondage between employees and management which results in the absence of adherence of EVM in their projects.
Cost factor	Most of the project managers are not ready to accept risks related to new technology with the note of high cost involved in the implementation of EVMS in a project.
Time duration	Due to the lack of expertise in the industry, a long period is required to acquire the mandatory knowledge and skills in the EVM software.

Barriers	Status
Accuracy of data	Lack of reliable data in the construction industry is a significant hindrance which requires regular monitoring to acquire them for productive implementation of EVM.
Lack of awareness on EVM	Most of the employees are not compatible with EVMS due to their lack of knowledge.
Fear for language	Lack of fluency in English acts as a hindrance for the employees to embrace and utilize EVM in the Sri Lankan context.
Minimum support from the top management	Some managers are reluctant to share their knowledge with the middle and lower-level employees, who may be the cause for negative attitudes in new implementations.
Technical issues	Since Sri Lanka lacks the technical facilities required, computer literacy, physical and human resources should be made available for a project to implement EVMS.
Demotivation of employees	Motivation and encouragement are required within the employees for the implementation of EVMs; however, within the Sri Lankan context, demotivation appeared to be a considerable barrier for the EVM implementation.

Source: Ekanayake *et al.* (2018)

3. RESEARCH METHODOLOGY

Research approach can be constructed as a general plan of how the researcher will go about answering the research question (Tan, 2002). Since the use of PMI's standard for EVM is confined to a limited area and also among only a handful of experts, the qualitative research approach was utilized to obtain data from the experienced practitioners in the industry. It was required to obtain information on the contemporary performance measurement practices and the degree of application of the EVM technique with particular reference to the PMI's standard in Sri Lanka. Accordingly, the opinions of practitioners concerning the current stance in the industry in terms of adopting the PMI's standard for EVM, potential challenges that may be encountered and the solutions that may be given via the PMI's standard were recognized. The qualitative data were contributed by a number of thirteen industry experts who are veterans when it comes to their level of experience in the construction industry as well as the profound knowledge of the EVM concepts shaped by enormous passion. Majority of them are professionals with an experience of more than twenty years, holding managerial positions within their respective organizations. The manual content analysis method was utilized in the data analysis. A brief sketch of the interviewees' profiles is illustrated in Table 2.

Table 2: The profile of the interviewees

Interviewee Code	Designation	Profession	Experience
Interviewee - 1	Chief Executive Officer	Chartered QS	25 years +
Interviewee - 2	Chief Executive Officer	Chartered QS	25 years +
Interviewee - 3	DGM – Contracts and Estimation	Chartered QS	12 years +
Interviewee - 4	Contracts Manager	Chartered QS	10 years +

Interviewee Code	Designation	Profession	Experience
Interviewee - 5	Director	Chartered QS	45 years +
Interviewee - 6	Contracts Manager	Chartered QS	15 years +
Interviewee - 7	AGM - Construction	Project Manager	35 years +
Interviewee - 8	AGM - Construction	Project Manager	25 years +
Interviewee - 9	Executive Senior QS	Chartered QS	20 years +
Interviewee – 10	Director - Projects	Chartered QS	30 years +
Interviewee – 11	Executive QS, who is passionate about the EVM technique	QS	2 years +
Interviewee – 12	PhD Candidate	QS	2 years +
Interviewee – 13	Associate Director – Projects	Project Manager	15 years +

4. DATA ANALYSIS, FINDINGS AND DISCUSSION

4.1 THE DEGREE OF IMPLEMENTATION OF EVM RELYING ON PMI'S STANDARD IN SRI LANKA

A thorough observation of the empirical findings revealed that there is a deficiency of a specific standard performance measurement application in Sri Lanka. Thus, the issue resulted in the practitioners to deal with several traditional project performance measurement techniques. Even though Sri Lanka is deprived of an EVM standard, it was identified that, for several decades, the industry had slight exposures to the EVM technique. Since the necessity of having a recognized standard as PMI to implement the EVM technique within the local construction industry was apprehended through the empirical findings. It was concluded that the PMI's standard had not been recognized by the practitioners to implement the EVM concepts yet. Subsequently, it was determined that only a few steps of the EVM process had been highly implemented in Sri Lanka, relying on the PMI's standard. The implementations are instead a set of steps adjusted to meet the organizational requirements in traditional project management procedure, rather than a developed or accurately standardized practice. Most of the key steps of the PMI's standard were identified as moderately performed steps in the construction industry of Sri Lanka. However, it was recognized that they were also not explicitly implemented with respect to a distinct performance measurement standard as PMI, but merely as generic project management formalities of the traditional project management practices of Sri Lanka. All the industry experts referred to two of the key steps of PMI's standard for EVM system as the least implemented steps in the local construction industry.

Each key step of PMI's standard based EVM was determined to establish its degree of implementation in the local construction industry, according to the knowledge and experience of experts. The significance of enhancing the traditional performance measurement practices to a new performance measurement standard, such as the PMI's standard based EVM concept, in the construction industry of Sri Lanka was stressed by the empirical findings.

The degree of implementation of key steps of the PMI's standard for EVM can be summarized as shown in Table 3.

Table 3: The degree of implementation of PMI's standard for EVM

Key Steps of the PMI's Standard for EVM	Degree of Implementation
Step 01 - Decompose work scope to a manageable level	Highly implemented but with several deviations to the standard practice of PMI's standard for EVM
Step 02 - Assign unambiguous management responsibility	Moderately performed; not individually as a critical step of EVM technique relying on PMI but as generic project management procedural
Step 03 - Develop a time-phased budget for each work task	Highly implemented but with several deviations to the standard practice of PMI's standard for EVM
Step 04 - Select EV measurement techniques for all functions	Least implemented in the local construction industry
Step 05 - Maintain the integrity of PMB throughout the project	Moderately performed; not individually as a critical step of EVM technique relying on PMI but as generic project management procedural
Step 06 - Record usage of resources during project execution	Highly implemented but with several deviations to the standard practice of PMI's standard for EVM
Step 07 - Objectively measure the progress of physical work	Moderately performed; not individually as a critical step of EVM technique relying on PMI but as generic project management procedural
Step 08 - Credit EV according to EV techniques	Least implemented in the local construction industry
Step 09 - Analyse and forecast cost/schedule performance	Moderately performed; not individually as a critical step of EVM technique relying on PMI but as generic project management procedural
Step 10 - Report performance problems and/or take actions	Moderately performed; not individually as a critical step of EVM technique relying on PMI but as generic project management procedural

4.2 THE CHALLENGES TO BE ENCOUNTERED AT THE TIME OF IMPLEMENTING EVM IN SRI LANKA

The empirical findings acknowledge that, when compared with PMI's standard for EVM, numerous nonconformities exist in contemporary project performance measurement practices in Sri Lanka. The definite necessity of having a conceptual framework to implement the EVM technique relying on PMI's standard was determined for the context of Sri Lanka. Considering the rigour involved in the introduction of a new performance measurement standard, the industry experts were interviewed to obtain awareness about the potential and predictable challenges during the implementing EVM concepts based on the PMI's standard. The industry experts highlighted numerous challenges as per the context of Sri Lanka. The most significant challenges which were highlighted by the majority of the experts are stipulated in Table 4 concerning each key step of the PMI's standard for EVM.

Table 4: Most significant challenges to be encountered

Key Steps of the PMI's Standard for EVM	Most Significant Challenges
Step 01 - Decompose work scope to a manageable level	UK Based BOQ system in Sri Lanka being unsupportive to decompose WBS and OBS as a program-based system
Step 02 - Assign unambiguous management responsibility	Lack of enough staff at the inception of the projects in Sri Lanka
Step 03 - Develop a time-phased budget for each work task	Shortage of skilled professionals to execute the task
Step 04 - Select EV measurement techniques for all functions	Insufficient knowledge of the project management personnel on EV
Step 05 - Maintain the integrity of PMB throughout the project	The high cost of maintenance and time consumption
Step 06 - Record usage of resources during project execution	Lack of proper record keeping in the local construction industry
Step 07 - Objectively measure the progress of physical work	Lack of exact benchmarks to measure the progress of physical work
Step 08 - Credit EV according to EV techniques	Insufficient knowledge to execute the EVM technique relying on the PMI's standard
Step 09 - Analyse and forecast cost/schedule performance	Lack of real-time progress feedbacks during the project
Step 10 - Report performance problems and/or take actions	Fear of failure / Top management pressure

4.3 SOLUTIONS TO OVERCOME THE CHALLENGES

For the effective implementation of EVM system as performance measurement and monitoring tool in Sri Lanka, the above-identified problems should be mitigated by controlling or embracing them by minimizing the undesirable impact on the local construction industry. The essential solutions should be proactively performed to overcome the challenges above, relying on the PMI's standard for EVM. Hence, the answers and the mitigation measures were concluded through the empirical findings. These solutions were contributed to creating a pathway to develop the conceptual framework for effective implementation of the EVM technique in the construction industry of Sri Lanka. The experts had made a significant contribution in recognizing the necessary proactive measures for the challenges documented concerning each key step of the PMI's standard as detailed in Table 5.

Table 5: The solutions to overcome the challenges

Key Steps of the PMI's Standard for EVM	Most Significant Challenges	Most Significant Solutions
Step 01 - Decompose work scope to a manageable level	UK Based BOQ system in Sri Lanka being unsupportive to	Development of formats, steps, and processes to convert existing BOQ

Key Steps of the PMI's Standard for EVM	Most Significant Challenges	Most Significant Solutions
	decompose WBS and OBS as a program-based system	system into program - based system with resources
Step 02 - Assign unambiguous management responsibility	Lack of enough staff at the inception of the projects in Sri Lanka	Appointing a well-equipped team with knowledge and technical know-how at the earliest possible
Step 03 - Develop a time-phased budget for each work task	Lack of skilled professionals to execute the task	Development of a duly prepared construction program
Step 04 - Select EV measurement techniques for all functions	Insufficient knowledge of the project management personnel on EV	Implementation of the EVM technique relying on PMI's standard for EVM to suit for Sri Lanka
Step 05 - Maintain the integrity of PMB throughout the project	The high cost of maintenance and time consumption	Implementation of a web-based information sharing system
Step 06 - Record usage of resources during project execution	Lack of proper record keeping in the local construction industry	Formation of an online collaborative system that enables live updates
Step 07 - Objectively measure the progress of physical work	Lack of exact benchmarks to measure the progress of physical work	Derive a scientific method in undertaking the tasks
Step 08 - Credit EV according to EV techniques	Insufficient knowledge to execute the EVM technique relying on the PMI's standard	Educate the professionals on EVM and EV measurement techniques based on PMI's standard for EVM
Step 09 - Analyse and forecast cost/schedule performance	Lack of real-time progress feedbacks during the project	Development of skills and competencies of QSs and Project Management professionals which would be benefited in the project performance measurement
Step 10 - Report performance problems and/or take actions	Fear of failure / Top management pressure	Identify how beneficial the application of the EVM system to the organization is and allocating the maximum support from the top management to implement the EVM process

A conceptual framework was developed based on the literature findings and empirical findings to conquer the aim of this research. The significant areas to be concerned about when implementing the EVM technique as a project performance measurement technique by adopting the popular PMI's standard for EVM, have been profoundly articulated within the conceptual framework (refer Figure 1).

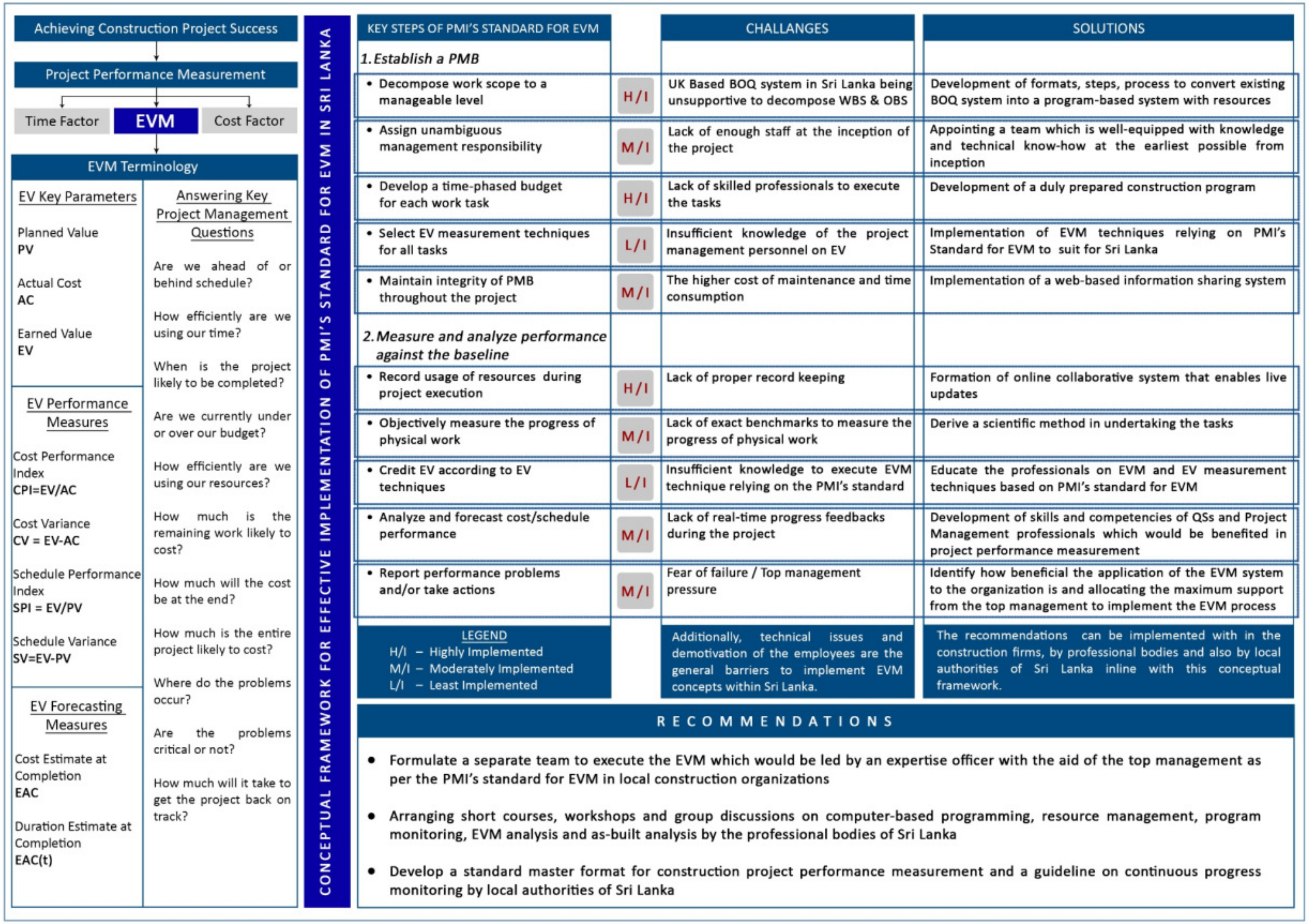

Figure 1: Conceptual framework

5. CONCLUSIONS AND RECOMMENDATIONS

The proposed framework can act as a novel yet a significant EVM tool for the stakeholders who intend to apply the EVM technique, with particular reference to the PMI's standard. It holds the potential of motivating the stakeholders with an accurate account of what they would encounter during the process of performance measurement in construction projects of Sri Lanka. The conceptual framework enables EVM stakeholders to improve the effectiveness and efficiency of the entire performance measurement and feedback processes. However, the research is limited by the fact that the conceptual framework only counts on the PMI's standard whereas there are other standards alike ANSI/EIA standard, 748-A guidelines published by National Defense Industrial Association (NDIA), AS4817 published by Australian standards committee to implement the EVM technique. Hence, as illustrated in Figure 1, paying attention and adherence to the conceptual framework will substantiate and uplift the traditional project performance measurement practices to a higher level by reaping the maximum benefits in terms of the grooming construction industry of Sri Lanka.

6. REFERENCES

Bhosekar, S. and Vyas, G., 2012. Cost Controlling Using Earned Value Analysis in Construction Industries. *International Journal of Engineering and Innovative Technology (IJEIT),* 1(4), pp.324-332.

Bowen, P. A., Cattel, K. S., Hall, K.A., Edwards, P. J. and Pearl, R. G., 2012. Perceptions of Time, Cost, and Quality Management on Building Projects. *The Australian Journal of Construction Economics and Building (AJCEB),* 2(2), pp.48-56.

Buyse, P. and Vandenbussche, T., 2010. *Performance Analysis of Earned Value Management in the Construction Industry.* Thesis (MSc). University GENT.

Chan, A. and Chan, A., 2004. Key Performance Indicators for Measuring Construction Success. *Benchmarking: An International Journal,* 11(2), pp.203-221.

Dissanayake, P. B. G., 2010. Earned Value Management System as a Project Management Tool for Major Multi-Disciplinary Projects. In: *International Conference on Sustainable Built Environment (ICSBE-2010)*, Kandy 13-14 December 2010. pp.14-21.

Ekanayake, M. G. C., Jayasena, H. S. and Kolugala, L. M. B. N., 2018. Potential of Applying Earned Value Management (EVM) As a Performance Evaluation Technique in Building Construction Projects in Sri Lanka. In: *The 7th World Construction Symposium,* Colombo 29 June -1 July 2018. pp.423-429.

Fleming, Q. and Koppelman, J., 2002. Earned Value Management – Mitigating the Risks Associated with Construction Projects. *Program Manager (PM),* March – April 2002, pp.90-95.

Hettipathirana, H. D. and Karunasena, G., 2014. Applicability of Earned Value Management as a Performance Measurement Tool for Sri Lankan Construction Industry. In: *The 3rd World Construction Symposium,* Colombo 20-23 June 2014. pp.423-429.

Khan, M. W. A., Khamidi, M. F. and Idruz, A., 2011. Application of Earned Value Management System on an Infrastructure Project: A Malaysian Case Study. In: *International Conference on Management and Service Science,* Singapore 2011. IACSIT Press, pp.11-15.

Kim, E. H., Wells, W. G. and Duffey, M. R., 2003. A Model for Effective Implementation of Earned Value Management Methodology. *International Journal of Project Management,* 21(5), pp.375-382.

Nimashanie, W. M. T. and Perera, A. A. D. A. J., 2013. Applicability of Earn Value Management in Sri Lankan Construction Projects. In: *ACEPS – 2013,* Sri Lanka. pp.37-43.

PMI, 2005. *Practice Standard for Earned Value Management.* Pennsylvania: Project Management Institute.

Soloman, P., 2002. *Using CMMI to Improve Earn Value Management*. Carnegie Mellon University.

Tan, W. C. K., 2002. *Practical Research Methods.* Prentice-Hall, New Jersey.

Wickramasooriya, K. J., Perera, B. A. K. S. and Rodrigo, M. N. N., 2017. Establishing a Framework for The Earned Value Management Approach in Large Scale Building Projects. In: Rajapaksha, U. (ed). *10th International Conference of FARU,* Wadduwa December 2017. University of Moratuwa, pp.135-147.

Willems, L. and Vanhoucke, M., 2015. Classification of Articles and Journals on Project Control and Earned Value Management. *International Journal of Project Management,* 33(7), pp.1610-1634.

Rajamanickam, T., Waidyasekara, K.G.A.S. and Pandithawatta, T.P.W.S.I., 2019. Conceptual framework for green supply chain practices in construction industry. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 200-209. DOI: doi.org/10.31705/WCS.2019.20. Available at: https://2019.ciobwcs.com/papers

CONCEPTUAL FRAMEWORK FOR GREEN SUPPLY CHAIN PRACTICES IN CONSTRUCTION INDUSTRY

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ABSTRACT

The construction industry plays an important role in improving quality of the environment. However, it was also found out that the construction activities create negative impacts on the environment. Reducing the negative environmental impact of the construction industry is one of the major challenges in the 21st century. However, regardless of the significance of this problem, limited efforts to deal with the negative effects have been largely fragmented and disjointed. Green Supply Chain Management is considered as one of the main efforts, which aim to integrate environmental parameters within the supply chain management. It reduces carbon emissions and improves environmental performances of organizations. The trend towards developing Green Supply Chain is now increasing among various industries. In the recent past, enterprises have started Green Supply Chain Management for the purpose of securing competitive advantages over other initiative due to the increase of international conventions related to the recent climate change, the global environmental protection regulations, the stakeholders and investors' need for environmental suitability and the consumer's choice for environmentally friendly products. Therefore, this paper aims to critically review the secondary data on Supply Chain Management, Sustainable Supply Chain Management, and Green Supply Chain Management in the construction industry. Finally, the paper presents a conceptual framework integrating concepts for Green Supply Chain Management practices to the construction sector.

Keywords: *Green Supply Chain Management; Supply Chain Management; Sustainable Supply Chain Management.*

1. INTRODUCTION

Supply chain management (SCM) is an incorporated approach, which assimilate the service providers to the end customers or suppliers to manufacturers (Fantazy *et al*., 2010). Retail organizations and manufacturing organizations are integrating SCM and from that they are able to enhance the efficiency and effectiveness of their business functions, but the construction industry has been slow to implementing SCM (Love *et al*., 2000). When compared to other sectors, construction supply shows some characteristic differences while it is an incorporated set of practice, which maintains and coordinate the total Supply Chain (SC) from raw material to end clients However, De Silva *et al*. (2008)

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stated that lack of resources is one of the main challenges faced by the Sri Lankan construction industry. In order to attain the potential future demand, companies wish to make their SCs in a way that doesn't impact the environment (Mahler, 2007). Especially in Sri Lankan context, with the booming economic development has tend the industry to focus on large scale construction projects, and it automatically leads to the environment resource depletion, so environment friendly development is needed in order to manage consistency between human and environment. Therefore, this research aimed to develop a conceptual framework for assessing the adaptation of Green Supply Chain Management (GSCM) practices in Sri Lankan construction industry.

2. RESEARCH METHODOLOGY

Research methodology refers to the overall approach to the research process that is from the theoretical underpinning to the collection and analysis of data. First step of the research process is conducting literature review. As Uyangoda (2010) mentions, literature review is a critical assessment of the existing body of knowledge on the theme or problem. Mainly, literature evidence was taken by referring journal articles, books, conference proceedings, industry reports and documents. During the literature survey the details relating to Supply Chain Management, Sustainable Supply Chain Management, and Green Supply Chain Management was reviewed. At the end a conceptual framework was built to show the relationships between those key areas.

3. LITERATURE REVIEW

3.1 SUPPLY CHAIN AND SUPPLY CHAIN MANAGEMENT

Supply Chain (SC) is the combination of activities that a firm proceeds to convert the raw materials into a final product. The most effective and efficient types of SC are capable to deliver quality goods in a quicker and cheaper manner (Wisner *et al*., 2014). Supply Chain Management (SCM) considered as a wide range of activities required to plan, control and execute a product, from purchasing raw materials to distribution of final product to the customer. SCM process improves the quality of product and reduces cost and delivers product, services, and information (Croxton *et al*., 2001). In other words, these SCM processes help firms to reach its objectives in effective and the efficient manner (Johnson, 2016). Tan (2001) stated that planning, product design and development, manufacturing and order fulfilment, customer management, and return are the process of SCM. By implementing SCM systems, the company can minimise the waste generation, costs and transportation delays in a systematic way. Improved inventory income, increased profits, cost reduction across the chain, increased customer awareness, more reliable on-time delivery, customer satisfaction, reduced purchasing costs, reduced inventory costs, proper inventory levels in the chain, minimize delays, and deliver good customer service were identified as some of the advantages of SCM (Fawcett *et al*., 2008).

3.2 CONSTRUCTION SUPPLY CHAIN MANAGEMENT

In order to increase performance of the construction sector, adoption of effective SCM is essential. Construction Supply Chain (CSC) is more complex compared to manufacturing supply chain, because of the large number of participants and comprehensiveness of the process. Effective and more efficient Construction Supply Chain Management (CSCM) provides multi-team communications in construction and increase the relationships between clients, consultants, contractors and subcontractors (Butković *et al*., 2016). CSCM is defined as the strategic management of information flows, activities, tasks, and processes, involving various networks of independent organizations and linkages (upstream and downstream) which produce value that is delivered to the owner in the form of a finished project (Cox and Ireland, 2002).

CSCM guarantee reliable material and labour flows to the site to avoid disturbance to the workflow. Moreover, it helps to improve the performance and productivity by minimizing the delays in the construction (Beheraa *et al*., 2015; Saad *et al*., 2002). Adoption and implementation of SCM in the construction industry is not easy due to the presence of many barriers. Failure to share project information, fear of loss of control, lack of self-awareness, lack of knowledge of the project complexity, inability to identify project goals, lack of understanding of SC, narrow-minded thinking, unfair strategies, and lack of support are identified major barriers of CSCM (Aloini *et al*., 2012; Panova and Hilletofth, 2018).

3.3 NEGATIVE ENVIRONMENTAL IMPACT OF CONSTRUCTION INDUSTRY AND REQUIREMENT OF SUSTAINABLE CONCEPT

Construction projects have a major impact on the global environment in a negative way through energy, materials, chemical products and waste production (Li *et al*., 2010). According to the International Energy Agency (2018) the construction sector contributes to 23% of air pollution, 50% of climatic change, 40% of water pollution, and 50% of landfill wastes. Furthermore, this report stated that the construction industry accounts for 40% of worldwide energy usage and responsible for 40% of global carbon emissions and 25% of global waste. Nowadays, many countries around the world are considering negative impacts to protect human, environment and resources. Therefore, the construction projects should be designed to have the greatest positive impact and the least negative impact on the environment (Enshassi *et al*., 2015).

Sustainable construction has been commonly defined as the growth that meets the needs of the present without compromising the capacity of future generations to meet their own needs (Singh and Trivedi, 2016). It incorporates elements of economic ability, environmental performance and social obligation (Gold *et al*., 2010). However, the incorporation of environmental, economic and social paradigms to achieve sustainable development is a main task for all industries. Initially, sustainability concepts primarily focus on environmental issues with less attention of social and economic concerns (Gold *et al*., 2010). Further this approach minimises the pollution and waste compared to SCM. Pagell and Shevchenko, (2013) said that Sustainable Supply Chain Management (SSCM) is *"the designing, organizing, coordinating, and controlling of supply chains to become truly sustainable with the minimum expectation of a truly sustainable supply chain being to maintain economic viability, while doing no harm to social or environmental systems"*.

The most influencing barrier to implement SSCM is the lack of support in developing countries (Vermeulen, 2006). It includes low levels of regulation, and lack of knowledge gap between top government officers. There is a common lack of awareness about sustainable practice and sustainable issues among consumers and suppliers of the developing countries (Soda *et al*., 2015) and a lack of request from customers for sustainable products. Green upfront costs can be very high for organizations in developing countries (Li *et al*., 2015).

When dealing with environmental issues, the organization focuses on green supply management programs designed to reduce harmful effects in the environment. Green construction goes a step further than sustainability and it minimizes the environmental impact in the construction process (Soda *et al*., 2015).

3.4 GREEN SUPPLY CHAIN MANAGEMENT IN THE CONSTRUCTION INDUSTRY

Over the past decade, the growing impact of global warming, climate change, waste and air pollution problems have involved increasing worldwide consideration of experts to think more environmentally friendly and solution towards "Green" (Rostamzadeh *et al*., 2015). Further, the environmental, social and economic impacts of the construction industry are increasing, driving the demand for sustainable construction. Use of large number of natural resources, environmental pollution and the immense usage of energy in production of materials create a significant impact on the environment (Balasubramanian, 2012). Green Supply Chain Management (GSCM) aims to integrate environmental thinking into SCM (Srivastava, 2007). As an alternative of reducing the dangerous things of business and SC operations, Green Supply Chain (GSC) minimizes air, water and waste pollution. Moreover, it also improve companies' performance in terms of less waste manufacturing, recycling, reducing production costs, improving asset efficiency, positive image building and customer (Chun *et al*., 2007; Fang and Zhang, 2018).

GSCM definition of construction industry integrates sustainable practices into upstream and downstream SCM, bringing long-term benefits by applying environmental and social behaviour responsible for all supply chain members (Chowdhury *et al*., 2016). The main aim of green practices is to reduce the negative environmental effects linked with construction activities. Some authors identified that green design, green construction, green material management, reverse logistics, and green operation and maintenance are the main green practices which falls under construction industry (Wibowo *et al*., 2018).

3.4.1 Green Design

Green design is the most important stage in GSCM practices, decisions taken at this stage will be influenced at every stage of the life cycle of the building from planning to material recycle and reuse phase (Srivastava, 2007). The purpose of the green design is to minimize negative environmental impacts of the construction projects throughout environmentally friendly way. The important aspect of green product design comprises the selection of raw material with high percentage of recycled content and small embodied energy. Green design reduces the environmental impact of building design and process (Ng *et al*., 2012). The dimensions of the green product design are design, innovation capability, product safety, environmental control, and building and environmental management (Govindan *et al*., 2015).

3.4.2 Green Material Management

Green material management is a method to replace more favourable activities or materials with potentially hazardous one. Green materials management selecting criteria emphasise that materials used in construction should be easily fragmented, flexible, or useful in restructuring existing processes (Nur *et al*., 2018). Material planning, material storage, green procurement, material handling, green material selection and green material sourcing are the main processes of green material management (Hafezalkotob, 2017).

3.4.3 Green Construction

Main goal of green construction is to eliminate or minimize negative environmental impacts on the design, construction and operation phase in addition to create buildings with a positive impact on the environment. Moreover, Green construction discusses the use of on-site practices to reduce the impact of building environment. Green transportation, on-site management and planning, site operation, residual, and environment society are overall theories that are primary components of green construction (Balasubramanian and Shukla, 2017).

3.4.4 Green Operation and Maintenance

Green operation and maintenance programs include teaching, cleaning, work applications and controls for protecting the green materials of the project according to environmental needs. Dimensions of green operation and maintenance are green building, green marketing management and green management policy (Chang *et al*., 2016; Chen, 2012).

3.4.5 Reverse Logistics

Environmental reverse logistics is a series of activities that help to return into forward SC of reusable, remanufacture, and recyclable materials and products (Ghobakhloo *et al*., 2013). Recycling is demarcated as a way to reuse materials that may otherwise be considered waste in a form other than the primary use. Remanufacturing is the method of returning a used product to at least its original performance. Reuse means a material is used again for the same purpose or may find a new product life in a different function (Ng *et al*., 2012).

3.5 Barriers and Drivers of Green Supply Chain Management

Table 1 shows the barriers and divers of the GSCM identified by the researchers. GSCM aims to minimize waste and pollution by consolidating environmental thoughts into design and end-life management. Implementation of these chains are influenced by the drivers and the barriers. The barriers are the forces which prevent the implementation of GSCM. Moreover, drivers are defined as the strengths to inspire organisations for the implementation of green supply chain.

Table 1: Barriers and drivers of green practice

Barriers and Drivers	Literature source							
	(Qi et al., 2010)	(Dube and Gawande, 2014)	(Balasubramanian and Shukla, 2017)	(Mathiyazhagan et al. 2017).	(Stremlau and Tao, 2016)	(Lamba and Thareja, 2016)	(Majumdar and Sinha, 2018)	(Pitt et al., 2009)
Internal Barriers								
Lack of availability of skilled human resource			X			X		
Lack of top level management commitment			X					

Barriers and Drivers	Literature source							
	(Qi et al., 2010)	(Dube and Gawande, 2014)	(Balasubramanian and Shukla, 2017)	(Mathiyazhagan et al. 2017).	(Stremlau and Tao, 2016)	(Lamba and Thareja. 2016)	(Majumdar and Sinha, 2018)	(Pitt et al., 2009)
Capital requirement for GSCM implementation			X					
Lack of technical knowledge and experience					X	X	X	
Lack of training in GSCM		X					X	
Lack of acceptance of new technology					X			
External Barriers								
Lack of green professionals			X					
Customer unawareness towards GSCM practices			X			X		
Shortage of green suppliers or recyclable materials		X						
Lack of stakeholder engagement		X			X			
Lack of government initiative systems		X	X			X	X	
Tight stakeholder deadlines						X		
External drivers								
Government rules and legislation	X	X						
Society or public pressure						X		
Client or Customer awareness and pressure								X
Stakeholder pressure								X
Improve the image of the construction industry								X
Competitor pressure		X						
Internal drivers								
Developers or Contractor's environmental mission or environmental commitment						X		X
Investors and shareholders' pressure		X						
Enhance reputation	X							
Increased employee or labour productivity	X							
Support from top managers		X						X

According to Table 1, the lack of a government initiative system is identified as the main barrier to the implementation of green practice, that this barrier was highlighted by four reference materials However, lack of knowledge and experience between stakeholders of SC about implementing GSCM also play a major role in the GSCM implementation because this barrier was commonly identified in many sources. Likewise, when considering the drivers of GSCM practices, the goal of company's developer or contractor's for his company and government rules and legislation for environment management plans were highlighted by two authors as most important drivers of green practices.

3.6 CONCEPTUAL FRAMEWORK FOR GREEN SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION INDUSTRY

The framework proposed (refer Figure 1) is based on the extensive review of literature to enable experts, managers and researchers to get the complete perspective of Green supply chain management practices in the construction industry. Green design, green construction, green material management, reverse logistics, and green operation and maintenance are the main green practices, which come under construction industry. The conceptual framework of green supply chain practices in the construction industry is presented in Figure1. These green supply chain practices in the construction industry is a cyclical process. In here materials from the reverse logistic were used in an another construction activity therefore waste generation from these GSCM is comparability low than traditional construction method.

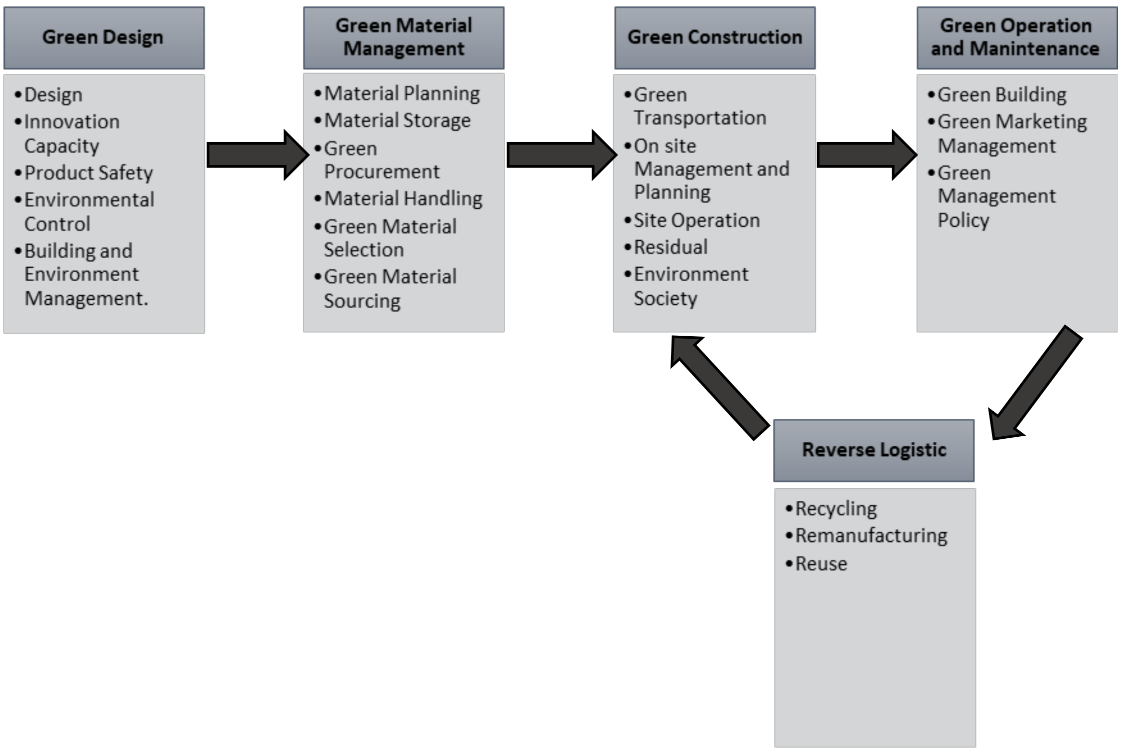

Figure 1: Conceptual framework of green practices in construction industry

4. SUMMARY AND WAY FORWARD

Green construction goes a step further than sustainability and minimizes the environmental impact in the construction process. As the environmental awareness is increasing, firms all over the world are facing a heavy pressure from different stakeholders including government and customers to mitigate their harmful impacts on the environment. When dealing with environmental issues, companies prefer to undertake GSCM programmes that aim to reduce harmful effects to the environment. The aim of this study is to elaborate literature available on green supply chain practices and to develop a conceptual framework of green practices in construction industry. These practices were mainly identified as, green design, green material management, green construction, green operation and maintenance, and reverse logistic. During the next step of the study, the GSC practices that are suitable to the Sri Lankan construction industry will be investigated along with their enablers and barriers. The future implications of this study will be beneficial to other developing countries during the implementation process of GSC practices.

5. REFERENCES

Aloini, D., Dulmin, R., Mininno, V. and Ponticelli, S., 2012. Supply Chain Management: A Review of Implementation Risks in The Construction Industry. *Business Process Management Journal*, 18(5), pp.735-761.

Behera, P., Mohanty, R.P. and Prakash, A., 2015. Understanding construction supply chain management. *Production Planning & Control*, *26*(16), pp.1332-1350.

Butković, L. L., Kauric, A. G. and Mikulic, J., 2016. Supply Chain Management in the Construction Industry-A Literature Review. *In 4th International OFEL Conference on Governance, Management and Entrepreneurship,* pp.798-811.

Central Bank, 2017. *Annual Report of Central Bank, Sri Lanka*: Central Bank of Sri Lanka.

Chang, Y. H., Huang, P. H., Chuang, T. F. and Chang, S. W., 2016. A Pilot Study of the Color Performance of Recycling Green Building Materials. *Journal of Building Engineering*, 7, pp.114-120.

Chen, C.C., 2012. A Business Strategy Selection of Green Supply Chain Management Via An Analytic Network Process. *Computers & Mathematics with Applications,* 64(8), pp.2544-2557.

Chowdhury, M., Upadhyay, A., Briggs, A. and Belal, M., 2016, May. An overview of green supply chain management practices in Bangladesh construction industries. In *POMS Conference 2016* (pp. 1-10).

Chun, S. H., Hwang, H. J. and Byun, Y. H., 2007. Green Supply Chain Management in the Construction Industry: Case of Korean Construction Companies. *Procedia - Social and Behavioral Sciences*, 186, pp.507-512.

Cox, A. and Ireland, P., 2002. Managing Construction Supply Chains: The Common Sense Approach. Engineering, *Construction and Architectural Management,* 9(5), pp.409-418.

Croxton, K. L., García-Dastugue, S. J., Lambert, D. M. and Rogers, D. S., 2001. The Supply Chain Management Processes. *The International Journal of Logistics Management*, 12(2), pp.13-36.

De Silva, N., Rajakaruna, R. W. D. W. C. A. B. and Bandara, K. A. T. N., 2008. Challenges Faced By the Construction Industry in Sri Lanka: Perspective of Clients and Contractors, In *Proceedings of the symposium conducted at the meeting of the Building Resilience*, School of the Built Environment, University of Salford.

Dhull, S. and Narwal, M. S., 2016. Drivers and Barriers in Green Supply Chain Management Adaptation: A State-of-Art Review. *Uncertain Supply Chain Management,* 4(1), pp.61-76.

Dube, A. S. and Gawande, R. R., 2014. *Barriers for Green Supply Chain Management Implementation.* SNJB's Late Sau. K. B. Jain College Of Engineering, Chandwad, pp.475-480.

Enshassi, A., Kochendoerfer, B. and Rizq, E., 2015. An Evaluation of Environmental Impacts of Construction Projects. *Revista Ingeniería de Construcción,* 29(3).

Fang, C. and Zhang, J., 2018. Performance of Green Supply Chain Management: A Systematic Review and Meta Analysis. *Journal of Cleaner Production*, 183, pp.1064-1081.

Fantazy, K. A., Kumar, V. and Kumar, U., 2010. Supply Management Practices and Performance in the Canadian Hospitality. *International Journal of Hospitality Management*, 29(4), pp.685 - 693.

Fawcett, S. E., Magnan, G. M. and McCarter, M. W., 2008. Benefits, Barriers, and Bridges to Effective Supply Chain Management. *Supply Chain Management: An International Journal*, 13(1), pp.35- 48

Ghobakhloo, M., Tang, S. H., Zulkifli, N. and Ariffin, M., 2013. An Integrated Framework of Green Supply Chain Management Implementation. *International Journal of Innovation, Management and Technology*, 4(1), p.86.

Gold, S., Seuring, S. and Beske, P., 2010. Sustainable Supply Chain Management and Inter-Organizational Resources: A Literature Review. *Corporate Social Responsibility and Environmental Management*, 17(4), pp.230-245.

Govindan, K., Rajendran, S., Sarkis, J. and Murugesan, P., 2015. Multi Criteria Decision Making Approaches for Green Supplier Evaluation and Selection: A Literature Review. *Journal of Cleaner Production*, 98, pp.66-83.

Hafezalkotob, A., 2017. Competition, Cooperation, and Coopetition of Green Supply Chains Under Regulations on Energy Saving Levels. *Transportation Review*, 97, pp.228-250.

Johnson, G. S. M., 2016. Integrating the Supply Chain… 25 Years on. *International Journal of Physical Distribution & Logistics Management*, 46(1), pp.19-42.

Lamba, N. and Thareja, P., 2016. Barriers of Green Supply Chain Management: A Review. *Journal of Advanced Research In Manufacturing, Material Science & Metallurgical Engineering*, 3(3&4), pp.4-15.

Li, J., Pan, S.Y., Kim, H., Linn, J.H. and Chiang, P.C., 2015. Building green supply chains in eco-industrial parks towards a green economy: Barriers and strategies. *Journal of Environmental Management*, *162*, pp.158-170.

Love, P. E., Li, H., Irani, Z. and Faniran, O., 2000. Total Quality Management and the Learning Organization: A Dialoque for Change in Construction. *Construction Management and Economics*, 18(3), pp.321 - 331.

Luthra, S., Garg, D. and Haleem, A., 2016. The Impacts of Critical Success Factors for Implementing Green Supply Chain Management Towards Sustainability: An Empirical Investigation of Indian Automobile Industry. *Journal of Cleaner Production,* 121, pp.142-158.

Mahler, D., 2007. The Sustainable Supply Chain. *Supply Chain Management Review,* 11(8), pp.59-60.

Majumdar, A. and Sinha, S., 2018. Modeling the Barriers of Green Supply Chain Management in Small and Medium Enterprises: A Case of Indian Clothing Industry. *Management of Environmental Quality: An International Journal,* 29(6), pp.1110-1122.

Mathiyazhagan, K., Datta, U., Singla, A. and Krishnamoorthi, S., 2018. Identification and prioritization of motivational factors for the green supply chain management adoption: case from Indian construction industries. *Opsearch*, *55*(1), pp.202-219.

Mentzer, J. T., 2004. *Fundamentals of supply chain management: twelve drivers of competitive advantage*. UK: Sage.

Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. and Zacharia, Z.G., 2001. Defining supply chain management. *Journal of Business Logistics*, *22*(2), pp.1-25.

Muduli, K. and Barve, A., 2013. Empirical investigation of the barriers of Green Supply Chain Management (GSCM) Implementation in Indian mining industries (ICBEMBS'2013). Singapore.

Ng, S. T., Wong, J. M., Skitmore, S. and Veronika, A., 2012. Carbon dioxide reduction in the building life cycle: a critical review. s.l., Thomas Telford Ltd., pp.281-292.

Nur, F., Handayani, N. U. and Wibowo, M. A., 2018. *Developing Indicators to Implementing Green Material.* EDP Sciences.

O'Brien, W. J., Formoso, C. T., Vrijhoef, R. and London, A. K. eds., 2009. *Construction supply chain management: handbook.* CRC Press.

Pagell, M. and Shevchenko, A., 2013. Why Research in Sustainable Supply Chain Management Should Have no Future. *Journal of Supply Chain Management, 5*0(1), pp.44-55.

Panova, Y. and Hilletofth, P., 2018. Managing supply chain risks and delays in construction project. *Industrial Management & Data Systems*, *118*(7), pp.1413-1431.

Papadopoulos, G. A., Zamer, N., Gayialis, S. P. and Tatsiopoulos, I. P., 2016. Supply Chain Improvement in Construction Industry. *Universal Journal of Management,* 4(10), pp.528-534.

Pitt, M., Tucker, M., Riley, M. and Longden, J., 2009. Towards Sustainable Construction: Promotion and Best Practices. *Construction Innovation,* 9(2), pp.201-224.

Qi, G. Y., Shen, L. Y., Zeng, S. X. and Jorge, O. J., 2010. The Drivers for Contractors' Green Innovation: An Industry Perspective. *Journal of Cleaner Production*, 18(14), pp.1358-1365.

Rostamzadeh, R., Govindan, K., Esmaeili, A. and Sabaghi, M., 2015. Application of Fuzzy VIKOR for Evaluation of Green Supply Chain Management Practices. *Ecological Indicators*, 49, pp.188-203.

Saad, M., Jones, M. and James, P., 2002. A Review of the Progress Towards the Adoption of Supply Chain Management (SCM) Relationships in Construction. *European Journal of Purchasing & Supply Management*, 8, pp.173-183.

Soda, S., Sachdeva, A. and Garg, R.K., 2015. GSCM: practices, trends and prospects in Indian context. *Journal of Manufacturing Technology Management,* 26, pp.889-910.

Serpell, A. and Heredia, B., 2004. Supply Chain Management in Construction: Diagnosis and Application Issues. *Globalisation and Construction*, pp.455-466.

Singh, A. and Trivedi, A., 2016. Sustainable Green Supply Chain Management: Trends and Current Practices. *Competitiveness Review,* 26(3), pp.265-288.

Srivastava, S. K., 2007. Green Supply-Chain Management: A State-of-the-Art Literature Review. *International Journal of Management Reviews,* 9(1), pp.53-80.

Stremlau, K. and Tao, J., 2016. Green Supply Chain Management Enablers and Barriers in Textile Supply Chains: What factors enable or aggravate the implementation of a GSCM strategy for textile, Thesis (Masters), University of Borås, Faculty of Textiles, Engineering and Business.

Tan, K. C., 2001. A Framework of Supply Chain Management Literature. *European Journal of Purchasing & Supply Management,* 7, pp.39- 48.

Thunberg, M. and Rudberg, M., 2017. Categorising on-Site Problems: A Supply Chain Management Perspective on Construction Projects. *Construction Innovation,* 17(1), pp.90-110.

Vermeulen, W. J., 2006. The Challenge of Greening Global Product Chains Meeting Both Ends. *Sustainable Development,* 14(4), pp.245-256

Vijayvargy, L., Thakkar, J. and Agarwal, G., 2017. Green Supply Chain Management Practices and Performance. *Journal of Manufacturing Technology Management,* 28(3), pp.229-323.

Wibowo, M.A., Handayani, N.U., Mustikasari, A., Nurdiana, A. and Soleh, M.N., 2018. Determining Factors for Implementing Green Supply Chain Management in the Construction Industry: A Literature Review. In *MATEC Web of Conferences* (Vol. 159, p. 01022). EDP Sciences.

Wisner, J. D., Tan, K.C. and Leong, G. K., 2014. *Principles of supply chain management: a balanced approach*. USA: Cengage Learning.

Zhang, X., Shen, L. and Wu, Y., 2011. Green Strategy for Gaining Competitive Advantage in Housing Development: A China Study. *Journal of Cleaner Production,* 19(2-3), pp.157-167.

Ridmika, K.D.H., 2019. Constructing plastic roads using polymer-modified bitumen: A literature review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 210-219. DOI: doi.org/10.31705/WCS.2019.21. Available at: https://2019.ciobwcs.com/papers

CONSTRUCTING PLASTIC ROADS USING POLYMER-MODIFIED BITUMEN: A LITERATURE REVIEW

Kuragamage Dona Hiruni Ridmika[1]

ABSTRACT

The flexible roads are the roads which are mainly constructed by using bitumen and asphalt. Flexible roads have problems due to their lack of durability, lack of strength etc. Therefore, this research was conducted to identify the possibility of using polymer-modified bitumen as a solution for those problems. The research methodology used was literature review. Plastic waste can be used to prepare polymer-modified bitumen. The applicability, cons and pros; the environmental aspect and economical aspect of the polymer-modified bitumen were identified in this research. Moreover, polymer-modified bitumen is identified as a solution for the flexible roads' problems. Using the polymer-modified bitumen in the road construction, addresses the problems of the flexible roads, by, increasing the roads' strength, avoiding breakage, facing the environmental conditions more effectively etc. Furthermore, it brings benefits such as the roads becoming more comfortable for the passengers. The most effective way of constructing the plastic roads is the dry process, over the wet process. Preparing the plastic roads is an environmentally friendly method, if only thermoplastics such as Low Density Polythene, High Density Polythene, Polyurethane and Polythene Terephthalate are used. So, the plastics which are recycled few times, Polyvinyl Chloride and thermosetting plastics usage needs to be avoided. This method is economical, because the bitumen content used in the road construction can be reduced and in long term, although the initial cost of implementing the method is high, the maintenance cost is reduced. Sri Lanka will be benefited, if this method is implemented in the construction industry.

Keywords: *Plastic Waste; Polymer-Modified Bitumen; Road Construction; Sri Lanka.*

1. INTRODUCTION

The resources used for the road construction vary due to the functions and the requirements of the roads (Hunter, 2000). Therefore, when selecting the materials for the road construction, considering its requirements are important. Mainly there are two types of pavements recognised as the flexible pavements and rigid pavements in the road construction (Mohod and Kadam, 2016). According to Mohod and Kadam (2016) bitumen and the asphalts are mostly used in the flexible pavements and whereas according to Chandra (2017) concrete is used in the rigid pavements, incorporated with subbase, base causes etc.

If the roads are high volume roads, the bitumen and concrete mixtures are used, whereas if the roads are low volume roads, normally simple unsurfaced compacted aggregates are used (Hunter, 2000). Therefore, flexible roads and the rigid pavements are mainly used for the high volume roads. Moreover, among those two, flexible road is the most

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constructed type of road, although in flexible roads cracks and the ratting are often (Mohod and Kadam, 2016). Finding a solution for the flexible roads' shortcomings, can decrease the cost of the maintenance, which is important for the road construction industry. But a question arises on how to improve the flexible roads' condition and would that method be economical considering to the maintenance of the flexible roads so far.

Professor R. Vasudevan, who is an Indian chemistry professor, identified that the plastic waste can be coated on the aggregates, prior to mixing with the bitumen and then added to the bitumen mix in the road construction (Menon, 2016). Bitumen is a binding material, in the road construction field (Jamal, 2017). Shaikh *et al*. (2017) mentioned that plastic coating technique increases the roads' strength and durability. Therefore, it can be studied as to whether the plastic waste mixed with the bitumen of the flexible roads could increase the roads' quality and performance.

Anyhow, plastic is a non-biodegradable material, and causes pollution known as micro plastic pollution (Valavanidis, 2016). Moreover, plastic cannot be recycled many times (can be only recycled up to 3-4 times) and toxic gases can be released during melting of plastic (Menon, 2016). Therefore, prior to using plastic in the road construction, it is important to identify the consequences of using plastic in the road construction and how it affects the environment. As plastic waste is a worldwide problem, it is only viable to use waste plastic as a substance to enhance the roads' performance, if only this method is environmentally friendly. Identifying the economical aspect of this method is also important. This method will only be feasible to implement, if the benefits are higher, than the cost of implementing the process.

This research has been conducted through a literature review. The aim of the research was to identify whether using plastic waste to prepare the polymer-modified bitumen is an economical and an environment friendly method. Therefore, in order to achieve this aim, this research has achieved milestones such as, identifying the applicability of plastic waste in preparing the polymer-modified bitumen, its advantages and disadvantages, identifying the effect to the environment of using this method and the economical aspect of this method. Moreover, at the latter part of the research, possibility of implementing the polymer-modified bitumen method in Sri Lanka has been discussed.

2. RESEARCH METHODOLOGY

In order to achieve the research aim and objectives, this research has been carried out through a literature review.

3. LITERATURE REVIEW

3.1 APPLICABILITY OF PLASTIC WASTE IN PREPARING THE POLYMER - MODIFIED BITUMEN

Bitumen is made out of highly condensed polycyclic aromatic hydrocarbons (Prakash *et al*., 2014). As mentioned above, bitumen is used as a binding material in the road construction. The asphalt concrete used in the road construction consists of bitumen and aggregate (Kumar and Satyanarayana, 2015). Those materials are mainly used in the flexible roads as stated. In the road constructions, the bitumen can be modified and modified-bitumen can be prepared using the substances such as plastic, fly ash, crumb rubber (Singhal *et al*., 2016).

The plastic consists of polymer along with the additives (Goodship, 2007). The polymer content can differ from 20%-100% depending on the requirement of plastic (Goodship, 2007). Therefore, the plastic is used to prepare the polymer-modified bitumen.

Figure 1 shows the mixes used in constructing the roads (CIPS, 2014). There are two types of mixtures used for road construction, known as hot mix and cold mix; and the plastics can be used as a binder or as a modifier under the hot mix (CIPS, 2014). Moreover, waste plastic can be used in other means such as modified processes, as additives etc., in the road construction process (CIPS, 2014).

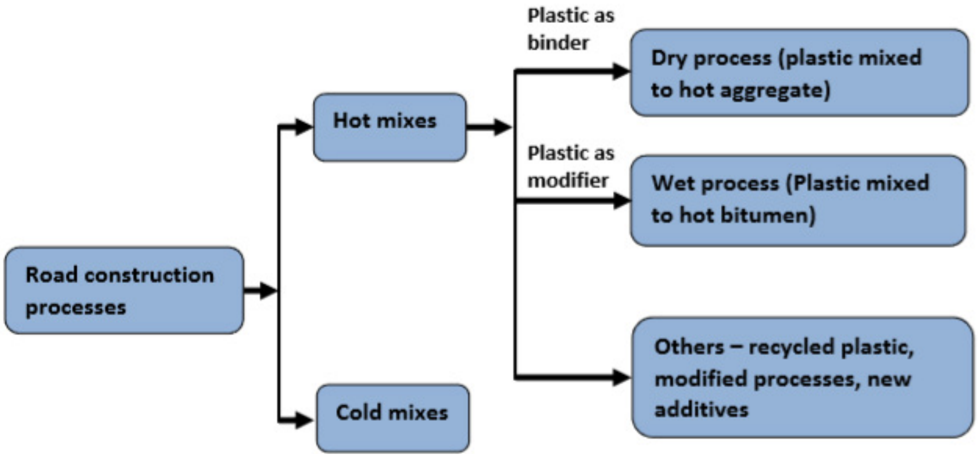

Figure 1: Mix types used in constructing roads (Source: Centre for Innovations in Public Systems [CIPS], 2014, p.36)

According to the Energy and Resources Institute (2017) plastic is only used in the hot mix because in order to prepare the polymer-modified bitumen, plastic is heated, therefore, only the hot mix is suitable. Therefore, the waste plastic can be used in the road construction process in different forms. But it's important to understand the most suitable process to use the waste plastic in the road construction process which brings more benefits to the society as well as which process is more environmental and economical friendly.

Figure 2 indicates dry process used in the road construction process (Yadav and Chandrakar, 2017). In the dry process, the plastic waste needs to be shredded and mixed with the hot aggregate, therefore, the waste plastic coated over the aggregate (Yadav and Chandrakar, 2017). In this process the waste plastic is used as a binder, which binds the mix (CIPS, 2014).

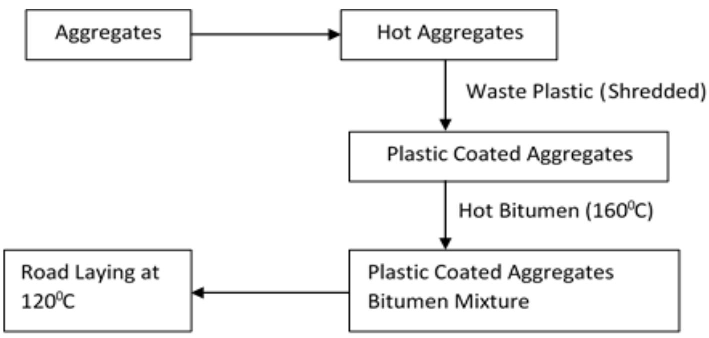

Figure 2: Dry process (Source: Yadav and Chandrakar, 2017, p.651)

Figure 3 indicates the wet process used in the road construction process (Yadav and Chandrakar, 2017). In this process the plastic is heated and added to the bitumen mixture without coating it to the aggregate first (Yadav and Chandrakar, 2017). Therefore, the main difference between the wet process and the dry process is the method which the waste plastic is added to the mixture prior to get laid on the roads. Anyhow in both processes, heat is needed to add the waste plastic.

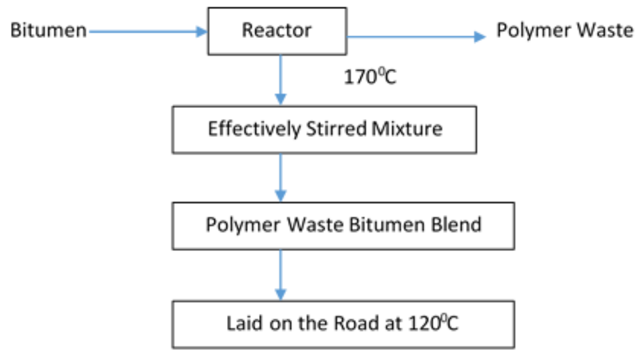

Figure 3: Wet process (Source: Yadav and Chandrakar, 2017, p.651)

Dry process can be used for plastic waste only, whereas wet process can be used for other materials such as rubber etc., as well (Gawande *et al*., 2012). But the wet process needs extra machineries and also other technologies, such as for cooling, to avoid air pockets (Gawande *et al*., 2012). Although the wet process can be used for other waste materials such as rubber, according to CIPS (2014), using the dry process makes the roads more durable and stronger. Yadav and Chandrakar (2017) stated that as in dry process the plastic is well coated on the aggregate, it increases the bonding between the substances in the mixture. Therefore, it can be understood that the reasons for the roads constructed using the dry process to have a higher strength and a durability is because the waste plastic increases the bonds between the materials, therefore, causes the roads to be strengthened.

According to the above discussion, it can be indicated that, although the wet process can be used for the waste materials such as rubber beside the plastic, the dry process is more effective if the plastic waste is used in preparing the bitumen, as it brings many benefits such as less cost due to lack of needs for special technology, higher strength, higher performance etc.

3.2 COMPARISON ON ROADS CONSTRUCTED USING POLYMER-MODIFIED BITUMEN AND REGULAR BITUMEN

Prior to using the polymer-modified bitumen in the road construction field, it's important to understand the advantages of the polymer-modified bitumen compared to the regular roads. According to the CIPS (2014) using polymer-modified bitumen doubles the binding property of the bitumen mix, and also increases the roads' strength compared to normal roads. As bitumen is used as a binder in the road construction process, using plastic to the bituminous mixture is an advantage. Therefore, the materials in the mixture tend to have a higher bond, which will increase the strength of the road as well.

Kashiyani *et al*. (2013) stated that the roads' pores also decreased in the plastic roads up to 2%. Moreover, using the modified bitumen affects the aggregates used in road construction in a beneficial way (Kashiyani *et al*., 2013). As the pores can be decreased in the roads by using polymer-modified bitumen, it reduces the bitumen oxidization which was the cause for the viscoelasticity and stops the bitumen from striping out from the aggregate (Kashiyani *et al*., 2013). Therefore, it can be understood that the plastic roads are more durable when compared to the normal flexible roads.

There is a limitation in the polymer-modified bitumen method, as due to the first rain, the plastic can be removed from the roads (Ali *et al*., 2018). But compared to the normal roads, polymer-modified bitumen roads can resist the rain and water logging due to less moisture absorbance (Kashiyani *et al*, 2013). So, plastic roads are beneficial, because although the first rain can affect the roads adversely, in long term it resists the adverse environmental condition effectively than the normal roads.

There can be potholes in the roads, where if the temperature of the environment increases up to 50°C, or roads that are constructed in the sites which have extreme hot or humid conditions (Naathan and Chinnaraj, 2017). But plastic roads avoid potholes (CIPS, 2014). Moreover, Ultra-violet radiation causes aging of roads which grounds for cracking and stripping in the roads (Luo, 2017). If polymer-modified bitumen is used in the road construction, it stops the ultra-violet radiation (CIPS, 2014). Therefore, the cost of the plastic road maintenance tends to be lower in comparison to the flexible roads and the plastic roads tend to have a higher life span and lesser maintenance.

There is no threat of leaching the plastic out from the roads due to any chemical reactions (CIPS, 2014). Therefore, the society does not have to be concern about the chances of any harmful effect arising by the plastic roads, due to any chemical reactions. By using the Marshall Stability test, the maximum load that can be bore by a specimen can be identified (Rashid *et al*., 2018). CIPS (2014) mentioned that the Marshall Stability value is increased in the plastic roads. Therefore, the plastic roads can bear more load than the normal flexible roads and because of that the transportation service is benefited.

Marga (2005, cited by Sukartha *et al*., 2014) stated that the rebound deflection means the vertical pressure arises from a road when a motion happens. In the plastic roads the rebound deflection has also been reduced (Kashiyani *et al*., 2013). So, it makes easier for the passengers to travel in the plastic roads, as those roads are more comfortable to travel. Following Table 1 indicates the summary of the above comparison.

Table 1: Summary of the comparison

Polymer-Modified Bitumen	Regular Bitumen
Binding ability has been doubled in comparison to the regular bitumen	Binding property is lower in comparison to the polymer-modified bitumen
Less pores in the roads even in the extremely hot/ humid environmental conditions	Comparatively, more pores on the roads
Reduce bitumen oxidization, which increases the road quality	Comparatively high bitumen oxidization
In the first rain, plastic can be washed away	No damages from the first rain
Comparatively, more resistant to adverse weather conditions	Comparatively, less resistant to the adverse weather conditions
No adverse chemical reactions	No adverse chemical reactions
The load which the road can bear is comparatively high	The load which the road can bear is comparatively low

Polymer-Modified Bitumen	Regular Bitumen
Helps to prevent the road aging caused by the ultra-violet radiation	Tends to face road aging by ultra-violet radiation
Less rebound deflect makes the passengers more comfortable	High rebound deflect can makes to passengers uncomfortable

According to the comparison, comparatively, by using polymer-modified bitumen, the performance of the flexible roads can be enhanced, compared to the normal flexible roads. Therefore, the strength, durability of the flexible roads increase, and the plastic roads addresses the problems in the normal flexible roads effectively.

3.3 ECOLOGICAL ASPECTS OF USING MODIFIED BITUMEN

The plastic waste has been an issue to the whole world. Plastics manufactured are mostly not recycled but dumped into the water, lands, etc (United Nations Environment, 2018). According to United Nations Environment (2018), only 9% of the manufactured plastic is recycled. Therefore, prior to using plastic in the road constructions, it is important to know how the plastic roads affect the environment.

Plastic is divided into two categories for recycling, mainly considering the molecular structure (Goodship, 2007). They are thermosetting plastics and thermoplastics (Goodship, 2007). The plastic which can be remoulded are thermoplastics (Indian roads congress [IRC], 2013). Thermosetting plastic cannot be remoulded (Goodship, 2007).

CIPS (2014) emphasized that the temperature at which the polymer-modified bitumen is prepared similar to the temperature which the roads are constructed. According to Gawande *et al*. (2012) in the temperature of 155^{o}C -165^{o}C the bitumen is prepared. When preparing the polymer-modified bitumen, when using thermoplastic, between the temperatures of 130^{o}C -180^{o}C, toxic gases are not released (Gawande et.al, 2012). Therefore, it's only safe to use thermoplastics to prepare the plastic roads.

So, to make the process of preparing the plastic roads safe, first, the plastic needs to be sorted out and only thermoplastic shall be used in the process. Moreover, this method is an environment friendly method because in the process of disposing, this method does not release Carbon Dioxide (CIPS, 2014). Gawande *et al*. (2012) and CIPS (2014) have also mentioned that this method as an eco-friendly method. It can be also mentioned as an eco-friendly way of thermoplastic recycling.

From the thermoplastics types, only LDPE, HOPE, Polyurethane and PET are the types relevant for constructing the plastic roads (IRC, 2013). Plastics that are recycled few times which become black in colour and PVC plastics tend to release toxic gases (CIPS, 2014). Therefore, those plastics cannot be used in this process. Moreover, the plastic which are mixed with toxins can be leached out from the plastic when cleaning; and also when the road is constructed if the chlorine had been mixed with the plastics that are used in the process, those chlorine can be released as HCL (Sabadra, 2017).

In order to make the plastic road preparation environment friendly, the plastic shall be sorted out and only the suitable plastics shall be used. And this method is a suitable method to recycle the thermoplastics. But the strict monitoring is important in order to make this a safely procedure and to prevent releasing toxic gases to the environment.

3.4 ECONOMIC ASPECTS OF USING MODIFIED BITUMEN

The preparation of plastic roads needs to be an impetus method for the government in order to implement it in a country. Moreover, the benefits of the method need to be higher than the cost, for this method to be effective.

Plastic collection process required resources (Gawande, 2013) and also the preparing process of polymer-modifiers has a cleaning and a shredding process (Sutar *et al*., 2016). Because of that, more mechanical power and the human power is needed for constructing the plastic roads comparing to the normal flexible roads. But when considering about the monetary aspect, it is important to consider about the long term benefits of plastic road method. As mentioned by Gawande (2013), generally in the normal flexible roads the maintenance cost is high as the roads degrade fast, therefore, upgradation needs to be done (Gawande, 2013). But in plastic roads the maintenance cost is reduced.

Taking an example from India, a few states in India use the technology of plastic roads positively according to Mir (2015). Moreover, this method increases the lifespan of the roads up to ten years which was 4-5 years in the normal flexible roads (Trimbakwala, 2017). Furthermore, the maintenance of the roads is reduced, as the roads only need to be maintained once in ten years, when the polymer modified bitumen is used, which is for normal roads, the roads need to be maintained more frequently (CIPS, 2014). As stated, since the maximum load borne by the plastic roads are higher, the roads tend to resist heavy loads. Therefore, the cracks in the roads can be minimized, which will lead to less maintenance again.

Moreover, bitumen is an important material used in the road construction process. The plastic roads cut the bitumen usage of the roads by around 10% and also in one km length four meters width road, 1 ton of bitumen can be reduced by the usage of waste plastic (Kashiyani *et al*., 2013). Therefore, the amount of the bitumen used can be reduced with the plastic usage. This is a huge benefit as the contractors can buy waste plastic for lower prices when comparing to the bitumen. Further, there is an opportunity for the society from the plastic roads, as the public health workers get more jobs (CIPS, 2014). As such, since the preparation of polymer-modified bitumen needs more workforce for collecting plastics, sorting the plastic etc., it is a huge opportunity for the public health workers.

Accordingly, the implementation process of the polymer-modified bitumen method can be high as extra machinery and workforce is needed. But as the bitumen content used is minimized, thus the cost of the construction can be reduced. Moreover, comparatively the future maintenance cost is reduced and therefore, the government can save a huge amount of money from the maintenance since the lifespan of the roads is nearly doubled as well.

3.5 POLYMER-MODIFIED BITUMEN CONSTRUCTION FOR SRI LANKA

In Sri Lanka, the Asset group of companies has introduced using plastic waste in the road construction by introducing an asphalt mix, which contains plastic (The Island, 2018). But yet the technique of preparing the polymer-modified bitumen for the roads using the waste plastic, is not popular within the country. The asset group is planning to make the plastic road a milestone in the Sri Lankan construction industry (The Island, 2018).

According to Economynext (2018), the first plastic road constructed in Sri Lanka is from Ratmalana to Borupana. Economynext (2018) discussed that in this road waste plastic is coated in the aggregate before mixing with aggregate. Therefore, it can be identified that the dry method is used in the pilot project in Sri Lanka. But still this method is not recognized by many Sri Lankan professionals yet.

Christopher (2016) stated that in Sri Lanka averagely 5,163,689 kilos of plastic waste is produced per day. If the plastic waste is sorted out and if only the thermoplastics are used for the road construction, the Sri Lankan road construction industry can be benefited without causing any harm to the environment. But prior to implementing this method, relevant safety measures need to be identified in order to prevent releasing toxic gases. Furthermore, if the Sri Lankan government can introduce a framework for a plastic road it will be more significant to the industry. Although the monetary value to be spent for the government is high, considering the long term benefits and the environmental benefits, the government shall implement this method in order to enhance the performance and durability of the roads and also as beneficial method to recycle the relevant thermoplastics.

4. CONCLUSIONS

This research has concluded that the polymer-modified bitumen process is a successful method if it is implemented with the relevant standards, such as only suitable plastics shall be used, the suitable temperature shall be used etc. Considering the advantages of using polymer-modified bitumen method to the road construction industry, over the normal flexible roads, the polymer-modified bitumen roads have more advantages and it is also an environmentally friendly to implement and more economically effective.

With the development of a country, the roads' quality needs to be enhanced. Therefore, the core importance of applying the plastic road method to the construction industry, is that with a bearable cost the government could develop the road construction industry by recycling the thermoplastic waste. It can be recommended that this is a suitable method to be implemented in Sri Lanka. The Sri Lankan government and also the construction industry of Sri Lanka can be benefited if this method is implemented. Not only that, this method will be a huge advantage to the transportation industry as well. But Sri Lanka needs to overcome the barrier of poor waste management.

It can be recommended for the Sri Lankan government to use the usage of plastic waste effectively in the construction process as a tender evaluation criterion in the future. But the plastic roads method is not familiar in the Sri Lankan industry. So, the stakeholders of the construction industry, need to implement an installation about this topic by conducting continuous Professional Development programs, seminars etc. Consequently, this research area needs to be carried forward in Sri Lanka. As a future research area, the researchers can carry forward this research to identify the method to advance the plastic road construction method to incorporate all types of plastic waste in flexible road construction. Moreover, the possibility of using waste plastic in other construction aspects can also be identified as a relevant research area for future studies.

5. REFERENCES

Ali, I., Kumar, R., Mev, U.K., Jakhar, M., and Ali, I., 2018. Application of Plastic Waste Management in Road Construction. *International Journal of Civil, Mechanical and Energy Science (IJCMES)*, *4*(2), pp.22-25.

Centre for innovations in public systems (CIPS)., 2014. *Use of plastics in road construction: Implementation of technology and roll out* [online]. Available from https://www.aphrdi.ap.gov.in/documents/Trainings@APHRDI/2017/4_Apr/Muncipal%20Waste%20 Management/Kshitij%20Aditeya.pdf [Accessed 15 February 2019]

Chandra, S., 2017. *Flexible pavement versus rigid pavement* [online]. Available from https://www.nbmcw.com/tech-articles/roads-and-pavements/36977-flexible-pavement-versus-rigid-pavement.html [Accessed 22 September 2019]

Christopher, C., 2016. Sri Lanka among the 'dirty five'. *The Sunday Times* [online], 1 May 2016. Available from http://www.sundaytimes.lk/160501/news/sri-lanka-among-the-dirty-five-191570.html [Accessed 23 September 2019]

Economynext., 2018. Sri Lanka paves first road with plastic waste. *Economynext* [online], 3 October 2018. Available from https://economynext.com/sri-lanka-paves-first-road-with-plastic-waste-11730/ [Accessed 23 September 2019]

Gawande, A., Zamre, G.S., Renge, V.C., Bharsakale, G.R., and Tayde, S., 2012. Utilization of waste plastic in asphalting of roads. *Scientific reviews and chemical communications, 2*(2), pp.147-157.

Gawande, A.P., 2013. Economics and viability of plastic road: a review. *Journal of current chemicals and pharmaceutical sciences*, *3*(4), pp.231- 242.

Goodship, V., 2007. Plastic recycling. *Science Progress*, *90*(4), pp.245–268.

Hunter, R.N., 2000. *Asphalts in road construction.* London: Thomas Telford.

Indian Roads Congress (IRC)., 2013. *Guidelines for the use of waste plastic in hot bituminous mixes (Dry process) in wearing courses* [online]. New Delhi: Indian Road Congress. IRC: SP:98-2013 Available from https://www.tce.edu/sites/default/files/PDF/IRC-Spec=Road-with-plastic-waste.pdf [Accessed 21 February 2019]

Jamal, H., 2017. *Types of bitumen and importance of bituminous materials* [online]. Available from https://www.aboutcivil.org/importance-types-of-bituminous-materials.html [Accessed 21 February 2019]

Kashiyani, B., Pitroda, J., and Umrigar, F.S., 2013. Plastic waste: opportunities for eco-friendly material of bituminous road construction [online]. In *Proceedings of National Conference*, Vasad 20-21 December 2013. Available from: https://www.researchgate.net/publication/281272210_PLASTIC_WASTE_OPPORTUNITIES_FOR_ECO-FRIENDLY_MATERIAL_OF_BITUMINOUS_ROAD_CONSTRUCTION [Accessed 25 February 2019]

Kumar, U.A. and Satyanarayana, P.V.V., 2015. Comparison of the Polyethylene and SBS Polymer Modified Bitumen's Effect: A Case Study. *International Journal of Engineering Trends and Technology (IJETT)*, *22*(7), pp.325-330.

Luo, M., 2017. Study of asphalt performance impact with ultraviolet aging. *IOP Conference Series: Materials Science and Engineering, Singapore 28-30 July* 2017. IOP Pubishing. Available from *https://www.researchgate.net/publication/319887049_Study_of_asphalt_performance_impact_with_ultraviolet_aging* [Accessed 21 February 2019]

Menon, A., 2016. *Roads Made of Plastic Waste in India? Yes! Meet the Professor Who Pioneered the Technique* [online]. Available from: https://www.thebetterindia.com/43685/plastic-waste-in-road-construction-plastic-man-india-prof-vasudevan/ [Accessed 17 January 2019]

Mir, A.H., 2015. Use of Plastic Waste in Pavement Construction: An Example of Creative Waste management. *IOSR Journal of Engineering (IOSRJEN)*, 5(2), pp.57-67.

Mohod, M.V., and Kadam, K.N., 2016. A Comparative Study on Rigid and Flexible Pavement: A Review. *IOSR Journal of Mechanical and Civil Engineering*, *13*(3), pp.84-88.

Naathan, S.B., and Chinnaraj, C., 2017. Effect of plastics and rubber in bitumen. *South Asian Journal of Engineering and Technology*, *3*(7), pp.162-169.

Prakash, K.S., Phanindra, M., Surya, S.R., and Naresh, J., 2014. Percentage replacement of bitumen with sugarcane waste molasses. *International Journal of Civil Engineering and Technology (IJCIET)* [online], *5*(7), pp.188- 197.

Rashid, G.M.H.O., Ahmed, B., Sobhan, M.A., and Rahman, N., 2018. Marshall Characteristics of Bituminous Mixes Using Reclaimed Asphalt Pavement. *American Journal of Traffic and Transportation Engineering*, *3*(4), pp.57-61.

Sabadra, V., 2017. Use of Polymer Modified Bitumen in Road Construction. *International Research Journal of Engineering and Technology (IRJET)*, *4*(12), pp.799-801.

Shaikh, A., Khan, N., Shah, F., Shukla, D., and Kale, G., 2017. Use of Plastic Waste in Road Construction. *International journal of advance research and development*, *2*(5), pp.14-19.

Singhal, M., Yadav, Y., and Mandal, R., 2016. Use of Modified Bitumen in Highway Construction. *International Journal for Innovative Research in Science and Technology*, *2*(12), pp.376-382.

Sukartha, M., Mochtar, I.B., and Santosa, W., 2014. Correlation of flexible pavement rebound deflection development trendline with its curve pattern after the road life cycle limit. *International Journal of Education and Research*, *2*(7), pp.481-504.

Sutar, D.M., Patil, S., and Waghmare, A.P., 2016. Feasibility of Plastic Coat Road with respect to Cost and their performance. *International Research Journal of Engineering and Technology (IRJET)*, *3*(12), pp.1513-1518.

The Energy and Resources Institute., 2017. *Life Cycle Assessment of Hot Mix and Cold Mix Technologies for Construction and Maintenance of Rural Roads* [online]. Available from: http://www.teriin.org/eventdocs/files/Report_Rural-Roads.pdf [Accessed 1 March 2019]

The Island., 2018. Waste plastic for road surfacing?. *The Island* [online], 3 October 2018. Available from *http://www.island.lk/index.php?page_cat=article-detailsandpage=article-detailsandcode_title=192136* [Accessed 12 February 2019]

Trimbakwala, A., 2017. Plastic Roads Use of Waste Plastic in Road Construction. *International Journal of Scientific and Research Publications*, *7*(4), pp.137-139.

United Nations Environment., 2018. *The state of plastics: World Environment Day Outlook 2018* [online]. Available from https://wedocs.unep.org/bitstream/handle/20.500.11822/25513/state_plastics_WED.pdf?isAllowed=y&sequence=1 [Accessed 20 February 2019]

Valavanidis, A., 2016. *Global Plastic Waste and oceans' Pollution: Million tons of plastic waste have gone missing in the world oceans?* [online]. Available from https://www.researchgate.net/publication/3019ZWRxs5wXgEwtXT6ixAMhK8zeuZNsCGGdceans'_Pollution_LeM254CsjJ3pzBgM4TkgbS48bY5oWKkqoK_Gone_Missing_in_the_World_Oceans [Accessed 2 February 2019]

Yadav, Y., and Chandrakar, R., 2017. Construction of plastic roads: An effective way to utilize wastes. *International Research Journal of Engineering and Technology (IRJET)*, 4(11), pp.650-652.

Madhuwanthi, B.G.K. and Somachandra, V., 2019. Corporate social responsibility practices for sustainability: Case of Sri Lankan cement manufacturing and supplying organisations. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 220-230. DOI: doi.org/10.31705/WCS.2019.22. Available at: https://2019.ciobwcs.com/papers

CORPORATE SOCIAL RESPONSIBILITY PRACTICES FOR SUSTAINABILITY: CASE OF SRI LANKAN CEMENT MANUFACTURING AND SUPPLYING ORGANISATIONS

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ABSTRACT

Construction industry is a booming industry worldwide and achieving sustainability in the construction industry has become a vital ambition. Nowadays, the concept of sustainability with its triple bottom line meaning is being adopted more and more by corporations and concerning construction trade, sustainability is about achieving a win-win output. Cement organisations' business is a crucial sub-segment of the construction industry. Apart from the frequent monetary benefits from the cement organisations, it is increasingly linked to various unethical business practices form numerous challenges that threaten sustainability in cement industry. Thus, in the direction to achieve corporate sustainability; Corporate Social Responsibility (CSR) was recognized as an effective tool. Sri Lankan cement manufacturing and supplying organizations usually publish details about CSR practices of the philanthropic, business environment and business process in their annual business reports. Therefore, this qualitative study based on five in-depth interviews focused on identifying the Sri Lankan cement companies' gap between their current practice and required practice of CSR within their business process. The results found could be categorised under three main sectors as CSR through philanthropic activities, CSR related to business environment and CSR related to business process. It was found that; Sri Lankan cement organizations' CSR practices related to philanthropic and business environment were at highest level. Even though there is a significant lacking point in the current practices of CSR linked to the business process and application of sustainable innovations for cement organisations' business process to achieve corporate sustainability.

Keywords: *Cement Organisation; Construction Industry; Corporate Social Responsibility (CSR); Sri Lanka; Sustainability.*

1. INTRODUCTION

Construction industry is one of the major booming industries in the world (Tradesmen, 2018). The ongoing growth and expansion of construction industry is progressively related to several sustainable improvement challenges, comprising various economic, environmental and social impacts (Shen *et al*., 2010). Murray and Dainty (2009) stated

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that the construction industry activities from the commencement to occupying and demolishing phase and their impacts on the environment, economy and society is significant. According to the Central Bank's Statistics Report (2017), the Sri Lankan construction industry, categorised under the industrial sector, contributed 26.8% of sectorial composition from economic activities to the GDP in 2016. Moreover, highest labour opportunities were noted from the construction industry under industrial sector (Department of Census and Statistics, 2017). However, more than 30 persons on average are admitted daily to the Colombo National Hospital due to the increasing number of construction workplace accidents (Warakapitiya, 2016).

Considering above economical, societal and environmental impacts from the Sri Lankan construction industry, achieving sustainability in construction industry has become a vital ambition of the country (Bal *et al*., 2013). The basic concept of sustainability is to provide long-standing affordability, quality and efficiency, importance to occupants and clients of buildings whereas reducing harmful ecological impressions and accelerating the profitable sustainability (Bal *et al*., 2013). To achieve construction industry sustainability, it is necessary to achieve sustainability in the construction business as it is an interwoven trade in the triple bottom line of economy, environment and society (Somachandra and Sylva, 2017). Nevertheless, concerning construction trade, sustainability is about achieving a win-win output (Shen *et al*., 2010).

Creating an improved environment along with innovative society and gaining competitive economic benefits for construction business with project stakeholders comprising with clients, architects, consultants, material manufacturing and supplying organisations, subcontractors and government are important (Shen *et al*., 2010). Out of these stakeholders, material manufacturing and supplying organizations play a significant role in the global construction industry consuming 300 metric tons of raw materials per year (Pacheco-Torgal and Labrincha, 2013). Concerning the Sri Lankan construction industry, SCI Report (2016); verified that 103.4Rs billions of raw materials consumed from all construction activities in 2015 with highest 20% weight was contributed from cement, under non-metallic mineral product manufacturing sector. As the fourth largest cement importing market in the world, Sri Lanka is estimated to remain a major importer with 3.3 million tons of domestic cement production. Hence, the competition between cement organisations is becoming more intensive (CMR Sri Lanka, 2017). Due to the above situation, Cement organisations' business is increasingly linked to various unethical business practices, such as ecological destruction, exploitation of labour, detriment on communities, and etc (Ulutaş, 2012). Presently Sri Lankan cement organisations typically develop CSR reports, conduct charitable work to expose their good corporate image in the cement industry. However, accepting what CSR means to cement organisations, and how to perform it, is limited (Zhao *et al*., 2012).

Hence, this study has focused to identify the Sri Lankan cement organisations' prevailing CSR practices. It has come into light that there is a gap between their current practice and required the practice of Corporate Social Responsibility (CSR) within their business process.

2. LITERATURE REVIEW

The term "sustainability" demonstrates the "ability to sustain", and sustainability is interweaved concept in the triple bottom line (Elkington, 1998). Hence, accepting sustainability for business process would address and lead to significant corporate benefits (Holton, 2009). Nevertheless, it presents that becoming more sustainable is as much about effective and gaining value for profit while protecting the environment and being responsible towards society (Holton, 2009). Nowadays, the concept of sustainability with its triple bottom line meaning is being adopted more and more by corporations (Holton, 2009). However, achieving corporate sustainability is a critical task (Holton, 2009). Developing for sustainability is weighted to be difficult for the improvement of corporate sustainability (Holton, 2009). Transposing the triple bottom line concept stated by Elkington (1998) to the corporate level, corporate sustainability can be defined as; improving corporate societal, ecological and economic achievement in a combined approach (Holton, 2009). Nevertheless, adopting corporate sustainability for business has become a priceless tool for identifying paths to control risky environment, and forecast essential inner changes in culture and corporate structure (Holton, 2009). The direction to achieve corporate sustainability the tool of Corporate Social Responsibility (CSR) was recognised as one of the milestone elements, which comprises corporate sustainability expression with worldwide business processes (Elkington, 1998).

CSR has been defined by ISO26000 as:

> *"The responsibility of an organisation for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour"*

Moreover, WBCSD (2009) argued; corporations must take full account of transparency for society and corporations to state responsively what their values are and to connect how well they live up to them. However, some corporations have converted the origin of CSR and they have accepted CSR as a defensive measure (Murray and Dainty, 2009) to enhance their corporate image and to attain economic benefits apart from improving corporate societal and environmental responsibilities (Zhao *et al*., 2012). Today, CSR goes far beyond the exact meaning and corporations have practised in the sections of CSR related to; business environment and process although CSR associated to philanthropic activities (Somachandra and Sylva, 2017). However, Carroll (1991), stated that CSR comprises philanthropic contribution (charity) but not restricted to them. Out of CSR activities, CSR related to business process is increasingly related to a number of direct impacts comprising economic, environmental and social. Due to above situation, WBCSD (2000) concentrated on evaluating the corporations' involvement towards sustainability in connection to their CSR actions within their business procedure.

Hence, WBCSD (2000) stated; the relationship between sustainability and CSR as:

> *"corporate commitment to contribute to sustainable economic development, employees and their families, local communities and the whole society in order to improve their quality of life" (WBCSD, 2000)*

If CSR methodology integrated into the business process, the final outcome could be far wider than purely monetary profits (Murray and Dainty, 2009).

2.1 THE CEMENT ORGANISATIONS' BUSINESS PROCESSES

The improved development of the key world economies outcomes in accelerating demand for the building materials (Pacheco-Torgal and Labrincha, 2013). As a consequence, the worldwide production of cement in 2030 is expected to grow to a stage nearly five times greater than its stage in 1990, with close to 5 billion tons (WWF International, n.d.) and it is difficult to imagine a modern life without cement (WBCSD, 2002). Cement is non-metallic mineral "adhesive" molded by mixing together with suitable natural particles such as limestone, iron mineral, bauxite and clay in a recognized quantities, heating them to a temperature of 1450˚C (2640˚F), and crushing the manufacturing product (clinker) with Gypsum to a powder (WBCSD, 2002). Apart from the production methodology, cement organisations' manufacturing procedure from the raw material extraction to final product introducing, its positive and harmful impacts towards the triple bottom line is significant (Zainudeen and Jeyamathan, 2004). In socio-economic viewpoint; cement industry generates numerous direct employment opportunities and provide a considerable contribution to the GDP (Zainudeen and Jeyamathan, 2004). Despite its acceptance and profitability, the cement industry aspects frequent barriers due to ecological harmful impacts and sustainability issues (Zainudeen and Jeyamathan, 2004). In socio-environmental viewpoint; cement manufacturing is accepted as a high energy concentrated procedure and key provider to the worldwide CO_2 emissions with 5% of total global CO_2 amount (Verma, 2011). The breakdown of the emissions from cement production, Verma (2011) demonstrated; that 52% of green gas emissions resulting from process of making clinker and 36% of exhaust gasses (NO_x, Chlorides, SO_x and CO) from incineration in the kiln. These releases have potential ecological impression causing global warming, ozone depletion, acid rain and reduced output of harvest (Verma, 2011). Nevertheless, above emissions are harmfully disturbing human health of cement factories' workers and local communities in several behaviours, like itchy eyes, breathing diseases like chest anxiety, asthma attacks and even premature death (Zainudeen and Jeyamathan, 2004). In the Cement manufacturing procedure, the estimated extraction quantities of raw materials were identified as; limestone 2470 ton/day and ground raw materials of nearly 2600 ton/day (Zainudeen and Jeyamathan, 2004). Thus, the main potential risks from cement manufacturing can be identified as; biodiversity losses in fauna and flora in and around the extraction site, dust, noise and vibration from material quarrying and explosives, conservation matters of cultural and heritage properties, and loss of livelihood (WBCSD, 2005). Apart from the frequent monetary benefits of the cement industry, due to the above harmful impacts, WBCSD (2005); stated that the cement manufacturing procedure and consumption regions form numerous challenges that threaten sustainability.

Further, it is necessary to achieve corporate sustainability in cement organisations' businesses under cement industry, and it was likely to make an essential involvement in the growth of sustainability in construction industry (WBCSD, 2005). Therefore, as argued by Mishra and Siddiqui (2014); the demand for cement is directly related to economic growth, and many growing economies are determining for rapid infrastructure progress in construction industry. Moreover, based on the cement organisations' contribution towards sustainability in the worldwide cement industry, some cement organisations have accepted CSR as an engine (Bhagwat, 2011) to attain economic benefits with improving corporate societal and environmental responsibilities towards sustainable development. One such implementation evident in Lafarge Holcim is to utilise waste-derived fuels and biomass as a replacement for fossil fuels to operate their cement kiln (Holcim, 2017). Therefore, Lafarge Holcim has become the most carbon-efficient cement corporation among world-wide peers (Holcim, 2017). Apart from that, Heidelberg Cement has gone for group-wide training initiative for line managers through that they have reduced their accident occurrence frequency by 21% from 2016 to 2017 (Heidelberg, 2017).

Turning towards the Sri Lankan context of cement production, Economics and Social Statistics of Sri Lanka (2017) stated that Sri Lanka is projected to be consuming about 5.8 million tons of cement per annum. Cement industrial corporations were contributing Rs .17.97 billion to GDP in the 2nd quarter of 2017. Sri Lanka imports 66% of its cement requirement, either in the type of cement or clinker (Holey, 2014). In manufacturing procedure, wet and dry processes are used worldwide, and out of them, Sri Lanka is perhaps the only country in this region, which practices 100% dry procedure for cement production (Zainudeen and Jeyamathan, 2004). Moreover, Sri Lanka extents on one combined and three grinding cement manufacturing plants (CMR Sri Lanka, 2017). On the other hand, Sri Lanka imports cement from various plants in relations countries like India, Vietnam, Pakistan, Malaysia, Indonesia and Thailand (Holey, 2014).

Moreover, the importing of cement has to fulfil with the Sri Lankan Standards of Cement under the Sri Lanka Standard Institute (SLSI) (Holey, 2014). The SLSI has strict coordination in place to monitor the strict quality assurance system under the contribution towards socio-environment and following to appropriate corporate performs as well as holding the appropriate credentials is a must (Holey, 2014). The cement manufacturing and supplying organisation units in Sri Lanka are controlled by Tokyo Cement, SiamCity Cement, Heidelberg Cement and Ultratech, etc (CMR Sri Lanka, 2017) and these cement organisations usually publish details about CSR activities of philanthropic, business environment and business process in their annual business reports.

3. METHODOLOGY

On the path to achieving the research hypothesis, a wide-ranging literature review was established and the capacity and forms of exploration already achieved with related to CSR, sustainability and cement organisations' business process. A qualitative research approach has been adopted to compile this research. As the most accessible and practical data collection tool, interviews were accepted. Thereby, five leading cement organisations (02 manufacturers and 03 suppliers) in the Sri Lankan cement industry were interviewed. This sample has been selected based on 'Snowball' sampling method. Factory managers, Sustainable officers and Research and development officers were the main respondent group. Data analysis was based on transcribing, coding and categorising the qualitative data to build and finalize the conclusions of the study. Based on the data analysis; Cement organisations CSR practice could be categorised to three main categories as Philanthropic, Business Environment (BE) and Business Process (BP).

4. RESULTS AND DISCUSSION

During the qualitative data analysis carried out, based on the transcribing, coding and classifying through data analysis, it has implied the CSR activities in the cement organisations could be categorised under three main categories as; CSR through philanthropic activities, CSR related to business environment and CSR related to business process. When considering the general understanding on CSR from the respondents, it was exposed that; it is completely different from the exact concept of CSR under the triple bottom line concept stated by Elkington (1998) to the corporate level. Most of the respondents' explanations have weighted under the charity, donations, community need assessment and community helping works, etc. According to the respondent CON_03:

> *…CSR is like doing good, just genuinely doing good things like charitable works, donations, community helping works, but not something apart of the core business…*

Through the sample, it revealed that CSR has a deeper meaning contrary to the conventional idea of performing well within philanthropic activities. Thus, in the first instance, it is clear that; cement organisations' industrial general understanding of CSR is not properly established. Therefore, almost all the cement organisations had wrongly perceived that, CSR as comprising simply that philanthropic giving. However, while philanthropy can be defined as one element of CSR, it is completely not the situation that CSR is fitted to philanthropy only (UNESCAP, 2011). Therefore, it has come into light that, there is a misconception among cement organisations on the exact viewpoint of the integration of CSR and business operations.

4.1 CSR THROUGH PHILANTHROPIC ACTIVITIES

Concerning on CSR through philanthropic activities, almost all the cement organisations' interviews have highlighted that; most of the CSR activities performed by cement organisations were focusing on philanthropic activities. However, Carroll (1991), specified that CSR doesn't limit only to charitable involvement.

As stated by CO_01:

> *…If you know, in Sri Lanka also when it comes to "Tsunami", our company has contributed for the Sri Lankan Government.*

As stated by CO_03:

> *…so we donate a lot of cement for low-income families to build their houses and donations for religious activities…we give meals for poor schools in the factory area. And we build houses for "Tsunami" affected peoples and also war-displaced peoples...we help school children to learn music…*

Hence, the identified philanthropic activities can be presented as; assessment of the families around the factory area that need houses and provide them with cement and other construction materials to build shelters, renovate canals, pre-schools and water tanks, facilitate; community halls, latrines and health clinic for the elderly community, implement cultural events and religious events to enhance the harmony among different ethnic groups, implement child protection and welfare programmes and charitable donations for people who faced with natural disasters like "tsunami", flooding. As per the above-identified activities, it was understood that; most of cement organisations' CSR through philanthropic activities are unfocused and diffuse. However, there is another important "Strategic Philanthropic" approach as evident by Porter and Kramer (2002). Further to that if this strategy fully incorporated in cement organisations' philanthropic contribution, it would direct to increase corporations' competitive advantages within creating good-will among society.

4.2 CSR RELATED TO THE BUSINESS ENVIRONMENT

When analysing CSR related to business environment practices of cement organisations, it has confirmed that; around 80% of respondents were implementing and continuing CSR related to business environment activities under the cement manufacturing and supplying operation in an effective manner. Thus, the identified business environment activities can be explained as; providing a range of employee welfare facilities, assist economic betterments; hospitalization insurance covers, the gratuity, pensions and post-retirement health compensations, provide the job related basic requirements; accommodations, meals, uniforms, personal protective equipment (PPE) and the implementation programmes, such as get-togethers, annual trips to motivate the employees' focusing on their happiness and satisfaction.

Moreover, almost all cement organisations had given highest concentrate about their employees and one of the respondents, i.e. CO_03, stated that;

> *…Our workers are a core corporate asset and a competitive benefit, and as such, the corporation sustained to contribute in their training, improvement and well-being…*

Further to that, they were provided national and international trainings of general training methods, training in health and safety to upgrade and enhance the productive skills of employees. Thus, awareness was conducted through maintaining occupational health and safety standards, assigning safety managers for each production task, illustrate safety notices and posters, provide PPE, and conduct weekly toolbox meetings. Apart from the cement organisations' concern under the improvement of employees' productivity, one organization has applied an open door grievance management systems to communicate difficulties of any employee under their factory. Nevertheless, it certifies employee privacy joined with reasonable action of all employees regardless of age, sex, religion or ethnicity.

According to CO_02;

> *…In factory workers side, there is an open door grievance mechanism, they can reach top management in their problematic matters…*

On the path to achieve corporate sustainability, corporations will have to focus on "Social Capital" concept, and it can be defined as content of connections between employees as well as corporations' entities (Dyllick and Hockerts, 2002). Through these explanations, it was understood that; cement organisations didn't have thorough understanding of the word "Social Capital". However, they have achieved and initiated actions which direct to adapt "Social Capital" through CSR related to business environment activities.

4.3 CSR RELATED TO BUSINESS PROCESS

When assessing, it was acknowledged that CSR concerning business process activities of cement organisations had accepted and confirmed that around 80% of the respondents do not have clear idea about CSR related business process activities and they have adopted that as day-to-day operational activities within legal and standardised necessities in cement industry. Consequently, their understandings on actions like; standardising with government institutions' environmental permits, rules and regulations under manufacturing procedure, complying with the Sri Lankan Standards of importing cement under SLS, maintaining ISO standards, maintaining greenery around the factory area, , proper housekeeping, internal auditing procedure, etc.

As stated by CO_02:

> *… Yes, we have obtained ISO 14001:2004 certification, we will study, all the environmental impacts according to the government rules and regulations, monitoring stack emissions, and production noise, dust everything being monitored…*

Moreover, apart from the cement organisations' above compliance with acceptance on industrial laws and regulation, accepting what CSR means to business process and how to perform it is limited. Therefore, CSR can be much more than a day-to-day operation and it is not an exclusive matter of mandated practices under legal and standards on cement industry. It is something beyond that organisations fix to improve above existing practices incorporating sustainability for long-term outputs. During the focus group interview held with a person who worked at the above cement organisation, stated that;

> *"In the last few months, I was worked in this cement factory. The dust from the factory were effected on the "Kadolana" trees in wetland area near the factory."*

WBSCD (2009) stated that; on the path to realise the transparency of the business process, corporations have to state responsively on what their business process is based on. Within this sense, according to focus group interview data, it signifies that, attention towards a morally obliged business process practice within considerateness on environmental impact mitigation lacked among cement organisations. Considering the environmental management systems (EMS) in cement manufacturing, it can be identified that it is a crucial factor which impacts on the production cycle of cement. However, limited responsiveness from the sample on EMS, revealed by one organisation implementing new EMS concept to reduce a resource depletion from their business process. As stated by CO_03:

> *…we take this samples of concrete based being wastes, and so we came up with the concept of the making reef-like structures, and they are coral reef balls…we maintain coral necessaries and do plants…so the coral grows, coral act as a carbon sink and the carbon is accumulated, because we burn the limestone to produce cement, it's a creation of the limestone back to nature…*

Subsequently, within this practice, this organisation had also been indirectly involved with one of the environmental aspects with regard to coral rehabilitation. Further to that, other organisations had not utilised any new concepts in EMS scope beyond the legal requirements. In the direction to attain corporate sustainability through CSR, corporations will have to apply sustainable innovations, and it can be defined as a procedure wherever sustainability considerations (ecological, societal, and economic) are combined into corporation arrangements from strategy creation through to investigation and improvement and commercialisation (Katerva, 2019).

Thus, CSR can lead to the application of innovative mind thorough the use of sustainable innovative drivers to create new products, services and process (Tello, S. and Yoon, E, 2014). Within the above sense, evaluating sustainable innovative performance is an essential factor. However, according to the sample, under limited awareness; only two cement organisations have applied and practised sustainable innovative solutions, which will be discussed below. Among them, one cement organisation has applied an innovative solution to operate its cement kiln from waste-derived fuels. As stated by CO_02:

> *…we take all the industrial waste from the construction and other industrial zones and some industrial factories likewise and we re-processing it and feeding it in to our kiln as a fuel around 30% -35% from the waste. So, that is the biggest advantage not only for us for the country we provide very good solution for the waste…*

Meanwhile, the above practice directs the energy efficiency under sustainability, and it provides identically a good solution for the construction industry waste management.

Moreover, from material excavation at the quarry until bagged cement loading process, it results in un-productive waste streams like gaseous and energy waste streams. Thus, solid and liquid waste streams are very rare in dry kiln process under Sri Lankan cement organisations. Out of these streams, energy conservation is a key factor in sustainability and in path to achieve this factor. The data revealed that amongst the two, there's only one cement organisation involving in an innovative idea addressing energy conservation. As stated by CO_03:

> *…we have agriculture waste biomass power plants…In cement manufacturing, biomass burning, and we have steam-generating with steam turbines and produce energy. But that ash in again porcelain silica ash being used in cement manufacturing. So it's a closed cycle procedure which gives energy and a like zero waste energy generation method.*

Thus, this organisation had fulfilled their groups' energy requirements by renewable biomass energy initiative without burdening the national power grid. It was observed that; remaining organisations in the sample have not taken any steps to develop the integration of the sustainable innovations for business process. Through these explanations, it was understood that cement organisations' main consideration is settled in market-place contest which measures the socio-economic performance characteristic within day-to-day operation. Nevertheless, the application of sustainable innovations in assessing ecological performance traits was not focusing well by the cement organisations.

5. CONCLUSIONS AND RECOMMENDATIONS

The study revealed that most of the Sri Lankan cement organisations' industrial general understanding on CSR is not properly established and they had wrongly perceived that, CSR as comprising simply that philanthropic giving. Therefore, it has come into light that, there is a misconception among cement organisations on the exact viewpoint of the integration of CSR and business operations. Thus, it was found that; almost all the cement organisations' CSR related to philanthropic and business environment involvement were at highest level, and there is a significant lacking point in the current practices of CSR linked to the business process. Moreover, compared to the worldwide cement industrial leaders' CSR related business process, Sri Lankan cement organisations are not very much involved and concerned about the application of sustainable innovations for their business process. Therefore, the entire cement industry needs to think beyond its current focus on market position competition under short-term monetary benefits and think about a morally obliged business process practice and the long-term win-win opportunities under the application of sustainable innovations on their business process. Thus, there is an emerging need of a proper framework or guideline addressing the above lacking situations on Sri Lankan cement organisations. In the direction to achieve morally obliged business process practice of cement organisations, environmental institutions under the government have a significant role to play in certifying that cement organisations behaviour allowing to the legal necessities and standards for improving corporate societal and environmental responsibilities towards sustainable development in the cement industry. Thus, they can legislate, foster, collaborate with cement organisations' businesses and endorse good practise to facilitate the improvement of accepting what CSR means to business process. Hence, establishing a "Sustainable Development institute of Cement" to verify Sri Lankan contribution towards production within sustainability would be of vital importance. It will be beneficial to control, associate institutes like cement organisations, dealers and suppliers to continue and support early-stage assessment to improve and evaluate innovative and latest business process mechanisms. Work together with small to high scale production chains from cement companies to minimise risk and accelerate the growth of advanced inventions.

Furthermore, a morally obliged business practice can enrich by improving research and development innovations for effective use of resources, use of alternative fuels and alternative raw materials within the cement manufacturing process. Further innovative practices were proposed by WBCSD (2002); as semi-open cut mining innovative method to develop precise quarry mining plans that optimize raw material extraction and liner extraction, vastly energy-efficient procedure tools like rotary kiln or solar kiln, alternative energy forms for cement production process, monitoring of air pollution and use innovative manage and detect tools; SNCR (selective non-catalytic reduction systems) to reduce NOX emissions and pulse-jet filters in kiln points at cement producing plants. Moreover, the WBCSD (2002), conducted extensive research with ten major cement organisations' sustainable innovations within business process across the world and they had recommended actions under "Toward a Sustainable Cement Industry" report to establish the internal and external process that facilitate more sustainable practices under the business process. Thus, it is necessary to accept this recommended guideline to fulfil the gap between current practice and required practice of CSR within their business process to achieve sustainability in the Sri Lankan cement organisations' businesses under cement industry and it was likely to make a vital impact on the development of sustainability in the Sri Lankan construction industry.

6. REFERENCES

Bal, M., Bryde, D., Fearon, D. and Ochieng, E., 2013. Stakeholder Engagement: Achieving Sustainability in the Construction Sector. *Sustainability*, 5(2), pp.695-710.

Bhagwat, P., 2011. Corporate social responsibility and sustainable development. In *Proceedings of the Articles and Case Studies: Inclusive & Sustainable Growth Conference*. 1 (1).

CMR Sri Lanka, 2017. Cement market report: Sri Lanka. CW Research.

Dyllick, T. and Hockerts, K., 2002. Beyond the business case for corporate sustainability. *Business Strategy and the Environment*, 11(2), pp.130-141.

Department of Census and Statistics, 2017. *Sri Lanka Labour Demand Survey,* Department of Census and Statistics, Ministry of National Policies and Economic Affairs, Sri Lanka.

Economics and Social Statistics of Sri Lanka, 2017. Central Bank of Sri Lanka, Statistics Department.

Elkington, J., 1998. Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental Quality Management*, 8(1), pp.37-51.

Heidelberg, C., 2017. *Sustainability Report*. [online] Heidelberg Cement. Available at: http://www.heidelbergcement.com/responsibility [Accessed 17 September 2018].

Holcim, L., 2017. *Sustainability Report*. LAFARGE HOLCIM.

Holey, S., 2014. Understanding Sri Lanka's cement industry from a customer's perspective. *The Sunday Times*.

Holton, I., 2009. *Developing a sector sustainability strategy for the UK precast concrete industry*. Undergraduate. Loughborough University.

ISO, 2010. 26000 Guidance on social responsibility. *Ginebra: ISO*.

Katerva, 2019. *Sustainable Innovation*. [ebook] Available at: https://katerva.net/about/sustainable-innovation [Accessed 20 February 2019].

Mishra, S. and Siddiqui, N.A., 2014. A review on environmental and health impacts of cement manufacturing emissions. *International Journal of Geology, Agriculture and Environmental Sciences*, *2*(3), pp.26-31.

Murray, M. and Dainty, A., 2009. *Corporate Social Responsibility in the Construction Industry*. 1st ed. Hoboken: Taylor and Francis.

Pacheco-Torgal, F. and Labrincha, J., 2013. The future of construction materials research and the seventh UN Millennium Development Goal: A few insights. *Construction and Building Materials*, 40, pp.729-737.

Porter, M. and Kramer, M., 2002. *The Competitive Advantage of Corporate Philanthropy.* Harvard Business Review.

SCI Report, 2016. *Department of Census & Statistics*. Available at: http://www.statistics.gov.lk/industry/SCI_Final_Report_2016.pdf [Accessed 10 August 2018].

Shen, L., Tam, V., Tam, L. and Ji, Y., 2010. Project feasibility study: the key to successful implementation of sustainable and socially responsible construction management practice. *Journal of Cleaner Production*, 18(3), pp.254-259.

Somachandra, V. and Sylva, K., 2018. Construction industry focus towards sustainability through corporate social responsibility. In: *International Conference of Disaster Management*. Indonesian Disaster Expert Association.

Tello, S. and Yoon, E., 2014. CSR reporting on the corporate commitment to sustainable innovation. *International Journal of Strategic Management*, 14(1), pp.71-82.

Tradesmen International, 2018. *Construction Industry Growth Trends Through 2020 | Tradesmen*.

Ulutaş, D., 2012. *Corporate social responsibility in construction industry* (Doctoral Dissertation).

UNESCAP, 2011. Promoting Sustainable and Responsible Business in Asia and the Pacific. *ESCAP Studies in Trade and Investment*.

Verma, M., 2011. *New Trends in Environmental and Socially Responsible Management in the Cement Manufacturing*. Undergraduate. University of Bradford, U.K.

Warakapitiya, K., 2016. Industrial accidents on the rise. *The Sunday Times*.

World Business Council for Sustainable Development, 2000. *Corporate Social Responsibility: Making Good Business Sense*. Geneva: World Business Council for Sustainable Development.

World Business Council for Sustainable Development, 2002. *Toward a Sustainable Cement Industry*. [online] World Business Council for Sustainable Development. Available at: https://www.wbcsdcement.org/pdf/battelle.pdf [Accessed 10 Sep. 2018].

World Business Council for Sustainable Development, 2005. *Cement Sustainability Initiative (CSI)*. Environmental and social impact assessment (ESIA) guidelines.

World Business Council for Sustainable Development, 2009. *Corporate Social Responsibility: Making Good Business Sense*. Geneva.

World Wildlife Fund International (n.d.). *A blueprint for a climate friendly cement industry*. [online] Gland, Switzerland: WWF International.

Zainudeen, N. and Jeyamathan, J. (2004). *Cement and its effect to the environment: A case study in Sri Lanka*. Department of Building Economic, University of Moratuwa (2004), pp.1408-1416

Zhao, Z., Zhao, X., Davidson, K. and Zuo, J., 2012. A corporate social responsibility indicator system for construction enterprises. *Journal of Cleaner Production*, 29-30, pp.277-289.

Madushani, S.D.A., Seneviratne, L.D.I.P. and Ganeshu, P., 2019. Deciding on the consultancy fee for re-measurement contracts in the Sri Lankan construction industry. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 231-238. DOI: doi.org/10.31705/WCS.2019.23. Available at: https://2019.ciobwcs.com/papers

DECIDING ON THE CONSULTANCY FEE FOR RE-MEASUREMENT CONTRACTS IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Construction industry is the necessary national backbone in developing countries. Consultants are the stakeholders who supplies objective and independent external service to the client. Consulting is gradually becoming a more standard service, price being the main factor in clients' contracting decision so consulting firms continually strives for cost reductions to provide a competitive pricing advantage. By conducting a comprehensive literature synthesis history about consulting fee decision criteria and IQSSL fee proposal were determined. Subsequently, expert interviews were conducted. Semi structured interviews and reviewing documents were used as data collection methods. Collected data was analysed using code based content analysis. It was revealed that, procurement methods and the consultancy fee have a relationship. Construction management contracts and the re-measurement contracts has the highest consultancy fee. There are number of factors to be considered when deciding on the consultancy fee. Findings suggested that independent quantity surveying consultancy fee is within the range between from 0.4% to 1.2% of the contract sum and IQSSL proposal has to accommodate number of improvements for it to be practiced in the Sri Lankan construction industry.

Keywords: *Consortium Service Fee; Consultancy Fee; Independent Quantity Surveying Service Fee; Re-measurement Contracts.*

1. INTRODUCTION

The consulting service plays an important role in world economy (Haverila, Bateman and Naumann, 2011). Molwus (2014) stated that Architect, Quantity Surveyor (QS), Engineer and Construction Manager are the consultants in the construction project. All construction professionals have important role in the construction process (Yadollahi *et al.*, 2014).

According to Oyegoke *et al*. (2009), project procurement has a relationship with the overall quality of the project in terms of the economic, social and environmental wellbeing. Most commonly used traditional methods in Sri Lanka are lump sum method and re-measurement method (Rameezdeen and Silva, 2002). Re-measurement procurement method is the system with separation of design and the construction process (Cox and Townsend, 1998).

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Consulting is gradually becoming a more standard service (Lassala, Carmona and Momparler, 2015). Moreover, price being the main factor in clients' contracting decision so consulting firms continually strive for cost reductions to provide a competitive pricing advantage. Furthermore, consultant reputation is especially important in consulting service industry, in which new assignments come largely through recommendations. Therefore, consulting fee deciding criteria is required for construction projects in the Sri Lankan construction industry.

Research on consultancy fee has been very minimal in the local as well as in the global context. Lassala *et al*. (2015) contends that higher level of client satisfaction denotes higher level of consultancy fee. Consultancy fee charges on daily basis but private sector clients demand lump sum price (Ozeroglu, 2014). Guideline for engineering consultancy fee is issued by the Institution of Engineers Sri Lanka (IESL). There is a guideline called professional fees for Quantity Surveying consultancy services published by the Institute of Quantity Surveyors Sri Lanka (IQSSL) for different types of projects and it has been implemented. There is no clear fee guideline to identify the consultancy fee in re-measurement contracts in Sri Lankan construction industry. Accordingly, the aim of the research was to identify consultancy fee for re-measurement contracts in the Sri Lankan construction industry.

2. LITERATURE REVIEW

2.1 FACTORS TO BE CONSIDERED WHEN DECIDING ON THE CONSULTANCY FEE

Lassala *et al*. (2016) stated that consulting firms use their qualification, capability, knowledge and creativity to enhance the value and customer satisfaction within the consulting firm. According to Ozeroglu (2014), price is not considered as the deciding factor however price is important at all times. In addition to that client expects the proper outcome for the fee paid. Moreover, these are the factors to be considered when deciding on the consultancy fee.

- The normal or going market rate for that particular type of work
- The fees charged by competitors
- If the "product or service" is new, we may have a "promotional" price to launch it
- The government, or a large company, may have norms for the payment of consultants and may not be prepared to go beyond these norms.
- The fee will have to be related to the image and status of the consultant in the market place
- The state of the development of the market for consultancy services, such as in Turkey where it is an emerging but not an established market
- The ability of the client to pay
- The value of the client as a potential long term client
- The workload of the consultancy company at the time of the proposal
- The potential for the use of the assignment as a training ground for younger less experienced consultants

2.2 HISTORY ON DECIDING ON THE CONSULTANCY FEE

These are the other methods adopted for payment for the consultants in the construction industry (The Institution of Engineers Sri Lanka [IESL], 2018).

- Man-month or time based
- Lump-sum
- Percentage

2.3 IQSSL FEE PROPOSAL

IQSSL fee proposal has been produced as a professional fees for Quantity Surveying consultancy services (Institute of Quantity Surveyors Sri Lanka [IQSSL], 2018). Furthermore, IQSSL identified the scope of Quantity Surveying consultancy services and computation of fees according to the building works and the civil engineering works. Moreover, building works are categorized into five types and civil engineering works are categorized into two types.

Table 1: Scale of fees for category A

Total Cost of Works	Fees Payable			
	Pre Contract		Post Contract	
25 m and below	1.20%	of Initial contract price	0.80%	of value of work done
26 m - 50 m	1.05%	of Initial contract price	0.70%	of value of work done
51 m - 100 m	0.90%	of Initial contract price	0.60%	of value of work done
101 m - 175 m	0.75%	of Initial contract price	0.50%	of value of work done
176 m - 250 m	0.60%	of Initial contract price	0.40%	of value of work done
251 m - 350 m	0.57%	of Initial contract price	0.38%	of value of work done
351 m - 500 m	0.48%	of Initial contract price	0.32%	of value of work done
over 500 m	0.45%	of Initial contract price	0.30%	of value of work done

3. METHODOLOGY

Mixed research approach is a combination of the qualitative approach and the quantitative approach. The mixed approach was used in this research to eliminate the drawbacks of the qualitative approach and the quantitative approach. Due to unavailability of consultancy fee guideline based on the procurement method, a preliminary interview was carried out to collect quantitative data and expert interviews collected both qualitative and quantitative data.

The research study aimed to decide the consultancy fee for re-measurement contracts in the Sri Lankan construction industry, the whole population cannot be practically surveyed therefore the constraints of the time and the resources. Non random sample was selected for this survey from the industry experts who had experience in the independent quantity surveying service.

One of the most commonly used data collection technique is interviewing. Expert interviews were the main data collection technique in this research. Semi structured interview guideline was used to gather information from the interviewees. Six number of semi structured interviews were conducted. They were experts in the deciding on the independent quantity surveying service fee within the Sri Lankan construction industry. Semi structured interview guideline's data highly depend on the thoughts of the interviewees.

Table 2: Details of interviewees

Interviewee No.	Designation	Work experience (years)	Organization
1	Director	25	Pure Quantity Surveying service
2	Director	25	Pure Quantity Surveying service
3	Director	40	Pure Quantity Surveying service
4	Senior QS	15	Pure Quantity Surveying service
5	Director	27	Pure Quantity Surveying service
6	Director	40	Pure Quantity Surveying service

Interviews were limited to six number since of the same findings repeated from the interviewees.

Data analysis derived the outcome of the research process. The results gathered from semi structured interviews were analysed using content analysis through NVivo 12 software. Mean weighted rating is used to evaluate the collected quantitative data from the expert interviews.

3.1 CONTENT ANALYSIS

Content analysis is the quantitative and qualitative data analysis method (Kondracki, Wellman and Amundson, 2002). Moreover, content analysis can be used to assess the word-based information from interviews and open-ended questionnaire survey questions.

3.2 MEAN WEIGHTED RATING

A mean weighted rating (adapted from Kothari, 2004) for each characteristic was computed using equation (01) to identify the impact of the factor to be considered when deciding on the consultancy service fee.

$$\mu = \frac{\Sigma v_i x_{fi}}{n} \qquad (01)$$

Where; V_i = Rating given by ith respondent; Fi = Frequency of responses; n = Total number of respondents

4. DATA ANALYSIS AND DISCUSSION

4.1 PURE QUANTITY SURVEYING FIRM

The respondents were experts in independent quantity surveying Consultancy service in the Sri Lankan construction industry.

4.1.1 Importance of using Quantity Surveying Service

These are the main reasons for using independent quantity surveying service in the Sri Lankan construction industry.

- Value for money
- Proper cost data reporting system
- Client knows the budget from the inception
- Client will get the expert advice to procure the project
- Reduction of problems and disputes
- Can give alternative systems for very costly systems
- Enhance the economical way of doing the project without harming to the concept
- Proper evaluation of bid prices
- Cost control
- Value Engineering
- Quality assurance
- Contractor can get fair amount for variation

Effective quantity surveying service in a project will ensure successful management of a project from inception to completion and handover with best outcome in terms of time and cost. Monitoring the project will be easier with proper Quantity Surveying service. QS is providing his or her service to client, contractor to reduce cost of construction and maximizing the project value by minimizing wastage. This term is called as value for money. Proper cost data reporting system is useful for future projects to get the overall idea of the project. Independent quantity surveying consultancy service fee. Independent quantity surveying consultancy service fee is gradually increasing. These are the reasons for increasing of the independent quantity surveying consultancy service fee.

Reasons for increasing independent quantity surveying consultancy service fee:

- Understanding the importance of QS role in the construction industry
- It safeguards the client interest
- Most important person to do the finance management
- Client ready to pay
- Competition
- Demand fluctuation
- Independent Quantity Surveying service has established in the market

4.1.2 Factors to be Considered when Deciding on the Independent Quantity Surveying Consultancy Service Fee

According to findings shown in Figure 1, industry practitioners consider the current market rate as well as their reputation in the Sri Lankan construction industry to decide on the independent quantity surveying consultancy service fee for a project. Competitors' fee, long term customer relationship to the independent quantity surveying service, organization past know how on handling the client and preferences of the client were the other factors to be considered. Accordingly, the independent quantity surveying service fee can be calculated. Further, independent quantity surveying service consider the current workload and the available staff in the organization to take the decision. Project value, project duration, location of the project, nature of the project and relationship between the clients are the other highly placed factors when deciding on the independent quantity surveying fee.

Name	Files	References
Factors to be considered when deciding on the Independent Quantity Surveying consultancy service fee	6	88
The normal or going market rate for that particular type of work	6	6
The fees charged by competitors	6	6
The fee will have to be related to the image and status of the consultant in the market place	6	6
The value of the client as a potential long term client	6	6
The workload of the consultant company at the time of the proposal	6	6
Project value	6	6
Project duration	6	6
Location of the project	6	6
Nature of the project	6	6
Relationship between the client	6	6
The government, or a large company, may have norms for the payment of consultants and may not	5	5
The potential for the use of the assignment as a training ground for younger less experienced consu	5	5
If the "product or service" is new, we may have a "promotional" price to launch it	4	4
The state of the development of the market for consultancy services, such as in Turkey where it is an	4	4
The ability of the client to pay	4	4
Business sustainability	3	3
Environmental factors	2	2
Professional liability	1	1

Figure 1: Factors to be considered when deciding on the independent quantity surveying consultancy service fee

4.1.3 Impact of Factors to be Considered when Deciding on the Independent Quantity Surveying Consultancy Service Fee

Figure 2 represents the impact of the independent quantity surveying consultancy service fee factors to the decision. The factors identified by Ozeroglu (2014) was used for the ranking. Accordingly, the respondents identified "The value of the client as a potential long term client", "The fees charged by competitors" and "The workload of the consultant company at the time of the proposal" as the highly impact factors when deciding on the independent quantity surveying consultancy service fee for the re-measurement contracts for the Sri Lankan construction industry.

4.1.4 Current Practice of Deciding on the Independent Quantity Surveying Consultancy Service Fee for Re-Measurement Contracts in the Sri Lankan Construction Industry

The research findings indicate that the fee percentage is not less than 0.4% of the contract sum. The respondents indicated that the cost details of the past projects plus reasonable mark-up had been considered in the calculation for the independent quantity surveying consultancy service fee for re-measurement contracts. Maximum fee percentage was stated as 1.2% of the contract sum. Detailed costing had been used to determine the fee for the project. Findings suggested that independent quantity surveying consultancy fee within the range of 0.4% to 1.2% of the contract sum. It will vary from the organization to organization and will change according to the factors to be considered when calculating the fee.

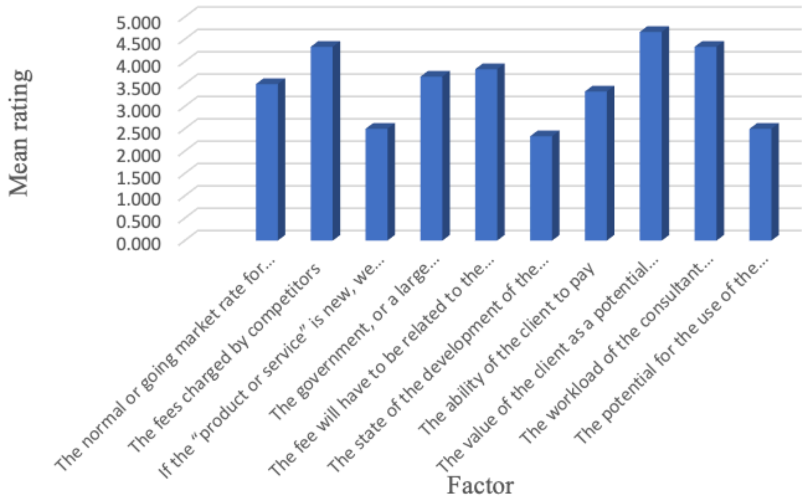

Figure 2: Impact of the factors to be considered when deciding on the Independent Quantity Surveying consultancy service fee

4.1.5 Published IQSSL Proposal relating to the Independent Quantity Surveying Consultancy Service Fee

IQSSL proposal attempts to find the standard fee guideline for independent quantity surveying consultancy service fee. However, according to the opinion of the respondents it will give guideline for the decision on the independent quantity surveying consultancy service fee.

4.1.6 Improvements Proposed for the IQSSL Fee Proposal

IQSSL fee proposal had been prepared for the traditional procurement system with Bill of Quantities and "measure and pay" payment methodology. The research established the need for guidelines for quoting fees for other type of procurement methods like integrated system, management oriented system and collaborative systems. Further, IQSSL fee proposal states the fee percentage for the different types of building projects. However according to the opinion of the respondents' fee percentage must be stated as a range. In addition, adjustment factors need to be proposed based on the nature of the construction, location of the project and specific details.

The research also found the importance of getting the constant feedback from the IQSSL members through a discussion forum established through the IQSSL web.

5. CONCLUSIONS AND RECOMMENDATIONS

Findings from the expert interviews demonstrated that quantity surveying service play a major role in a construction project to ensure the value for money. There are number of services are provided under the quantity surveying service. According to the opinion of the respondents it was revealed that construction management contracts and the re-measurement contracts have the highest independent quantity surveying consultancy service fees. Re-measurement contracts are popular therefore it is the traditional way of procuring for a long period in Sri Lanka.

The normal or going market rate for that particular type of work, the fees charged by the competitors, the fee in relation to the image and status of the consultant in the market place, the value of the client as a potential long term client, the workload of the consultant company at the time of the proposal, project value, project duration, location of the project, nature of the project and relationship between the client are the most important factors when calculating and quoting the independent Quantity Surveying consultancy service fees for re-measurement contracts in the Sri Lankan construction industry. Further according to the opinion of the respondents IQSSL published fee proposal will only be a guideline for decision on the independent Quantity Surveying consultancy service fee. Findings suggested that Independent Quantity Surveying consultancy fee is within the range between from 0.4% to 1.2% of the contract sum and IQSSL proposal has to accommodate number of improvements to be effectively practiced in the Sri Lankan construction industry.

6. REFERENCES

Cox, A. and Townsend, M., 1998. *Strategic Procurement in Construction: Towards Better Practice in Management of Construction Supply Chain*. London: Thomas Telford.

Haverila, M., Bateman, E. R., and Naumann, E. R., 2011. The drivers of customer satisfaction in strategic consulting engagements a global study. *Management Decision*, 49(8), pp.1354-1370.

Institute of Quantity Surveyors Sri Lanka [IQSSL]., 2018. Professional fees for Quantity Surveying consultancy services. Available from: http://www.iqssl.lk/resources/qs-fee-scale.html

Kondracki, N., Wellman, N., and Amundson, D., 2002. Content analysis: Review of methods and their applications in nutrition education. *Journal of Nutrition Education and Behaviour, 34*(4), pp.224-230.

Kothari, C. R., 2004. *Research methodology: Methods and techniques.* New Delhi, India: New Age International (Pvt) Ltd.

Lassala, C., Carmona, P., and Momparler, A., 2015. Quality of consulting services and consulting fees. *Journal of Business Research, 68*(7), pp.1458-1462.

Lassala, C., Carmona, P., and Momparler, A., 2016. Alternative paths to high consulting fees: a fuzzy-set analysis. *Journal of Business Research, 69*(4), pp.1367-1371.

Molwus, J. J., 2014. *Stakeholder management in construction projects: A life cycle based framework* . (Doctoral thesis), Heriot Watt University.

Oyegoke, A. S., Dickinson, M., Khalfan, M. M., McDermott, P., and Rowlinson, S., 2009. Construction project procurement routes: an in-depth critique. *International Journal of Managing Projects in Business, 2*(3), pp.338-354.

Ozeroglu, A. I., 2014. Financial framework of consultancy services. *Procedia - Social and Behavioral Sciences, 114*, pp.787-793.

Rameezdeen, R., and Silva, S. D., (2002). Trends in construction procurement systems in Sri Lanka. *Built-Environment Sri Lanka, 2*(1), pp.2-9.

The Institution of Engineers Sri Lanka [IESL]. (2018). *IESL guideline structure for engineering consultancy fees*. Sri Lanka.

Yadollahi, M., Mirghasemi, M., Zin, R. M., and Singh, B., 2014. Architect critical challenges as a project manager in construction projects: a case study. *Advances in Civil Engineering, 2014*, pp.1-15.

Samaranayake, R.A.D.I.U., Jayawickrama, T.S., Melagoda, D.G. and Rathnayake, R.M.D.I.M., 2019. Decision making on adaptive reuse of historic buildings in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 239-247. DOI: doi.org/10.31705/WCS.2019.24. Available at: https://2019.ciobwcs.com/papers

DECISION MAKING ON ADAPTIVE REUSE OF HISTORIC BUILDINGS IN SRI LANKA

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ABSTRACT

The construction industry is consistently involved with improving the economic, social and environmental parameters of sustainability. This has led the sustainability in construction to shift from an original focus on cleaner and leaner project delivery to a restorative and regenerative approach. Increasing demand for urban regeneration has driven the act of preserving and reusing parts of cities with historical significance for a variety of uses. Thereby, adaptive reuse serves as an attractive and superior alternative for reusing buildings with architectural and historical importance in terms of sustainability and a circular economy. However, many historic buildings are being disused or demolished due to the inability of determining viable new uses for historic buildings. Thus, this study aimed at providing systematic guidance for decision-making on Adaptive Reuse of Historic Buildings (ARHB) in Sri Lanka. A comprehensive literature review was conducted to explore the concept of adaptive reuse, related regulations, drivers and barriers, new uses for historic buildings and factors affecting decision-making on adaptive reuse of buildings. Finally, this paper proposes a conceptual framework to assist decision making on ARHB in Sri Lanka.

Keywords: *Adaptive Reuse; Decision-making; Historic Buildings; New Uses.*

1. INTRODUCTION

According to Dean *et al*. (2016), buildings are responsible for more than 30% of global energy use and represent more than one third of global final energy consumption while contributing to nearly one quarter of greenhouse gas emissions worldwide. Hence, the built environment has a prominent role to play in minimizing the overall carbon emissions, particularly as it demands 40% of global resources and generates a proportionate amount of waste (Langston, 2008). In this vein, Conejos *et al*. (2015) suggest that the concept of adaptive reuse is rapidly gaining global recognition as an effective strategy to improve the built environment sustainability. Historic buildings constitute a higher portion of the overall building stock in the world, making it impossible to preserve them all intact (Yung and Chan, 2012). As the paradigm in conservation has changed from preserving something from the past to utilize the past in the present, adaptive reuse can be distinguished as an important conservation intercession to recycle the past resources and transform them into experiences in and for the present (Ashworth, 2011). Internationally many researches (Ball, 1989, 2002; Bullen, 2007; Langston and

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Shen, 2007; Langston *et al*., 2008; Bullen and Love, 2010, 2011; Langston, 2012; Hong and Chen, 2017) have studied on adaptive reuse of buildings, mainly focusing on implementation challenges, design strategies, decision-making and adaptive reuse potential of buildings. De Silva *et al*. (2017) conducted a study on strategies, challenges and barriers of adaptive reuse of buildings in Sri Lankan context. Yet, comprehensive research content is not found regarding decision-making on adaptive reuse of historic buildings (ARHB) in developing countries. This study seeks to address this gap by determining the critical decision-making factors for ARHB and, compatible and viable new uses for historic buildings in Sri Lanka.

2. ADAPTIVE REUSE AS THE BEST ALTERNATIVE FOR INEFFECTIVE BUILDINGS

The incorporation of historic conservation with environmental concerns has turned into an intrinsic component of an agenda to support sustainability (Bullen and Love, 2011). To promote sustainability, many buildings of notable cultural and historical values are being adapted and reused instead of being subjected to demolition as part of a wider reinvigoration strategy (Bullen and Love, 2011; Langston and Shen, 2007). Reusing an existing building not only increases the life of a building but also lower material, transport, energy consumption and pollution, thus making a significant contribution to sustainability (Love and Bullen, 2009). Douglas (2006), and Kohler and Yang (2007) have stated that costs of reusing buildings are lower than the equivalent costs of demolition when the related benefits, relative costs and constraints of reuse vs demolition and reconstruction are concerned. Bullen (2007) argues that even though adapted building may not entirely correspond with the performance of a new building, the shortfall should be balanced against the gains in social value. Adaptive reuse of buildings has a considerable part to play in sustainable development of communities, producing valuable community capital from unproductive properties, controlling sprawl and revitalizing existing neighbourhoods (Bullen, 2007).

3. EXISTING MODELS FOR ADAPTIVE REUSE DECISION-MAKING

Ball (1989, 2002) carried out a survey about vacant industrial premises in Stoke-on-Trent in UK and argued that identified characteristics of industrial property stock that were reoccupied or reused in comparison to vacant ones suggested the adaptive reuse potential of a building. Langston's model recognizes applicability of adaptive reuse of buildings in different countries and to various building typologies as well as when the planning for building's adaptive reuse should be commenced (Langston, 2012). The model took account of the current age and expected physical life of the building and requires an assessment of functional, economical, physical, social, technological and legal obsolescence which was believed to have reduced the useful life. Based on Langston *et al*.'s (2008) ARP model, Conejos *et al*. (2013) further developed an AdaptSTAR model which was a weighted checklist of design strategies, intended to consider adaptive reuse in the initial design process. But Hong and Chen (2017) indicated that the proposed model did not recognize the uniqueness of historic buildings of which the socio-cultural value might outweigh other aspects and the best intervention points might have already passed for many historic buildings.

Furthermore, a group of researchers proposed a decision - making tool for selecting Office Building Upgrading Solutions (TOBUS) targeting office buildings in Europe to assist building owners and managers diagnose energy consumption, indoor environment quality, physical and functional obsolescence of office buildings; to estimate costs and elaborate refurbishment scenarios (Caccavelli and Gugerli, 2002). A similar tool, namely National Australian Built Environment Rating System (NABERS) was introduced to measure the environmental performance of existing residential and commercial office buildings during operation. However, both tools are targeted at individual buildings and do not take social, historical and artistic values of buildings into consideration (Hong and Chen, 2017). An Australian group of researchers proposed a decision-making model for adaptive reuse of buildings aimed at providing a point of reference to assist practitioners with making decisions regarding reuse or demolition in the Australian context (Bullen and Love, 2010, 2011). The model identified key issues related to adaptive reuse of buildings that need to be addressed by developers, policy makers and building owners during the design stage of projects to achieve more sustainable outcomes.

4. THE EXTENT AND NATURE OF PHYSICAL CHANGE

Numerous changes are required for adaptive reuse, the most dynamic form of preservation to be successful (Compton, 2005). Adaptive reuse projects may require certain materials to be reconstituted to retain the ambiance of the site (Smallwood, 2012). Aged materials provide the authenticity, credibility and sense of status to the building and community, required to create a unique civic character (Bullen and Love, 2010; Langston *et al*., 2007; Smallwood, 2012). The study of Kincaid (2003) identified two main types of physical changes that must be considered, namely, those to the external building fabric and those to the internal spaces and layout and developed four basic strategies for adaptation as shown in Figure 1.

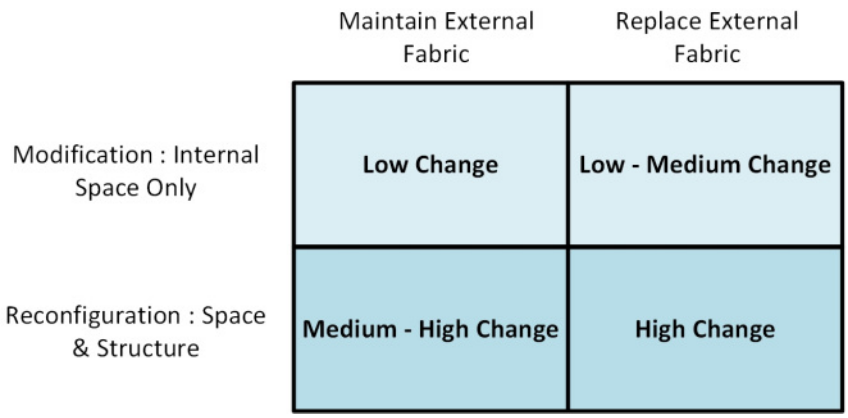

Figure 1: Types of physical change to buildings (Source: Kincaid, 2003)

5. FACTORS AFFECTING ADAPTIVE REUSE DECISION-MAKING OF BUILDINGS

Previous studies conducted on building adaptability have identified key building attributes in favour of adaptation (Wilkinson *et al*., 2009). Most influential factors for adaptive reuse decision-making of historic buildings are presented in Table 1, based on available literature.

Table 1: Factors affecting adaptive reuse decision-making of buildings

ARHB Decision Criteria	Relevant research study
Structural Integrity	Gann and Barlow (1996), Swallow (1997), Larssen and Bjorbery (2004), Snyder (2005), Kersting (2006), Bullen and Love (2011), Hong and Chen (2017)
Residual Service Life	Barras and Clark (1996), Ball (1999, 2002), Fianchini (2007), Bullen and Love (2011)
Internal Layout	Gann and Barlow (1996), Swallow (1997), Fianchini (2007), Szarejko and Trocka-Lesczynska (2007), Bullen and Love (2011), Hong and Chen (2017)
Internal and External Space	Gann and Barlow (1996), Keymer (2000), Ball (2002), Larssen and Bjorbery (2004), Szarejko and Trocka-Lesczynska (2007) Bullen and Love (2011), Hong and Chen (2017)
Functionality	Gann and Barlow (1996), Fianchini (2007), Rawlinson and Harrison (2009), Bullen and Love (2011), Wilkinson (2014), Manewa *et al*. (2016)
Location	Bryson (1997), Ball (1999, 2002), Douglas (2006), Remoy and van der Voordt (2007), Bullen and Love (2011), Hong and Chen (2017)
Site condition	Kincaid (2003), Larssen and Bjorbery (2004), Douglas (2006), Highfield (2009), Bullen and Love (2011), Hong and Chen (2017)
Surrounding condition	Bullen and Love (2011), Hong and Chen (2017)
Infrastructure	Gann and Barlow (1996), Ball (2002), Ellison and Sayce (2007), Remoy and van der Voordt (2007), Hong and Chen (2017)
Public Transport	Kincaid (2000), Bullen and Love (2011), Hong and Chen (2017)
Tectonic Beauty	Ball (2002), Bullen and Love (2011), Hong and Chen (2017)
Landscaping Quality	Bullen and Love (2011), Hong and Chen (2017)
Economic Return	Ball (2002), Bullen and Love (2010, 2011), Hong and Chen (2017)
Use Value	Bullen and Love (2011), Hong and Chen (2017)
Marketability	Ball (2002), Bullen and Love (2011)
Historical Value	Brereton (1995), Ball (2002), Snyder (2005), Bullen and Love (2011), Hong and Chen (2017)
Cultural Value	O'Donnell (2004), Myers and Wyatt (2004), Bullen and Love (2011), Langston *et al*. (2008), Langston (2012), Hong and Chen (2017)
Facilitating Public Education	Hong and Chen (2017)
Facilitating Social Interaction	O'Donnell (2004), Langston *et al*. (2008), Hong and Chen (2017)
Value Exhibition	Kincaid (2003), Hong and Chen (2017)
Legislation	Gann and Barlow (1996), Ball (2002), Snyder (2005), Shipley *et al*. (2006), Kersting (2006), Highfield (2009), Bullen and Love (2011), Hong and Chen (2017)

6. ADAPTIVE REUSE OF HISTORIC BUILDINGS

As pointed out by Pearce (2014), rather than just preserving buildings for their heritage and architectural significance, adaptive reuse allows buildings to be preserved and used as a way of life of those labelled 'ordinary people'. Unlike other preserving policies that are concerned with accurate restoration and limited change, adaptive reuse supports the idea of change instead of considering historic buildings as just an art object, making them a product of a whole socio-economic system (Mengüşoğlu and Boyacioğlu, 2016). Finding suitable alternative uses to preserve such buildings was further emphasized.

6.1 DRIVERS AND BARRIERS FOR ADAPTIVE REUSE OF HISTORIC BUILDINGS

Reuse of historic buildings does not necessarily avert displacement of native residents but may retain the social meaning of place to a certain extent (Hong and Chen, 2017). Rehabilitating existing spaces is much faster than reconstructing new spaces in the same floor area which will consequently reduce costs (Johnson, 1996). However, Ellison *et al*. (2007) and Ball (1999) argue that in some cases refurbishing an old building to a specific sustainable standard could be more expensive and may require a significant investment to renovate and maintain if its external fabric has begun to deteriorate or founded with severe structural problems.

The study of Yung and Chan (2012) identified several significant implementation challenges regarding ARHB. Uncertainty about economic viability, difficulty in achieving cost efficiency, hindrance of social inclusiveness due to accessibility, difficulty in establishing a sense of place and identity, continuity of local community life, overlooking the relationship between the historic building and the surrounding environment, ambiguities and difficulties in retaining historic setting, government policies and strategies (differences in granted lease periods from site to site and delay of timely completion of projects due to the use of government funding), effective and appropriate community engagement opportunities (difficulty in involving many stakeholders in every stage of the project since it takes a very long time to obtain a constructive consensus), inadequate transparency and efficiency for the adaptive reuse policy are the main implementation challenges identified. In addition, Bullen and Love (2011) indicated that older buildings have difficulties complying with building codes during adaptive reuse, especially in areas of parking allocation, fire protection and disabled access requirements. From a purely financial perspective, scarcity of land has made investors believe that given very high land values, replacement of existing buildings with new structures is the only way to make a reasonable profit from using the land (Langston *et al*., 2007; Shipley *et al*., 2006).

Despite these impediments, Pendlebury (2002) argues that historic buildings carry a market cachet. Shipley *et al*. (2006) identifies, heritage buildings to have a great marketing leverage. Langston *et al*. (2007) highlighted that many older buildings were soundly constructed using a range of quality materials, typically displaying a useful life well in excess of their modern counterparts. Furthermore, many older buildings deliver long term operational efficiencies as they employ massive construction in their external envelop that can reduce energy consumption in heating and cooling (Mine, 2013). Socio-cultural benefits are usually given less priority as they are being difficult to measure (Bullen and Love, 2011). Therefore, ARHB should be assured in government policies to ensure the continuity of social life that contributes to the cultural significance and the diversity of the place.

6.2 NEW USES OF HISTORIC BUILDINGS

Compared to new development, adaptive reuse projects are unique and require a creative process in overcoming building challenges to adapt for new uses (Shipley *et al*., 2006). When drawing up for possible adaptive reuse proposals, Langston and Shen (2007) stated that a series of relevant factors should be considered, including building structure, historical background, district characteristics, tourism attractiveness, transportation and laws regulating the use. Kincaid (2003) stressed that identification of all the major players involved in decision making and implementation of adaptive reuse projects is necessary to assess which uses are likely to be financially and functionally viable. Although it may appear that adaptability potential of buildings is mainly constrained by internal space configurations and structure, Kincaid (2003) argues that most buildings are physically capable for adaptation as wide variety of uses are not necessarily limited by the space needs of a significant range of human activities. To deal with the question of what use a certain building could be best adapted to when found obsolete for its original or previous use, physical and locational characteristics of buildings should be identified and compared with a set of characteristics that describe the needs of a usage (Kincaid, 2000; Langston and Shen, 2007).

According to Shipley *et al*. (2006), the viability of proposed new uses needs to be examined against three critical sets of criteria namely; functional and use viability, technical and physical viability, and financial and economic viability. The designers should consider both refurbishments and new work of which characteristics give the built asset the most robust set of feasible use options in the future that could make a significant contribution to sustainability of cities as they are developed and changed (Kincaid, 2000).

6.3 REGULATIONS CONCERNING ADAPTIVE REUSE OF HISTORIC BUILDINGS IN SRI LANKA

Buildings of historical or archaeological importance are governed under Antiquities Ordinance (1940) in Sri Lanka and are deemed to be the absolute property of the state, maintained by the archaeological department. According to Antiquities (amendment) Act (1998), *"any specific monument which has existed or is believed to have existed for a period of not less than hundred years, shall be deemed to be an ancient monument"*. When it comes to regulations concerning adaptive reuse in Sri Lankan context, a detailed guideline exists for the Galle Fort area (Urban Development Authority, 2009). This development plan for Galle urban development area has detailed the historical background, physical settings, environmental characters, archaeological importance, land use, economic activities, infrastructure, proposed zoning plan, zoning regulations and boundaries for further development. Yet, legislation concerning historic buildings in Sri Lanka tend to be a lot less flexible. Work associated with demolition, alteration or extension of historic buildings are restricted to a great extent due to lack of leadership and encouragement by the government, making it difficult to embrace ARHB in Sri Lanka.

7. CONCEPTUAL FRAMEWORK

The conceptual framework summarizes the literature findings of the study as illustrated in Figure 2. The findings include drivers and barriers for ARHB and why adaptive reuse is considered as a superior alternative to renovation, restoration, demolition and reconstruction. Conceptual framework depicts 22 factors affecting ARHB decision identified through literature. Further, the extent and nature of physical change to the existing building resulting from adaptive reuse has been identified.

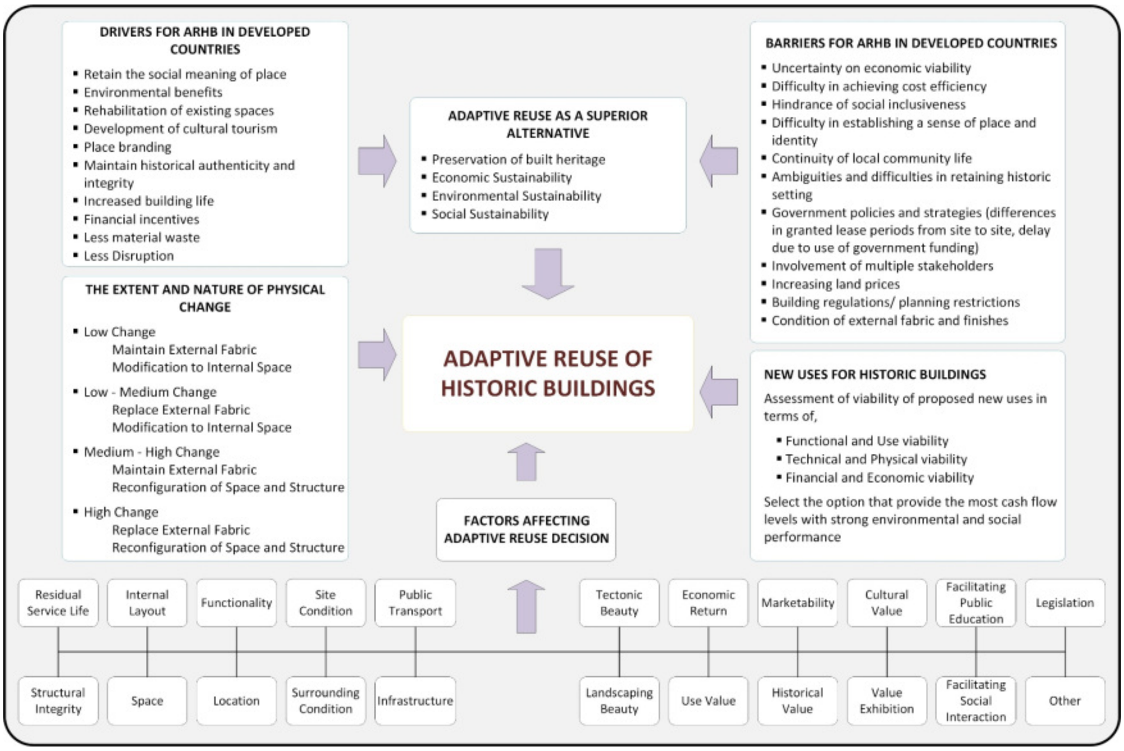

Figure 2: Conceptual framework

8. CONCLUSIONS

This study critically reviewed the adaptive reuse concept, alternative strategies for ineffective buildings, factors affecting the adaptive reuse of buildings and existing models concerning adaptive reuse decision-making in relation to previous research studies. Furthermore, drivers and barriers of ARHB were discussed, identifying adaptive reuse as a better alternative to obsolete buildings involved with many long-term benefits. Selecting a viable new use for a historic asset was revealed to be the most critical factor for the success of ARHB. As this is still a novel concept to Sri Lanka and most professionals and local authorities are yet unaware, this study concluded the need to develop a proper framework to guide adaptive reuse decision-making process concerning historic buildings in Sri Lanka.

9. REFERENCES

Antiquities (amendment) Act No. 24 of 1998. Sri Lanka: Department of Government Printing.

Antiquities Ordinance, 1940. Antiquities Ordinance of Sri Lanka (revised in 1956). *Colombo: Government of Sri Lanka*.

Ashworth, G., 2011. Preservation, conservation and heritage: Approaches to the past in the present through the built environment. *Asian Anthropology*, 10(1), pp.1-18.

Ball, R., 1999. Developers, regeneration and sustainability issues in the reuse of vacant industrial buildings. *Building Research and Information*, 27(3), pp.140-148.

Ball, R.M., 1989. Vacant industrial premises and local development: A survey, analysis and policy assessment of the problem in Stoke-on-Trent. *Land Development Studies*, 6(2), pp.105-128.

Ball, R.M., 2002. Re use potential and vacant industrial premises: revisiting the regeneration issue in Stoke-on-Trent. *Journal of Property Research*, 19(2), pp.93-110.

Barras, R. and Clark, P., 1996. Obsolescence and performance in the Central London office market. *Journal of Property Valuation and Investment*, 14(4), pp.63-78.

Brereton, C., 1995. *The repair of historic buildings*. London: English Heritage.

Bryson, J.R., 1997. Obsolescence and the process of creative reconstruction. *Urban Studies*, 34(9), pp.1439-1458.

Bullen, P.A. and Love, P.E., 2011. A new future for the past: a model for adaptive reuse decision-making. *Built Environment Project and Asset Management*, 1(1), pp.32-44.

Bullen, P., 2007. Adaptive reuse and sustainability of commercial buildings. *Facilities*, 25(1/2), pp.20-31.

Bullen, P.A. and Love, P.E., 2010. The rhetoric of adaptive reuse or reality of demolition: Views from the field. *Cities*, 27(4), pp.215-224.

Caccavelli, D. and Gugerli, H.T.O.B.U.S., 2002. TOBUS—a European diagnosis and decision-making tool for office building upgrading. *Energy and Buildings*, 34(2), pp.113-119.

Compton, B., 2005. Adaptive Reuse: Preservation's Next Argument. In: *The Association of Collegiate Schools of Architecture Annual Meeting*. Miami University, Ohio: ACSA Press, pp.128-136.

Conejos, S., Langston, C. and Smith, J., 2013. AdaptSTAR model: A climate-friendly strategy to promote built environment sustainability. *Habitat International*, 37, pp.95-103.

Conejos, S., Langston, C. and Smith, J., 2015. Enhancing sustainability through designing for adaptive reuse from the outset: A comparison of adaptSTAR and Adaptive Reuse Potential (ARP) models. *Facilities*, 33(9/10), pp.531-552.

De Silva, G.D.R., Perera, B.A.K.S. and Rodrigo, M.N.N., 2019. Adaptive reuse of buildings: the case of Sri Lanka. *Journal of Financial Management of Property and Construction*, 24(1), pp.79-96

Dean, B., Dulac, J., Petrichenko, K. and Graham, P., 2016. Towards zero-emission efficient and resilient buildings.: Global Status Report.

Douglas, J., 2006. *Building adaptation*. 2nd ed. Routledge.

Ellison, L., Sayce, S. and Smith, J., 2007. Socially responsible property investment: quantifying the relationship between sustainability and investment property worth. *Journal of Property Research*, 24(3), pp.191-219.

Fianchini, M., 2007. Fitness for purpose: a performance evaluation methodology for the management of university buildings. *Facilities*, 25(3/4), pp.137-146.

Gann, D.M. and Barlow, J., 1996. Flexibility in building use: the technical feasibility of converting redundant offices into flats. *Construction Management and Economics*, 14(1), pp.55-66.

Highfield, D. and Gorse, C., 2009. *Refurbishment and upgrading of buildings*. Spon Press.

Hong, Y. and Chen, F., 2017. Evaluating the adaptive reuse potential of buildings in conservation areas. *Facilities*, 35(3/4), pp.202-219.

Johnson, A., 1996. Rehabilitation and re-use of existing buildings. In Mills E. D. *Building maintenance and preservation: A guide to design and management,* pp.209-230. Oxford: Architectural Press.

Kersting, J.M., 2006. *Integrating past and present: the story of a building through adaptive reuse* (Doctoral dissertation), University of Cincinnati.

Keymer, M.A., 2000. *Design strategies for new and renovation construction that increase the capacity of buildings to accommodate change* (Doctoral dissertation, Massachusetts Institute of Technology).

Kincaid, D., 2000. Adaptability potentials for buildings and infrastructure in sustainable cities. *Facilities*, 18(3/4), pp.155-161.

Kincaid, D., 2003. *Adapting buildings for changing uses: guidelines for change of use refurbishment*. Routledge.

Kohler, N. and Yang, W., 2007. Long-term management of building stocks. *Building Research and Information*, 35(4), pp.351-362.

Langston, C. and Shen, L.Y., 2007. Application of the adaptive reuse potential model in Hong Kong: a case study of Lui Seng Chun. *International Journal of Strategic Property Management*, 11(4), pp.193-207.

Langston, C., 2008, November. The sustainability implications of building adaptive reuse. In *CRIOCM 2008 International Research Symposium on Advancement of Construction Management and Real Estate, Beijing, China*.

Langston, C., 2012. Validation of the adaptive reuse potential (ARP) model using iconCUR. *Facilities*, 30(3/4), pp.105-123.

Langston, C., Wong, F.K., Hui, E.C. and Shen, L.Y., 2008. Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Building and Environment*, 43(10), pp.1709-1718.

Larssen, A.K. and Bjorbery, S., 2004, December. Users demand for functionality and adaptability of buildings-A model and a tool for evaluation of buildings. In *Proceedings of the CIBW70 2004 Hong Kong International Symposium, Kowloon Shangri-La Hotel, Hong Kong, 7-8 December* (pp. 167-176).

Love, P.E. and Bullen, P.A., 2009. Toward the sustainable adaptation of existing facilities. *Facilities*, 27(9/10), pp.357-367.

Manewa, A., Siriwardena, M., Ross, A. and Madanayake, U., 2016. Adaptable buildings for sustainable built environment. *Built Environment Project and Asset Management*, 6(2), pp.139-158.

Mengüşoğlu, N. and Boyacioğlu, E., 2016. Reuse of industrial built heritage for residential purposes in Manchester. *METU Journal of the Faculty of Architecture*, 30(1).

Mine, T., 2013. Adaptive re-use of monuments "restoring religious buildings with different uses". *Journal of Cultural Heritage*, 14(3), pp.S14-S19.

Myers, D. and Wyatt, P., 2004. Rethinking urban capacity: identifying and appraising vacant buildings. *Building Research and Information*, 32(4), pp.285-292.

O'Donnell, C., 2004. Getting serious about green dollars. *Property Australia*, 18(4), pp.1-2.

Pearce, D., 2014. *Conservation Today: Conservation in Britain Since 1975*. Routledge.

Pendlebury, J., 2002. Conservation and regeneration: complementary or conflicting processes? The case of Grainger Town, Newcastle upon Tyne. *Planning Practice and Research*, 17(2), pp.145-158.

Rawlinson, S. and Harrison, I., 2009. Cost model office refurbishment. *Building Magazine*, 10(3), pp.48-53.

Remøy, H.T. and van der Voordt, T.J., 2007. A new life: conversion of vacant office buildings into housing. *Facilities*, 25(3/4), pp.88-103.

Shipley, R., Utz, S. and Parsons, M., 2006. Does adaptive reuse pay? A study of the business of building renovation in Ontario, Canada. *International Journal of Heritage Studies*, 12(6), pp.505-520.

Smallwood, C., 2012. The role of adaptive (re)use. In: *PMI® Global Congress 2012*. North America, Vancouver, British Columbia, Canada. Newtown Square: PA: Project Management Institute.

Snyder, G., 2005. *Sustainability through Adaptive Reuse: The Conversion of Industrial Buildings*. Thesis (Master of Architecture). University of Cincinnati.

Swallow, P., 1997. Managing unoccupied buildings and sites. *Structural Survey*, 15(2), pp.74-79.

Szarejko, W. and Trocka-Leszczynska, E., 2007. Aspect of functionality in modernization of office buildings. *Facilities*, 25(3/4), pp.163-170.

Urban Development Authority (2009). *Development Plan for Galle Urban Development Area 2008 - 2025*. Battaramulla, Sri Lanka: Urban Development Authority.

Wilkinson, S., 2014. How buildings learn: Adaptation of low grade commercial buildings for sustainability in Melbourne. *Facilities*, 32(7/8), pp.382-395.

Wilkinson, S.J., James, K. and Reed, R., 2009. Using building adaptation to deliver sustainability in Australia. *Structural survey*, 27(1), pp.46-61.

Yung, E.H. and Chan, E.H., 2012. Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat International*, 36(3), pp.352-361.

Kavinda, H. and Jayalath, C., 2019. Deriving a baseline score for selecting adaptive reusable projects: A quantitative approach. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 248-257. DOI: doi.org/10.31705/WCS.2019.25. Available at: https://2019.ciobwcs.com/papers

DERIVING A BASELINE SCORE FOR SELECTING ADAPTIVE REUSABLE PROJECTS: A QUANTITATIVE APPROACH

Himesh Kavinda[1] and Chandana Jayalath[2]

ABSTRACT

Building Adaptive Reuse (BAR) has been recognized to be a viable option to deal with old building stock in spite of the trivial decision of either demolish or reuse. An objective scale to gauge the accuracy of this choice is however non-existent even there is a potential to do so. Hence, the aim of this research is to ease out this decision by developing a rational framework. A comprehensive literature survey, expert's interview and questionnaire survey was carried out. 35 experienced industry personnel participated in the questionnaire survey. The topics entailed were their exposure to BAR projects in Sri Lanka, BAR potential and drivers and barriers affecting BAR decision. Expert opinion was taken to verify the findings. In order to understand the importance level of each of the recognized factors, the Relative Important Index (RII) technique was used as the primary data analysis method. Analytical Hierarchical Process that involves pair-wise comparison, normalised comparison and consistency calculations was used to augment a baseline score in order to make the BAR decision rational. It was found that structural integrity is the highest priority acquiring 12.8% in the total factor score out of 36 globally important indices. The Overall Global Importance score has been considered in this decision making model against 5 successive adaptive reuse projects in Sri Lanka. A pass mark of 60 has to be the minimum threshold to proceed with adaptive reuse. The outcome offers a national benchmark.

Keywords: *Analytical Hierarchical Process; Building Adaptive Reuse; Relative Importance Index.*

1. INTRODUCTION

In the long run, buildings become obsolete or redundant. Continuous maintenance and restoration are needed in the building usage even if their life span extends up to decades and centuries (Langston andShen 2007). With this concern, a trend is to explore the possibility of reuse of old buildings before they fall into disrepair (Langston *et al*. 2008). The Department of Environmental and Heritage (DEH 2004) defines Building Adaptive Reuse (BAR) as "a process that changes a disused or in effective item into a new item that can be used for a different purpose". The benefit is that it gives neglected, out-dated buildings a liveliness that makes them once again attractive and useful (Campbell 1996). Almost all the historic cities now have realized that adaptive reuse of historic buildings marks a vital part of building renovation (Ball 2002). The processes of BAR is heavily contributed towards environmental sustainability through the mitigation of CO_2

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emissions (Bullen 2007). It reduces huge amounts of non-digested wastage generated through the demolition of old buildings. Adaptive reuse postures quite challenging for designers as the function changes of the buildings warrants the fulfilment of new regulatory conditions (Langston and Shen 2007). A successful adaptation is the one that respects the prevailing building and its historic background (DEH 2004). In Sri Lanka, a noticeable amount of buildings are located in Colombo, Galle Fort, Kandy as well as Jaffna and it could there be inferred that Sri Lanka has the potential of adopting BAR solutions. This arises the quest of rationality behind selection of projects for adaptive building reuse.

The aim of this research is to derive a decision making support model that enhances rationality of BAR decision. The objectives are to diagnose the factors that affect the decision making of building adaptive reuse, prioritize the most critical factors involved, develop a hierarchical order for identified critical factors that influence adaptation and augment a baseline score to make the BAR decisions, that are cogent and sensible.

2. RESEARCH METHODOLOGY

The process of decision making is dynamic so that an interpretative research would be ideal (Bullen and Love 2011; Loosemore 1999). A comprehensive literature survey was carried out using textbooks and research papers. 35 experienced industrial experts who had at least in a single BAR experience participated in the questionnaire survey. The topics entailed were the BAR potential, benefits, driving factors, the barriers affecting BAR decision. Expert opinion was taken to verify the findings. The Relative Important Index (RII) technique was used to obtain a ranking relative to the importance of such factors. RII was calculated using formula (01).

$$RII = \frac{\Sigma W \times 100}{A \times N} \qquad (01)$$

Where, W= weightage given to each factor by respondents, A= the highest weighting and N= total Number in the Responses.

The next step is the Analytic Hierarchy Process (AHP) which is a multi-criteria analysis on complex human judgments instead of analysis of mere information (Saaty 1990). This involves Pair-wise Comparison, Normalise the Comparison (deriving priority vectors) and Consistency Calculation (Ehrhardt and Tullar 2008). The decision maker expresses his preference between each pair of elements verbally according to a predefined numerical code based on its level of importance (Bayazit 2005). Accordingly, the numerical values from 1 to 9 were used to scale the responses. The ratio scales are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

3. ORIGINALITY AND IMPLICATIONS

While the advantages of BAR have been generally embraced hither and thither, there is no consistency among the building owners to legitimize and assess their opinions as to its worth to reuse or demolish the existing assets (Bullen and Love 2011). On the other hand, BAR process is found to have been not that widespread in Sri Lanka. There is neither BAR base nor a BAR model. The focus of this study is to establish a rational approach to make this choice.

4. LITERATURE REVIEW

Building obsolescence arises when there is an imbalance between the rate of change in market stresses and the rate at which the building stock is able to vary according to those changes (Williams 1986). According to Williams (1986), there are six types of building obsolescence; *Physical obsolescence*: relates to the condition of the building fabrics; *Statutory obsolescenc*e: occurs due to financial or technical difficulties arising from statutory requirements focussed on buildings; *Economic obsolescence*: relates to the building type demand and focus indirectly on the goods and services produced at the premises; *Functional obsolescence*: relates to the spatial arrangements of the building and its location site; *Locational obsolescence*: operational advantages related to the building location which is dependent on the market variations; *Community obsolescence*: local conflicts of interest as a result of the purpose and use of a building. Various forms of obsolescence are relative (Williams 1986). The main reason for this is, even if a building is outmoded in the context of a particular set of user requirements, it can still be renovated and used for alternative uses which can yield a high level of utility.

According to Langston and Shen (2007), physical factors can be identified and evaluated by examining the policy of maintenance and performance of a given building. Economic factors are mainly evaluated by the locality of the building. If the building is located in a business hub the economic value of the building is very high. The factors related to technology can be appraised with the building's energy consumption in operational activities (Conejos at el. 2014). Functional factors are assessed through the flexibility to change embedded in the design of the old building stock (Ellison *et al*. 2007). Social factors are often combined with the building function and the market place (Bullen 2007). Regulatory factors need to be evaluated in order to check whether the old building can meet the new existing building standards (Wilkinson and James 2009). Environmental factors can be assessed through the quality of the original design of the old building.

5. DATA ANALYSIS

Several factors impinge upon the BAR process; environmental, regulatory, social, technological, functional, economical and physical. Experts too held the same view. The sub factors which were identified through expert's interviews are given bold and italicized at last in each category for easy identification. In tracing out the existing level of involvement in the BAR practice, the questionnaire participants were requested to assign the level of importance.

The Relative Importance Indices (RII) of each sub factor was calculated to rank the most valuable factors (Table 1). The factors which were gained the RII value less than 0.6 were disregarded as they are not that significant for the BAR process (Holt 2004). The factors which the RII values over and above 0.6 are transferred for further analysis.

Table 1: Relative importance indices of factors

Main Factors	Rank	Sub Factors	RII
Physical Factors	1	Material Durability	0.967
	2	Structural Integrity	0.883
	3	Foundation	0.817
	4	Maintainability	0.783
	5	Workmanship	0.767

Main Factors	Rank	Sub Factors	RII
	6	Design Complexity	0.683
	7	**Prevailing Climate**	**0.583**
Economic Factor	1	Cost of Construction	0.933
	2	Market Proximity	0.917
	3	Touristic Attraction	0.876
	4	Transport Infrastructure	0.850
	5	Plot Size	0.783
	6	Planning Constrain	0.767
Functional Factor	1	Flexibility	0.967
	2	Structural Grid	0.917
	3	Service Duct and Corridor	0.883
	4	Convertibility	0.817
	5	Disassembly	0.783
	6	Spatial Flow and Atria	0.717
	7	**Compartmentalization**	**0.550**
	8	**Tenancies**	**0.500**
Technological Factors	1	Orientation	0.917
	2	Complexity	0.900
	3	Glazing	0.783
	4	Insulation and Shading	0.767
	5	Natural Lighting and Ventilation	0.750
	6	**Building Management System**	**0.500**
Social Factor	1	History	0.850
	2	Urban Master Plan	0.833
	3	Image	0.817
	4	Passion and Identity	0.812
	5	Landscape	0.800
	6	Aesthetic	0.783
	7	**Adjacent Building**	**0.550**
	8	**Sense of Belonging**	**0.526**
Regulatory Factor	1	Indoor Environmental Quality	0.817
	2	Occupational Health and Safety	0.800
	3	Standard of Finishes	0.783
	4	Fire Protection	0.767
	5	Disability Access	0.683
	6	**Security**	**0.533**
Environmental Factor	1	Raw Material Consumption	0.900
	2	Pollution and Biodiversity	0.817
	3	Conservation	0.800
	4	Waste Creation	0.717
	5	Cleanliness/ Good Appearance	0.705
	6	Acoustic	0.683
	7	Ecological Footprint	0.700
	8	**Community Interest**	0.567

5.1 PAIRWISE COMPARISON

A total number of 21 comparisons were considered. The average of level of importance obtained through 35 respondents is given in Table 2 in **bold**. Basically, each cell value of the comparison matrix enhances the numerical representation of the importance relationship between two main factors.

Table 2: Pairwise comparison matrix for main factors

Factors	Physical	Economic	Functional	Technological	Social	Regulatory	Envir'
Physical	1.000	**1.548**	**1.474**	**2.359**	**2.011**	**2.769**	**2.867**
Economic	0.646	1.000	**0.641**	**2.115**	**1.571**	**2.354**	**1.381**
Functional	0.678	1.560	1.000	**2.684**	**2.592**	**3.004**	**2.226**
Technological	0.424	0.473	0.373	1.000	**0.724**	**1.597**	**0.488**
Social	0.497	0.637	0.386	1.382	1.000	**1.854**	**0.561**
Regulatory	0.361	0.425	0.333	0.626	0.539	1.000	**0.456**
Environmental	0.349	0.724	0.446	2.048	1.783	2.192	1.000
Total	3.956	6.366	4.656	12.214	10.20	14.700	8.979

5.2 NORMALIZED COMPARISON

Data summarized in the pairwise comparison matrix were then transferred to normalize by dividing each comparison matrix cell entry by the sum of the respective column. Moving forward each of the row total were then calculated to derive the average of each row with the mean of the "Importance Index" of each main factor. These main factors' overall importance can also be named as main factor "Performance Score" or "Relative Weightings" (Saaty, 1990). To fill the lower triangular matrix, the reciprocal values of the upper diagonal were used (refer Table 3).

Table 3: Normalized weighting matrix for main factors

Normalized Weightings Matrix: Main Factors								Sum	Importance Index
Factor	**Physical**	**Economic**	**Functional**	**Technological**	**Social**	**Regulatory**	**Envir'**		
Physical	0.253	0.243	0.317	0.193	0.197	0.187	0.319	1.709	**0.244**
Economical	0.163	0.157	0.138	0.173	0.154	0.159	0.154	1.098	**0.157**
Functional	0.172	0.245	0.215	0.220	0.254	0.203	0.248	1.556	**0.222**
Technological	0.107	0.074	0.080	0.082	0.071	0.108	0.054	0.577	**0.082**
Social	0.126	0.100	0.083	0.113	0.098	0.126	0.062	0.708	**0.101**
Regulatory	0.091	0.067	0.072	0.051	0.053	0.068	0.051	0.452	**0.065**
Environmental	0.088	0.114	0.096	0.168	0.174	0.148	0.111	0.900	**0.129**
								7.000	**1.000**

5.3 CONSISTENCY CALCULATION

Being the final step in the AHP process, it is required to validate the data collected through the questionnaires and measure the consistency of judgments made by the respondents. The results are tabulated in Table 4. The Consistency Index as deviation or degree of consistency was calculated using formula (02).

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (02)$$

Table 4: Consistency calculation matrix for main factors

Consistency Calculations Matrix: Main Factors								Sum	Sum ÷ Importance Index
Factor	**Physical**	**Economic**	**Functional**	**Technological**	**Social**	**Regulatory**	**Envir'**		
Physical	0.244	0.243	0.328	0.194	0.203	0.179	0.369	1.760	7.207
Economical	0.158	0.157	0.142	0.174	0.159	0.152	0.178	1.120	7.138
Functional	0.166	0.245	0.222	0.221	0.262	0.194	0.286	1.596	7.180
Technological	0.104	0.074	0.083	0.082	0.073	0.103	0.063	0.582	7.065
Social	0.121	0.100	0.086	0.114	0.101	0.120	0.072	0.714	7.062
Regulatory	0.088	0.067	0.074	0.052	0.055	0.065	0.059	0.458	7.094
Environmental	0.085	0.114	0.100	0.169	0.180	0.142	0.129	0.918	7.135
	λ_{max} = 7.126			CI = 0.021			CR = 0.016		

Considering the space constraints in this research paper, AHP Approach for Individual Sub-Factors and their net resultant impact is not given.

5.4 ASSIGNING GLOBAL PRIORITIES FOR SUB FACTORS

The Overall Factor Score was calculated by multiplying each sub-factor local importance index from the importance index of their main factor category (refer Table 5). The global factor scores are listed together with their global ranking as each and every sub-factors earned.

Table 5: Global importance indices for sub-factors

Main Factor		Sub Factors			
Factor name	**Importance Index**	**Sub-Factor name**	**Local Importance Index**	**Global Importance Index**	**Global Rank**
Physical Factor	0.244	Material Durability	0.229	0.056	3
		Structural Integrity	0.324	0.079	1
		Foundation	0.167	0.041	5
		Maintainability	0.123	0.030	11
		Workmanship	0.073	0.018	26
		Design Complexity	0.084	0.020	19
Economic Factor	0.157	Cost of Constructing Building	0.226	0.035	8
		Market Proximity	0.185	0.029	12
		Touristic Attraction & Value	0.289	0.045	4
		Transport Infrastructure	0.082	0.013	29
		Plot Size	0.149	0.023	16

Main Factor		Sub Factors			
Factor name	Importance Index	Sub-Factor name	Local Importance Index	Global Importance Index	Global Rank
		Planning Constrain	0.068	0.011	33
Functional Factor	0.222	Flexibility	0.332	0.074	2
		Structural Grid	0.181	0.040	7
		Service Duct and Corridor	0.151	0.034	9
		Convertibility	0.100	0.022	17
		Disassembly	0.089	0.020	21
		Spatial Flow & Atria	0.148	0.033	10
Technological Factor	0.082	Orientation	0.322	0.027	15
		Complexity	0.218	0.018	25
		Glazing	0.111	0.009	37
		Insulation and Shading	0.229	0.019	22
		Natural Lighting & Ventilation	0.120	0.010	36
Social Factor	0.101	History	0.277	0.028	13
		Urban Master Plan	0.205	0.021	18
		Image	0.157	0.016	28
		Passion and Identity	0.171	0.017	27
		Landscape	0.084	0.008	38
		Aesthetic	0.107	0.011	32
Regulatory Factor	0.065	Indoor Environmental Quality	0.286	0.018	24
		Occupational Health and Safety	0.310	0.020	20
		Standard of Finishes	0.165	0.011	34
		Fire Protection	0.129	0.008	39
		Disability Access	0.110	0.007	41
Environmental Factor	0.129	Raw Material Consumption	0.316	0.041	6
		Pollution and Biodiversity	0.215	0.028	14
		Conservation	0.145	0.019	23
		Waste Creation	0.080	0.010	35
		Cleanliness & Good Appearance	0.095	0.012	30
		Acoustic	0.089	0.011	31
		Ecological Footprint	0.060	0.008	40

5.5 ASSIGNING BENCHMARK SCORE

Five industrial experts were requested to score between 0-100 considering the use of each shortlisted critical factor. Average of each respondent's scores is summarized in Table 6. Accordingly, the minimum total score among these BAR projects was selected as the base line score of the developed model.

Table 6: Total factor score in BAR decision making model

Global Ranking of the Factor	Selection Factors	Overall Importance Indices	Project A		Project B		Project C		Project D		Project E	
			U.F.	Score	U.F.	Score	U.F.	Score	U.F.	Score	U.F.	Score
1	Structural Integrity	0.128	81.50	10.42	76.50	9.78	52.00	6.65	60.50	7.74	73.40	9.39
2	Flexibility	0.119	72.00	8.58	67.40	8.03	66.00	7.86	55.70	6.63	81.50	9.71
3	Material Durability	0.090	75.40	6.82	85.60	7.74	66.20	5.98	84.60	7.65	72.80	6.58
4	Touristic Attraction & Value	0.073	84.60	6.20	91.50	6.71	77.70	5.70	66.50	4.88	99.00	7.26
5	Foundation	0.066	77.70	5.13	95.30	6.29	70.80	4.67	36.80	2.43	91.70	6.05
6	Raw Material Consumption	0.066	77.70	5.10	62.50	4.10	70.00	4.60	28.60	1.88	79.60	5.23
7	Structural Grid	0.065	78.50	5.11	86.50	5.63	60.80	3.95	43.50	2.83	75.70	4.92
8	Cost of Constructing Building	0.057	32.50	1.86	65.20	3.73	58.50	3.35	55.80	3.19	77.60	4.44
9	Service Duct & Corridor	0.054	62.30	3.38	33.50	1.82	70.60	3.83	73.50	3.99	81.40	4.42
10	Spatial Flow & Atria	0.053	54.80	2.91	63.60	3.37	80.40	4.26	76.40	4.05	79.50	4.22
11	Maintainability	0.048	63.50	3.07	71.50	3.46	84.60	4.09	67.60	3.27	75.40	3.64
12	Market Proximity	0.047	66.40	3.11	84.60	3.97	87.60	4.11	58.90	2.76	89.50	4.20
13	History	0.045	80.80	3.65	94.50	4.27	72.60	3.28	75.60	3.42	95.10	4.30
14	Pollution and Biodiversity	0.045	64.60	2.89	77.50	3.47	74.50	3.33	69.60	3.11	70.90	3.17
15	Orientation	0.043	68.10	2.92	83.70	3.59	71.20	3.05	58.80	2.52	72.70	3.12
	Total Score	1.000	71.15		75.95		68.72		60.35		80.64	
	Base Line Score for Successive BAR Project Selection										60%	

6. FINDINGS AND CONCLUSIONS

If the CR becomes less than 0.10, it means the used data were consistent (Saaty, 1990). As the CR value in the above matrix is 0.016, it can be inferred that the data used for developing the "Importance Indices" of Main Factors are obtained through consistent judgments. Accordingly, the Importance Indices and their individual perceptions entail a higher level of validity. Among the sub-factors the highest level of overall importance was indicated by "Structural Integrity". The first 15 highest ranking sub-factors were taken to consider and locate the Overall Importance or the Global Importance score. This was implemented on 5 different BAR projects and revealed that 60% score is the minimum threshold in qualifying a successful adaptive reuse project.

7. REFERENCES

Ball, R.M., 2002. Re-use potential and vacant industrial premises: Revisiting the regeneration issue in Stoke-on-Trent, *Journal of Property Research*, 19(2), pp.93-110

Bayazit, O., 2005. Use of AHP in decision-making for flexible manufacturing systems, *Journal of Manufacturing Technology Management*, 16(7), pp.808-819.

Bullen, P.A., 2007. Adaptive reuse and sustainability of commercial buildings, *Facilities*, 25(1/2), pp.20-31.

Bullen, P.A. and Love, P.E.D., 2009. Residential regeneration and adaptive reuse: Learning from the experiences of Los Angeles, *Structural Survey*, 27(5), pp.351-360.

Bullen, P.A. and Love, P.E.D., 2010. The rhetoric of adaptive reuse or reality of demolition: Views from the field, *Cities*, 27(4), pp.215–224.

Bullen, P.A. and Love, P.E.D., 2011. Factors influencing the adaptive re-use of buildings, *Journal of Engineering, Design and Technology*, 9(1), pp.32–46.

Bullen, P.A. and Love, P.E.D., 2011a. A new future for the past: A model for adaptive reuse decision-making, *Built Environment Project and Asset Management*, 1(1), pp.32– 44.

Bullen, P.A. and Love, P.E.D., 2011b. Adaptive reuse of heritage buildings, Structural Survey, 29(5), pp. 411-421.

Campbell, J., 1996. Is your building a candidate for adaptive reuse?, *Journal of Property Management,* 61(1), pp.26-29.

Cantell, S.F., 2005. *The Adaptive reuse of historic industrial buildings: Regulation barriers, best practices and case studies.* Available at: http://sig.urbanismosevilla.org/Sevilla.art/SevLab/r001US2_files/r001_US_1.pdf [Accessed on 14 August 2016].

Conejos, S., Langston, C. and Smith, J., 2014. Designing for better building adaptability: A comparison of adaptSTAR and ARP models, *Habitat International*, 41, pp.85–91.

Department of Environment and Heritage, 2004. *Adaptive Reuse.* Available at: https://www.environment.gov.au/system/files/resources/3845f27a-ad2c-4d40-8827-18c643c7adcd/files/adaptive-reuse.pdf [Accessed on 2 August 2016].

Douglas, J., 2006. *Building Adaptation.* 2nd edn. Oxon: Spon Press.

Ehrhardt R., and Tuller, W.L., 2008. Rating Recruiting Sources at Simtec Instruments Corporation: Applying Multiple-criterion Decision Making in an HR Setting. *Journal of Human Resources Education*, 2(1), pp.1-11.

Holt, G., 2014. Asking questions, analysing answers: relative importance revisited. *Construction Innovation*, 14(1), pp. 2-16.

Langston, C., 2011. *On Archetypes and Building Adaptive Reuse.* Available at: http://www.prres.net/papers/langston_on_archetypes_and_building_adaptive_reuse.pdf [Accessed on 25 June 2016].

Langston, C. and Shen, L.Y., 2007. Application of the adaptive reuse potential model in Hong Kong: a case study of Lui Seng Chun. *International Journal of Strategic Property Management*, *11*(4), pp.193-207.

Langston, C., Wong, F.K.W., Hui, E.C.M. and Shen, L.Y., 2008. Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Building and Environment*, 43(10), pp.1709–1718.

Loosemore, M., 1999. A grounded theory of construction crisis management. *Construction Management and Economics,* 17(1), pp.9-19.

Saaty, T. L., 1990. How to Make a Decision: The Analytic Hierarchy Process. *European Journal of Operational Research*, 48(1), pp.9-26.

Thomsen, A.C.A. and Flier, K.V.D., 2011. Understanding obsolescence: a conceptual model for buildings. *Building Research & Information*, 39(4), pp.352-362.

Velthuis, KK. and Spennemann, DD.H.R., 2007. The future of defunct religious buildings: Dutch approaches to their Adaptive re-use, *Cultural Trends,* 16(1), pp.43-66.

Wilkinson, SS., Remøy, HH. and Langston, C., 2014. Sustainable building adaptation: Innovations in decision-making. United Kingdom: Wiley-Blackwell.

Wilkinson, S.J., James, K. and Reed, R., 2009. Using building adaptation to deliver sustainability in Australia. *Structural survey*, *27*(1), pp.46-61.

Wong, J.K. and Li, H., 2008. Application of the analytic hierarchy process (AHP) in multi-criteria analysis of the selection of intelligent building systems. *Building and Environment*, *43*(1), pp.108-125.

Madhuwanthi, H.A.S., Seneviratne, L.D.I.P. and Ganeshu, P., 2019. Developing a pre-task plan for the Sri Lankan construction industry. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 258 -265. DOI: doi.org/10.31705/WCS.2019.26. Available at: https://2019.ciobwcs.com/papers

DEVELOPING A PRE-TASK PLAN FOR THE SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

Earlier planning outputs a larger impact against unprecedented changes in construction projects. Pre-task planning (PTP) is a collaborative process that allied prior planning and safety together at the site in the daily basis. PTP allows task-based planning in the sense of associated hazard identification, mitigation and resource allocation. PTP starts with the task definition and moves with job hazard analysis while mandating the scheduling and a pre-job briefing. Therefore, the research was aimed at investigating the use of PTP in the construction projects in Sri Lanka. The study adopted a qualitative research approach. An extensive literature review was conducted and twelve, semi-structured interviews involving project managers, safety engineers, site supervisors and site engineers were carried out to investigate the application of PTP in the construction industry, process of PTP, responsible parties to conduct pre-task planning and proposing a suitable format for a pre-task plan. The collected data through the expert interviews were then subjected to a content analysis. Findings confirmed that Construction industry of Sri Lanka is practicing the pre-task planning as safety and resource allocating technique. Further, tasks identification, recognition of potential hazards associated with the tasks, mitigation measures, record, and report were identified as key steps in the process of pre-task planning. Site supervisor was the key responsible party over others in conducting pre-task planning. Primary components that need to be included in the pre-task plan as emphasized by the respondents are; equipment, material, labour, personal protective equipment, work plan and hazards and precautions.

Keywords: *Definition; Pre-task Planning; Pre-task Plans; Process; Responsible Parties.*

1. INTRODUCTION

"Planning is a crucial determinate of a project's success" (Hamzeh, *et al*., 2016, p. 68). According to Gibson and Gebken (2003), many participants consider that the earlier planning is implemented, the impact on project output will be larger. Meanwhile, Amara (2014) highlighted pre-task planning as a collaborative process that allows crew to plan and act together while providing feedback on their specific work tasks on a daily basis. Hinze and Wilson (2000) noted pre-task planning as a high-impact zero accident technique which used for effective safety management in construction projects. Many construction firms need to move in a proactive approach in safety management rather than taking a reactive approach (Kines, *et al*., 2010). Moreover, Jackson (2014) revealed that pre-task planning encourages crew members to recognize and document the possible hazards and controls to lessen the related risks. Planning ahead of daily work activities is

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beneficial to the safety performance of the line level workers (Mitropoulos and Cupido, 2009). Hence, Alarcón *et al.* (2016) recommended pre-task planning as a key practice to conduct a better safety management.

In past researches that have been done in both internationally (Hinze and Wilson, 2000) and in Sri Lankan context (Bhagyani and Kottawatta, 2015) pre-task planning was identified as a major technique used in safety management. But the literature on pre-task planning is less in the Sri Lankan context. Further, for contractors in Sri Lanka, there is a lack of clear and standardized format to be used for pre-task planning. Hence, there is a necessity to recognize the role of pre-task planning in construction project and to develop an appropriate format to use as a pre-task plan.

2. LITERATURE REVIEW

2.1 PRE-TASK PLANNING

Pre-task planning is the final step of construction planning (Ahmadu and Ijigah, 2014). Figure 1 shows the stages of construction planning including the position of pre-task planning in the planning stages.

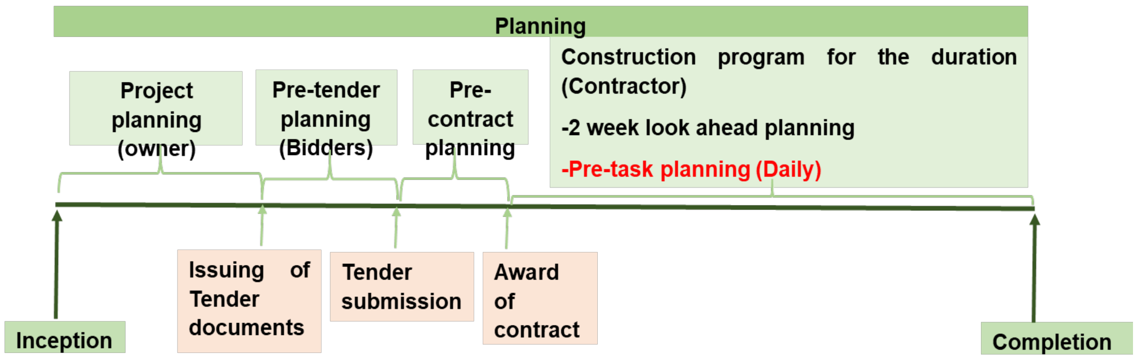

Figure 1: Position of pre-task planning in construction planning stages

The Pre-task planning is dynamic and an active tool for delving into specific hazards, safe work practices, and control over specific and often unique tasks or activities (Jazayeri and Dadi, 2017). According to Thompson and Shea (2016) pre-task planning analysis can be detailed under five components as, define the scope of work, analyse the hazards, develop and implement hazard controls, perform work within hazard control and provide feedback. In the construction industry pre-task safety planning is carrying out to examine work tasks and to identify and manage related hazards (Sacks *et al.,* 2009). Pre-task safety planning includes discussing hazard controls, changing the order of tasks, guards or using personal protective equipment to eliminate and avoid or manage risk (Guo and Yiu, 2015).

2.1.1 Need of Pre-task Plans in the Sri Lankan Construction Industry

According to Hinze (2002), in the process of pre-task planning, pre-task plans are documented prior to performing any task which includes procedures to be implemented in terms of safety to identify hazards and means to eliminate or reduce the identified hazards. Pre-task plan have benefits of providing directions and information, including expectations, hazards, work procedures to ensure safety, recent dispatches, changes or updates of weather and immediately collecting the sign-off and buys at the right time before initiating tasks (Thompson and Shea, 2016. Evidently, literature suggests that process of pre-task planning and pre-task plans are advantageous in terms of safety performance.

Furthermore, in the study conducted in Sri Lankan context De Silva and Wimalaratne (2012) stated that pre-task plans which is the site level safety and health documentation is vital as a mechanism to eliminate risks. However, the construction industry of Sri Lanka needs more satisfactory efforts to improve the safety (Priyadarshani, *et al.*, 2013). This is due to the neglection of shared duty by project participants towards preventing injuries at the work sites (De Silva and Wimalaratne, 2012). In a way to avoid this, preparing pre-task plans provides opportunity to remind and induce workers to involve in the safety planning. So, it is clear that encouraging using pre-task plans would be a possible solution to the construction industry in Sri Lanka to improve safety.

3. RESEARCH METHODOLOGY

A research approach can be defined as the process of systematically organizing the research events and collecting data in order to successfully achieve goals and objectives (Thurairajah *et al.,* 2007). Creswell (2013) studied on three types of research approaches as quantitative approach, qualitative and mixed approach. When the purpose of the study is to conduct a narrow survey and the number of involved respondents is large, quantitative approach is more appropriate (Kothari, 2004). According to Fellows and Liu (2003) when a study is designed to conduct in-depth investigations and the number of involved respondents is small, the qualitative approach is appropriate. Moreover, Creswell (2013) avowed that integration of both quantitative and qualitative approaches leads to a mixed approach that involves in collecting both quantitative and qualitative data. Considering the all aforementioned factors, this study followed the qualitative approach. Using the non-probability sampling technique professionals were selected. In order to carry out the study, twelve semi structured interviews were conducted with twelve experts in the construction industry. Respondents with more than 5 years' experience in the construction industry who practice Pre-task planning in construction were selected including project managers, safety engineers, site supervisors and site engineers were considered in collecting data

To develop a pre-task plan format, existing pre-task plans collected from selected organizations were reviewed. Content analysis that provides particular interpretation texts via systematic patterns and a coding was selected to analyse the data. In order to enable content analysis of the study, NVivo software was used as a content analysis technique.

4. ANALYSIS AND RESEARCH FINDINGS

4.1 PRACTICE OF PRE-TASK PLANNING IN SRI LANKA

Literature findings revealed that in global context, pre-task planning is practiced in the construction industry considering various aspects. However, in the Sri Lankan context, existing literature is not adequately highlighting use of pre-task planning in the local construction industry. However, all the respondents opined that pre-task planning is practiced in the local construction industry. Moreover, all most all the respondents stated that, their current projects are using the pre-task planning. Respondents emphasized that pre-task planning is used in the construction industry as a safety technique as well as a resource-allocating tool.

4.1.1 Definition of Pre-task Planning

Extensive literature review highlighted the non-existence of a standard definition for pre-task planning and the need of formulating a definition for the same. Therefore, a definition was derived based on literature as mentioned below and presented to the respondents for their opinions.

> *"Pre-task planning is a process of defining the work to be completed and the way it is performed while identifying the hazards, risks and their control methods including job hazard analysis, scheduling and a pre job briefing (Sacks et al., 2009; Guo and Yiu, 2015; Thompson and Shea,2016)"*

All the respondents endorsed the proposed definition. In summary, respondents emphasized that tool and equipment, hazards, materials, mitigation controls, work force and two-way dialogues are components that needed to be considered in compiling the definition.

Equipment + Material + Work force= Resource allocation

Hazards + Mitigation controls = Job hazard analysis

Two-way dialogues = Pre job briefing

Major addition was the fact "resource allocation" to the definition. Based on the comments, a modified definition for pre-task planning was developed as below.

> *"Pre-task planning is a process of defining the work to be completed and* ***resource allocation for the task*** *with the way it is performed while identifying the hazards, risks and their control methods including job hazard analysis, scheduling and a pre job briefing"*

4.1.2 Responsible Parties to Conduct Pre-task Planning

According to the findings site supervisor was identified by most of the respondents as the responsible party over others in conducting pre-task planning. This was similarly argued by Amara (2014) in his study.

4.1.3 Pre-task Planning Process

Majority of the respondents stressed tasks identification, recognition of potential hazards associated with the tasks, mitigation measures, record, and report as key steps. All the respondents also emphasized the need of going for a new pre-task plan in a change of working condition. Subsequently, when comparing the existing literature and the practices in the construction industry regarding the process of pre-task planning few differences can be observed.

As in the literature first step of defining the scope of work have been identified by the respondents as task and site conditions identification. Moreover, both the literature and the practice advised on hazard identification, mitigation controls and providing feed backs through recording and reporting. As an addition to the literature, adhering to the method statement and conducting morning meetings are highlighted by the respondents during the interviews. Resources and time required for safe completion of activities was another aspect identified by the experts in the pre-task planning process. Steps, which were detailed by the respondents, and the steps identified in the literature review are demonstrated in Figure 2.

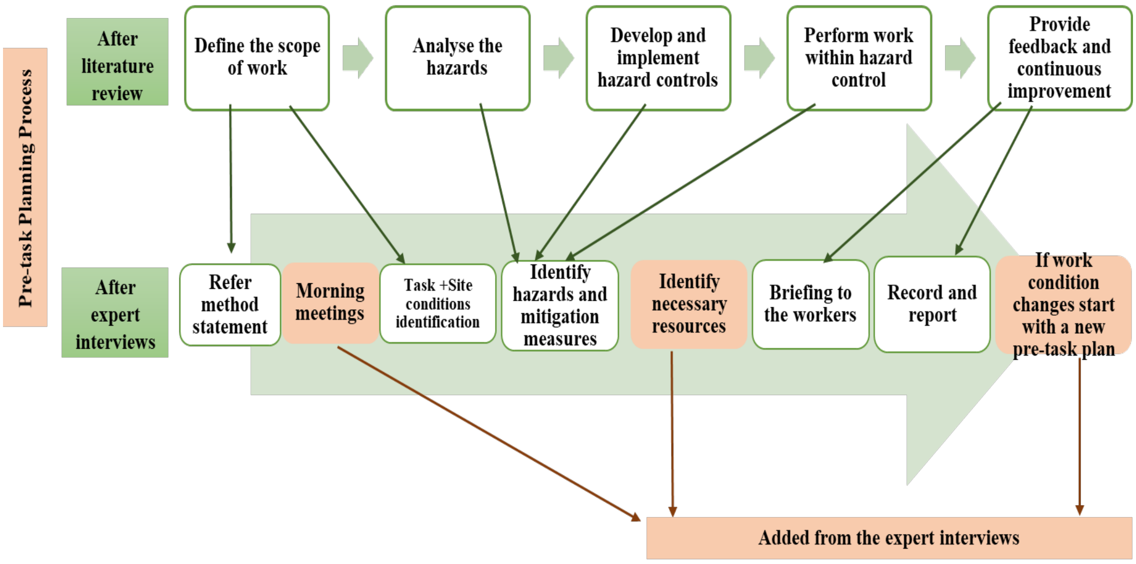

Figure 2: Pre-task planning process

4.2 PRE-TASK PLAN FORMATS

According to the responses of the all the experts, there is no standard format for pre-task plans in Sri Lanka. Figure 3 shows a summary of findings on components in pre-task plans.

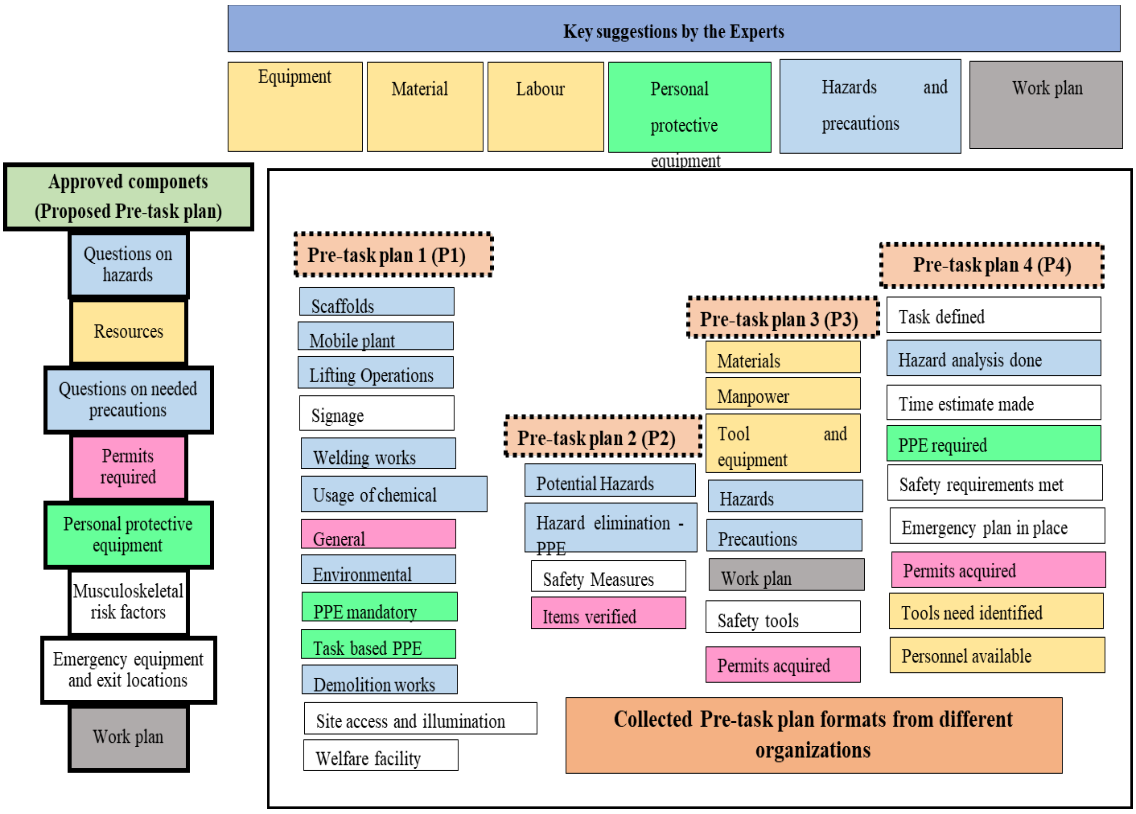

Figure 3: Summary of components of pre-task plans and suggestions of the experts

The main components that should be included in the pre-task plan as emphasized by the respondents are; equipment, material, labour, personal protective equipment, work plan and hazards and precautions. Complying with the suggestions of the experts, the proposed pre-task plan also included the components as ‘Hazards, Precautions, Personal protective equipment and work plan’. However, collected pre-task plan formats (i.e. P1, P2, P3 and P4) also include aforementioned components. Therefore, it is clear that, those are mandatory components to a pre-task plan. Considering the suggestions of the experts, hazards and precautions were divided into categories according to the categories identified in P1.

When considering the experts suggestions further, additionally ‘Materials, Equipment and Labour’ also need to be included in the pre-task plan. P3 also highlights the need of ‘materials, equipment and labour (manpower)’ components while P4 specifies ‘labour and equipment’ components. However, P1 and P2 keep silent regarding these three components. In the Resources component of the proposed pre-task plan materials, labour and equipment were included and the experts agreed with ‘Resources component’. Therefore, being accordance with all the above facts, ‘Materials, Equipment and Labour’ also have to be included in the pre-task plan. Even though ‘Permits required’ was not emphasized by the respondents as a component, all the four formats required it as an important component (P1-in General section, P2-Items verified, P3 and P4-Permits acquired).

Moreover, ‘musculoskeletal risk factors’ and ‘Emergency equipment and exit locations’ were included in the proposed pre-task plan. Respondents agreed that those two components should have included in a pre-task plan. P1 also identified musculoskeletal risk factors under the category of ‘welfare facility’. However, respondents asked to change the word ‘musculoskeletal risk factors’ and advice to use a simple wording. Therefore, ‘personal risk factors’ was used instead of ‘musculoskeletal risk factors’. Further, P2, P3 and P4 highlighted the Emergency equipment component as safety measures, safety tools and emergency plan respectively. Considering all the above arguments, modified pre-task plan was prepared (Refer Figure 4).

5. CONCLUSIONS

Most of the current projects apply pre-task planning as a safety technique in Sri Lankan construction industry. Further, industry uses pre-task planning as a resource-allocating tool. Pre-task plans are the key elements in the pre-task planning process. Pre-task plans are used as checklists to ensure whether safety aspects are appropriately concerned or not in the construction site. Prior to each task supervisor prepared the pre-task plan at the site. Literature identified components of a pre-task plan as hazards, precautions, permits required, resources, work plan, Personal protective equipment, musculoskeletal risk factors, emergency equipment and exit locations. Expert interviews further added environmental, material, labour and equipment components to the pre-task plan. Apart from the aforementioned components in the pre-task plan, general information including company name, location of work, project, task, date, time and the crew size also have to be included. However, pre-task plan to be user-friendly and for ease handling, has to be limited to one-page format. Further, this research proposes a pre-task plan format to industry practitioners to use in their daily works.

Pre-Task Plan

Company Name: **Project:**
Date: **Time:** **Type of Crew size:**

General					**N/A**	**Yes**	**No**
Does every crew member know how to use assigned tools & equipment?							
Does this task require special training?							
Do you need additional personnel to complete this work?							
Do you need additional materials and tools to do the task?							
Are ladders, Mobile Elevated Work Platform (MEWP), scaffolds or work platforms needed to perform task? Circle the needed item.							
Will the task generate important amounts of dust/vibration/ fumes/noise/ odors							
Permits required	**N/A**	**Yes**	**No**	**Environmental**	**N/A**	**Yes**	**No**
Hot work permit				Spill kits and dip trays available			
Confined space Entry				Chemical proper storage system			
Excavation permit				MSDS(Material safety data sheet) displayed			
Demolition permit				Waste disposable system available			
Work at height							
Road closure permit				Noise control available			
Critical lift plan				Dust control implemented			
Personal Risk factors	**N/A**	**Yes**	**No**	**Personal protective equipment**	**N/A**	**Yes**	**No**
Forceful exertion				Hard hat			
Vibration				Overalls			
Repetitive motion				Safety shoes			
Static postures				Eye protection			
Contact stress				Dust masks/Filter masks			
Shoulders				Hand gloves/ Rubber gloves			
Neck				Ear plugs			
Back				Welding shield			
Knees				Full face shield			
Arms				Gum boots			
Emergency equipment	**N/A**	**Yes**	**No**	**Other**	**N/A**	**Yes**	**No**
Fire extinguishers				Barricades			
Eye shower							
First aid kits							
Emergency lights available							
Signage provided							

Figure 4: The proposed pre-task plan

6. REFERENCES

Ahmadu, B. S. and Ijigah, E. A., 2014. An empirical survey on production planning practice of Nigeria's small and medium sized construction firms. *International Journal of Engineering Research and Technology, 3*(4), pp.2681-2689.

Alarcón, L. F., Acuña, D., Diethelm, S. and Pellicer, E., 2016. Strategies for improving safety performance in construction firms. *Accident Analysis and Prevention, 94*, pp.107-118.

Amara, J., 2014. 5 Core Components of Effective Pre-Task Planning. *Construction Business Owner Magazine*. Available from: http://www.constructionbusinessowner.com/safety/safety/october-2014-5-core-components-effective-pre-task-planning-analysis [Accessed 05 December 2017].

Bhagyani, A. A. B. and Kottawatta, H., 2015. Empirical investigation of safety practices in the large scale construction industry in Sri Lanka. *Human Resource Management Journal, 3*(1), pp.18-32.

Creswell, J., 2013. *Research design: Quantitative, qualitative and mixed methods approach.* 3 ed. United Kingdom: Sage Publications Ltd.

De Silva, N. and Wimalaratne, P., 2012. OSH management framework for workers at construction sites in Sri Lanka. *Engineering, Construction and Architectural Management, 19*(4), pp.369-392.

Fellows, R. and Liu, A., 2003. *Research methods for construction.* 3 ed. Oxford: Blackwell Science.

Gibson, E. and Gebken, R., 2003. Design quality in pre-project planning: Applications of project definition rating index. *Building Research and Information, 31*(5), pp.346-356.

Guo, B. H. W. and Yiu, T. W., 2015. Developing leading indicators to monitor the safety conditions of construction projects. *Journal of Management in Engineering, 32*(1), p.04015016.

Hamzeh, F., Zankou, E. and Sakka, F. E., 2016. Removing constraints to make tasks ready in weekly work planning. *Creative Construction Conference 2016*, pp.68-74.

Hinze, J., 2002. Designing for deconstruction safety. *Designing for Deconstruction and Material Reuse*, 272.

Hinze, J. and Wilson, G., 2000. Moving toward a zero injury objective. *Journal of Construction Engineering and Management, 126*(5), pp.399-403.

Jackson, D., 2014. Make Your Pre-job briefing an open dialogue on safety. *BIC Magazine*. Available from: http://www.bicmagazine.com/departments/health-safety-environmental-subsection/make-your-ore-job-biefing-an-open-dialogue-on-safety/ [Accessed 05 December 2017].

Jazayeri, E. and Dadi, G. B., 2017. Construction safety management systems and methods of safety performance measurement: A review. *Journal of Safety Engineering, 6*(2), pp.15-28.

Kines, P., Andersen, L. P., Spangenberg, S., Mikkelsen, K. L., Dyreborg, J. and Zohar, D., (2010). Improving construction site safety through leader-based verbal safety. *Journal of Safety Research, 41*(5), pp.399–406.

Kothari, C. R., 2004. *Research Methodology; Methods and Techniques.* 2 ed. New Delhi: New Age International (Pvt.) Ltd.

Mitropoulos, P. T. and Cupido, G., 2009. The role of production and teamwork practices in construction safety: A cognitive model and an empirical case study. *Journal of Safety Research, 40*(4), pp.265-275.

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), pp.33-51.

Sacks, R., Rozenfeld, O. and Rosenfeld, Y., 2009. Spatial and temporal exposure to safety hazards in construction. *Journal of Construction Engineering and Management, 135*(8), pp.726-736.

Thompson, D. and Shea, J., 2016. Pre-job planning and job hazard analysis. California. Available from: https://www.agc-ca.org/uploadedFiles/Member_Services/Safety-Health/Safety_Bulletins/SS09_02.pdf [Accessed 03 January 2018].

Thurairajah, N., Haigh, R. and Amaratunga, R., 2007. Leadership in construction partnering projects: Research methodological perspective. pp.35-48.

Chandraratne, K.A.D.S.M., Devapriya, K.A.K. and Pandithawatta, T.P.W.S.I., 2019. Development of a computer model for cost estimation in educational buildings. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 266-275. DOI: doi.org/10.31705/WCS.2019.27. Available at: https://2019.ciobwcs.com/papers

DEVELOPMENT OF A COMPUTER MODEL FOR COST ESTIMATION IN EDUCATIONAL BUILDINGS

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ABSTRACT

Cost estimating in construction is critical at the early stage of the project in order to determine whether the project is feasible or not to the client. Cost estimators are facing numerous difficult moments due to incomplete project details and unavailability of cost estimation instruments in early stages of a project. This issue uplifts the necessity of novel and advanced cost model which would be simple, understandable and more reliable. Within the Sri Lankan context, the accuracy of the estimated amount is solely based on the experience and skills of the estimator due to unavailability of reliable cost estimation tool for educational institution buildings in Sri Lanka. Therefore, this paper aims to discuss about the development of a computer model for cost estimation in educational buildings with the current practices and related issues in preparing preliminary project estimates. Semi structured interviews were conducted between twelve experts from consultancy and contractor organisations and the necessary cost data were selected from twenty educational buildings. The Multiple Regression Analysis and Artificial Neural Network methods were utilised to analyse the collected data. Each method has a unique way of building relationships between predictors and responses. However, both the methods were succeeded only in estimating cost of limited number of sub-elements. Multiple Regression Analysis succeeded on five occasions and Artificial Neural Network method had presented efficacy in seven sub-elements only. Altogether eight elements were succeeded in estimating the cost of an educational institution buildings.

Keywords: *Artificial Neural Networks; Cost Estimation Models; Educational Buildings; Elemental Cost Estimation; Multiple Regression Analysis.*

1. INTRODUCTION

Construction projects need to be performed and delivered under specific constraints. These constraints can be listed as scope, time and cost. Out of that, the cost is one, which decides the initiation of the project. Moreover, in the competitive world, to maintain a profit margin and a market share, cost planning plays a significant role in the early stage of building design (Gunaydin and Dogan, 2004). Before the commencement of the construction, the investor needs to have an idea about the cost as early as possible (Ferry *et al*., 1999).

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According to Venkatachalam (1993), the field of Cost planning has been changed like all other areas, from its original path after the arrival of Information Technology (IT). Computer-based estimating models has many pros like effective data collection, accurate estimation, ability to deal with large volumes of data and to present results in an organized, neat, and consistent manner (Yaman and TAŞ, 2007). With its accuracy and consistency, construction cost estimation models are widely used in all over the world. However, those existing computer-aided and manual models are not matching for the Sri Lankan education buildings with its inherent complexities. Moreover, there's also a lack of computer-based estimation models in Sri Lankan Construction Industry. Therefore, it is a timely need to develop a cost estimation model for education buildings in Sri Lanka.

2. LITERATURE SYNTHESIS

2.1 CONSTRUCTION COST ESTIMATE

Since the industrial development directly affects the construction sector, the projects are getting more complicated to complete within quality standards, budgeted cost limits and expected time frame (Yaman and TAŞ, 2007). Therefore, the modern architectural and engineering firms submit cost estimates and participate in cost control activities for each phase to overcome this complexity (Division of Capital Assets Management, 2006). Latief *et al*., (2013) showed that cost estimates evolve with the whole project life cycle and can be prepared using a variety of methods appropriate to the level of information and the time available to prepare the estimate. This estimation should provide the path for maximisation of the value of money.

The process of forecasting the cost of building or a physical structure is considered as the construction cost estimating process and it is similar in most cases. Moreover, both builders and clients worry about the financial impact of cost overruns and failing to complete a project. This process is critical because the structured estimating process should produce quality estimates, accuracy, confidence, reduced uncertainty, minimum costs and time savings (Adesola, 2012). Washington State Department of Transportation (2017) developed a flow chart to demonstrate cost estimation process, and it says the process should include following steps.

1. Determine Estimate Basis
2. Prepare Base Estimate
3. Review Estimate
4. Determine Risks and Set Total Project Cost
5. Determine Estimate Communication Approach
6. Obtain Management Endorsement (Approval)

2.2 BUILDING COST ESTIMATION MODELS

The cost estimation models came into act to improve the accuracy of estimation of construction costs in a construction project with minimum project information at the initial stage (Kim, An, and Kang, 2004). Cost modelling is a symbolic form of a system, and the content is defined with the factors affecting the cost (Holm, 2005). Further, Holm (2005) described that it is hard to understand the cause-effect relationship between the design parameters and the building cost, and to develop models to estimate the building cost. Models can be developed to provide various resource requirements within the cost and time (Lastra and Borja, 2014).

2.3 CONSTRUCTION COST DATABASE

For an estimation model development, cost database is essential. A cost database consisting of cost books (may be internal records at a particular company/agency /individual or public collection of data), the electronic equivalent of a cost book, or cost reference book, which used by cost estimators for more extended periods (Nardon, 1995). In a cost database estimators store data in a structured manner, which can be easily managed and retrieve in future (Samphaongoen, 2010).

2.4 SOFTWARE COST ESTIMATION

With the improvements in estimation techniques, formulas became more complex and spreadsheet errors became more frequent (Caulkins, Morrison, and Weidemann, 2008). As a result, cost estimating software applications were made with other benefits like reference databases for costs and other data, professional reports, speed, accuracy, and overall process standardisation. (Software Advice, 2014). After several years, more advanced features, such as saving data for reuse and trade-specific calculations, ability to work with multiple cost books, track project status, automatically compare estimates, clone, integrated sophisticated visual estimating and quantity take-off (QTO) tools have become available (Construction Software Review, 2017). Further, for the software development, programming languages give instructions to create the output from its input.

3. RESEARCH METHODOLOGY

At the outset a comprehensive literature survey was carried out with books, journals and articles to obtain the existing knowledge on various types of cost estimation models that used in the construction industry. Then semi-structured interviews have been carried out with twelve key individuals from consultancy and contractor organisations in Sri Lanka, in order to obtain expert opinions of the necessity of a cost estimation model, current practices in Sri Lanka. Further, the necessary information was gathered to determine the independent variables, dependent variables, relationships between parameters and methods to develop a sophisticated and accurate cost estimation model. After that, with the purposive sampling technique, twenty educational buildings, which constructed in last twenty years were selected. In order to collect data from these selected projects several documents (drawings and specifications, bills of quantities, preliminary project estimates, final bills and price catalogues) were reviewed. Then the MRA (Multiple Regression Analysis) and ANN (Artificial Neural Network) methods were utilised to analyse the collected data by using Minitab 18 and Neuroph Studio respectively. Finally, the cost estimation model was developed.

4. RESEARCH FINDINGS

4.1 CURRENT PRACTICES AND RELATED ISSUES IN PREPARING PRELIMINARY PROJECT ESTIMATE

All of the experts were practising similar type of methods in preparing Preliminary Project Estimates (PPE), which lead to similar kind of weaknesses, faults and laborious. Most of the respondents indicated that the method used to prepare the initial estimate mainly depends on the availability of the project data. Therefore, within the Sri Lankan context, there is no standard practice implemented in building cost estimation modelling.

However, during the process of predicting cost in the initial stage of the project, estimators do not have the actual details and specification for the structural elements, finishes etc. So, most of the time, estimators assume those details which can be different from the actual details. Most of the respondents identified this as a major issue which can affect to the precision of the cost estimate. Even though data is available, issues can arise when preparing PPE. Most of the time, rates derived from cost analysis are not adjusted according to the time and place. The main reasons for this are lack of knowledge of estimators and limited time frame. As per the respondents, most of the Architects make their basic plans based on their experience without even utilising analysed cost data. Further, most of the Quantity Surveyors use traditional and manual methods and do not use any framework or cost model to prepare PPEs. These traditional and manual methods require much time and are their precision is doubtful.

4.2 DETERMINATION OF INDEPENDENT AND DEPENDENT VARIABLES

To develop an accurate model, selection of the variables is a critical aspect. Each of the following variables ranked based on RII values of experts' opinions calculated based on 1 to 5 weighted scale. These based ranks of each variables are illustrated in Table 1.

Table 1: RII ranking of predictors

Variable	RII (Relative index of inequality)	Based Rank
Gross Floor area	0.983	1
No of Floors	0.967	2
Structural Material	0.967	2
Building Height	0.917	4
Foundation Type	0.900	5
Type of Building	0.817	6
Project Location	0.817	6
Roof Type	0.817	6
Duration of the project	0.767	9
Construction Year	0.767	9
External Girth	0.650	11
Doors and Windows Area	0.617	12
Average Storey Height	0.617	13
Upper Floor Area	0.600	14
Wall Area	0.600	14
Ground Floor Area	0.517	16

First 10 variables were selected as the predictors for the development of cost estimation model to avoid over fitting which can be caused by adding too many independent variables. Over fitting can cause more variance by decreasing the reliability of the model. Predictors can be categorised in to two types, continuous and categorical. Categorical variables contain a finite number of categories or distinct groups while Continuous variables are numeric variables that have an infinite number of values between any two values. Table 2 shows the category of the above selected variables.

Table 2: Types of variables

Continuous Predictors	Categorical Predictors
Duration	Type of Building
Gross Floor Area	Project Location
No of Floors	Construction Year
Building Height	Foundation Type
	Roof Type
	Structural Material

According to the experts, following items were identified as cost significant items in educational building.

- Pilling
- Excavation and Earthwork
- Concrete Works
- Masonry Works
- Water Proofing
- Structural Metal Work
- Metal Work
- Roof Covering/ Roof Plumbing
- Electrical Installations
- Floor/ Wall/ Ceiling Finishes
- Painting
- Drainage System
- Partitions / Linings / Suspended Ceilings
- Woodwork
- Plumbing / Sanitary Installations

Data of above-mentioned variables was collected through data retrieval for the development of the database. Table 3 shows the related input variables for each cost significant item.

Table 3: Parameters which are expected to be related

Sub Element	Input Variables	
	Continuous Predictors	Categorical Predictors
Pilling	Gross Floor Area/ No of Floors/ Building Height	Type of Building/ Foundation Type
Excavation and Earthwork	Gross Floor Area	Type of Building/Structure
Concrete Works	Gross Floor Area/ No of Floors/ Building Height	Type of Building/ Province/ Construction Year/ Duration/ Foundation Type/ Roof Type/ Structure
Masonry Works	Gross Floor Area/ No of Floors/ Building Height	-
Water Proofing	Gross Floor Area	Foundation Type/ Roof Type
Structural Metal Work	Gross Floor Area/ No of Floors/ Building Height	Type of Building/ Roof Type/ Structure
Metal Work	Gross Floor Area/ No of Floors	-
Roof Covering/ Roof Plumbing	Gross Floor Area/ Building Height	Type of Building/ Province/ Construction Year/ Duration/ Foundation Type/ Roof Type/ Structure

Sub Element	Input Variables	
	Continuous Predictors	**Categorical Predictors**
Electrical Installations	Gross Floor Area	Type of Building
Floor/ Wall/ Ceiling Finishes	Gross Floor Area/ Building Height	Type of Building/ Roof Type/ Structure
Painting	No of Floors/ Building Height	-
Drainage System	Gross Floor Area/ No of Floors	Type of Building/ Structure
Partitions/ Linings/ Suspended Ceilings	Gross Floor Area	Type of Building
Woodwork	Gross Floor Area	Province
Plumbing/ Sanitary Installations	Gross Floor Area/ No of Floors/ Building Height	Province/ Type of Building

4.3 DATABASE DEVELOPMENT

Altogether, 20 educational buildings were considered for the development of cost database to perform multiple regression analysis and to train the neural network. This database consists of cost data of above selected cost significant items (sub building elements) and the characteristics of continuous and categorical variables. MS Excel, which is the most popular software in Sri Lanka to develop cost databases, was used to develop the cost database. MRA and ANN methods were selected because of its inherent strengths over weaknesses, such as accuracy of results, assessment tools, use of multi-variable, input for new management trends.

4.4 MULTIPLE REGRESSION ANALYSIS

Table 4 illustrates the relationship between dependent and independent variables according to the multiple regression analysis. Separate equations for each successful categorical predictor are shown under every sub building element. Therefore, the most suitable equation should be selected for the predictions by considering characteristics of the building.

Fifteen cost significant items were analysed using MRA method to develop the estimation model. However, only five of them gave desired outcome with the equation. As a rule of thumb, typically R^2 values greater than 0.5 were considered as acceptable. Due to the overfitting issue, four of the elements were removed from the model development, and another three were eliminated due to insufficient database entries. Further, another three elements were discarded due to the low R-sq (pred).

Table 4: Summary of regression equations

Sub Building Element	R-sq(adj)	R-sq(pred)	Equation (Rs.)
Masonry Works	68.43%	60.83%	MASONARY WORKS = -29624179 + 1030 Gross Floor Area(m^2) - 38826226 No of Floors + 10592149 Building Height (m)+ 5175993 Duration of the Project (months)

Sub Building Element	R-sq(adj)	R-sq(pred)	Equation (Rs.)
Water Proofing	85.35%	72.18%	WATER PROOFING = 4509627 + 1517 Gross Floor Area (m^2) [Pile/Roof Slab] WATER PROOFING = 1268479 + 1517 Gross Floor Area (m^2)[Pile/Steel structure – ZnAl] WATER PROOFING = 1405491 + 1517 Gross Floor Area (m^2)[RCC Foundation/Roof Slab] WATER PROOFING = -1835657 + 1517 Gross Floor Area (m^2)[RCC Foundation/Steel structure - Zn Al]
Metal Works	79.66%	73.25%	METAL WORK = -2965626 + 10416 Gross Floor Area (m^2) - 2645482 No of Floors
Floor/ Wall/ Ceiling Finishes	76.59%	67.61%	FLOOR/ WALL/ CEILING FINISHES =19219407 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Public/Roof Slab/Concrete] FLOOR/ WALL/ CEILING FINISHES =19891025 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Public/Roof Slab/Steel] FLOOR/ WALL/ CEILING FINISHES = -24472810 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Public/Steel structure - Zn Al/Concrete] FLOOR/ WALL/ CEILING FINISHES = -23801192 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Public/Steel structure - Zn Al/Steel] FLOOR/ WALL/ CEILING FINISHES = 25387057 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Technical College/Roof Slab/Concrete] FLOOR/ WALL/ CEILING FINISHES =26058675 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Technical College/Roof Slab/Steel] FLOOR/ WALL/ CEILING FINISHES =-18305160 + 13375 Gross Floor Area (m^2)

Sub Building Element	R-sq(adj)	R-sq(pred)	Equation (Rs.)
			+ 639111 Building Height (m) [Technical College/Steel structure - Zn Al/Concrete] FLOOR/ WALL/ CEILING FINISHES =-17633542 + 13375 Gross Floor Area (m^2) + 639111 Building Height (m) [Technical College/Steel structure - Zn Al/Steel]
Painting	80.63%	74.09%	PAINTING = -5781796 + 2239 Gross Floor Area (m^2) - 8283350 No of Floors + 2909923 Building Height (m)

4.5 ARTIFICIAL NEURAL NETWORK

Artificial Neural Networks were created for each building sub-element of an educational institute building which was opted at literature synthesis and interviews. The Neural Networks were trained and tested by using the selected 20 numbers of educational institutional buildings. When analysing the data using ANN method, continuous predictors were ignored.

Table 5: Summary of ANN

Element	Inputs	Outputs	Hidden Neurons	Learning rate	Momentum	Iteration	MSE
Concrete Works	4	1	2	0.1	0.6	1546	0.010186
Masonry Works	4	1	3	0.2	0.6	2380	0.009621
Metal Works	2	1	2	0.3	0.6	957	0.012009
Roof Covering/ Roof Plumbing	3	1	2	0.2	0.7	4995	0.010917
Floor/ Wall/ Ceiling Finishes	2	1	1	0.2	0.6	2030	0.014242
Painting	3	1	2	0.1	0.6	1267	0.012343
Plumbing/ Sanitary Installations	3	1	2	0.2	0.6	1296	0.010864

Table 5 shows the summary of ANN and its learnings. During the analysis seven elements were identified with less than 5000 iterations and less than 0.01 Medium Standard Error (MSE). And for the other eight cases all the training attempts by Neuroph Studio failed to trained the neural network in 5000 iterations. When the number of hidden neurons is getting closer to the number of inputs, MSE figure become less. Finally, the equations and relationships were validated to determine the performance of the two techniques.

4.6 VALIDATION OF THE MRA AND ANN

To validate the results, trial and error method was used by estimating a sample project, which is not included in the cost database. In this case both the MRA and ANN models are having error percentage of 3.50 % and 2.78% respectively. However, the error range of MRA models (+-26.91 %) is pretty high compared to the ANN architectures (+-18.72%). In the MRA model, most of the positive errors and negative errors are settled against each other. That is the reason for the low overall error. However, both the estimations have estimated with an overall estimation error less than 10%, which was established by the interviewees. Hence, both the methods have pros and cons when comes to the building cost estimations modelling. Table 6 shows validation of MRA and ANN.

Table 6: Validation of MRA and ANN

Element	Actual Amount	Predicted Amount		Difference		Error Percentage	
		MRA	ANN	MRA	ANN	MRA (%)	ANN (%)
Concrete Works	57,442,450.00		55,248,365.00		(2,194,085.00)		-3.82
Masonry Works	15,317,000.00	13,585,937.10	16,458,124.25	(1,731,062.90)	1,141,124.25	-11.30	7.45
Water Proofing	6,873,200.00	7,148,371.00		275,171.00		4.00	
Metal Works	18,620,300.00	21,533,898.00	18,245,667.00	2,913,598.00	(374,633.00)	15.65	-2.01
Roof Covering/ Roof Plumbing	1,688,300.00		1,458,214.00		(230,086.00)		-13.63
Floor/ Wall/ Ceiling Finishes	35,954,085.00	38,169,665.90	42,684,246.00	2,215,580.90	6,730,161.00	6.16	18.72
Painting	3,248,145.20	2,374,166.70	2,854,621.00	(873,978.50)	(393,524.20)	-26.91	-12.12
Plumbing/ Sanitary Installations	8,038,615.00		7,254,698.00		(783,917.00)		-9.75
Total	147,182,095.20	82,812,038.70	144,203,935.25	2,799,308.50	3,895,040.05	3.50	2.78

5. CONCLUSIONS

The educational buildings are designed for different primary, secondary or higher education systems and often includes living areas for students. Majority of the universities, schools, technical colleges are constructed and controlled by the Sri Lankan government. Therefore, the accuracy and the transparency of financial transactions should be crystal clear. These projects are funded by tax money of public and foreign investments which need to be properly managed. With the limited amount of details available, it is arduous to make accurate predictions in early stages. Different parameters should identify from the initial drawings and available details. In Sri Lanka, the accuracy of the estimated amount is based on the experience and skills of the QS due to unavailability of reliable cost estimation tool for educational institution buildings in Sri Lanka. This is a must to improve the precision of the estimated amount. With the improvement of ICT and artificial intelligence lot of multi and nonlinear relationship estimation techniques comes to the stage. These methods and techniques will be the future of construction cost estimation. The computer model was developed using cost data of educational building in western province and southern province. Therefore, the model cannot be used to estimate the construction cost of a buildings located in the different areas. Furthermore, this model can estimate only the cost of conventional buildings, i.e. universities and technical colleges. Both the MRA and ANN methods were succeeded only in estimating of cost of limited number of sub-elements. MRA succeeded on five occasions which delivered provided significant R-Squared predicting values. On the other hand, ANN method was presented efficacy in seven sub-elements in different combinations of hidden neurons, learning rates and momentums. Altogether eight elements were succeeded in estimating the cost of an educational institution building.

6. REFERENCES

Adesola, A., 2012. *The Estimating Process.* Yangon: SPDC.

Caulkins, J.P., Morrison, E.L. and Weidemann, T., 2009. Do Spreadsheet Errors Lead to Bad Decisions? Perspectives of Executives and Senior Managers. In *Evolutionary Concepts in End User Productivity and Performance: Applications for Organizational Progress* (pp. 44-62). IGI Global.

Construction Software Review, 2017. *Construction Estimating Software Buyer's Guide: Benefits*. Available from: http://www.constructionsoftwarereview.com/learning_center/buyers_guides/construction-estimating-software-buyers-guide/construction-estimating-2 [Accessed 06 July 2017]

Division of Capital Assets Management, Building for the Commenwealth, 2006. *Consultants Estimating Manual.* London: Commonwealth of Massachusetts.

Ferry, D. J., Brandon, P. S., and Ferry, J. D., 1999. *Cost Planning of Buildings.* London: Blackwell Science Ltd.

Gunaydın, H. M., and Dogan, S. Z., 2004. A Neural Network Approach for Early Cost Estimation of Structural Systems of Buildings. *International Journal of Project Management*, pp.595–602.

Holm, L., 2005. *Construction Cost Estimating: Process and Practices.* Washington: Pearson/Prentice Hall.

Kim, G.H., An, S.H., and Kang, K.I., 2004. Comparison of Construction Cost Estimating Models Based on Regression Analysis, Neural Networks, and Case-Based Reasoning. *Building and Environment,* 39, pp.1235 – 1242.

Lastra, G. D., and Borja, 2014. *A Methodology to Make Accurate Preliminary Estimates of Construction Material Quantities for Construction Projects.*

Latief, Y., Wibowo, A., and Isvara, W., 2013. Preliminary Cost Estimation Using Regression Analysis Incorporated With Adaptive Neuro Fuzzy Inference System. *International Journal of Technology*, 1, pp.63-72.

Nardon, J. D., 1995. *Bridge and Structure Estimating.* New York City: McGraw-Hill Book Company.

Samphaongoen, P., 2010. *A Visual Approach to Construction Cost Estimating.* Available from: http://epublications.marquette.edu/theses_open/28 [Accessed 02 July 2017]

Software Advice, 2014. *Construction Cost Estimating Software Comparison*. Available from: http://www.softwareadvice.com/construction/cost-estimating-software-comparison/ [Accessed 01 May 2017]

Venkatachalam, A.R., 1993, October. Software cost estimation using artificial neural networks. In *Proceedings of 1993 International Conference on Neural Networks (IJCNN-93-Nagoya, Japan)* (Vol. 1, pp. 987-990). IEEE.

Washington State Department of Transportation, 2017. Cost Estimate Process. Available from: http://www.wsdot.wa.gov/Projects/ProjectMgmt/RiskAssessment/Process/ [Accessed 30 June 2017].

Yaman, H., and Tas, E., 2007. A Building Cost Estimation Model Based on Functional Elements. *A|Z ITU Journal of the Faculty of Architecture,* 4, pp.73-87.

Rowlinson, S., 2019. Development of a roadmap for occupational health, safety and wellbeing in the Hong Kong construction industry: An institutional analysis. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 276-285. DOI: doi.org/10.31705/WCS.2019.28. Available at: https://2019.ciobwcs.com/papers

DEVELOPMENT OF A ROADMAP FOR OCCUPATIONAL HEALTH, SAFETY AND WELLBEING IN THE HONG KONG CONSTRUCTION INDUSTRY: AN INSTITUTIONAL ANALYSIS

Steve Rowlinson[1]

ABSTRACT

The industrial accident rate in Hong Kong has steadily declined over the past 20 years, but has plateaued over the past 5 years and worryingly the fatality rate has been flat for over 15 years. This clearly highlights a level of under reporting of accidents in that normally accidents and fatalities are in a roughly constant proportion to one another. This is corroborated by informal discussions with the insurance industry. Using an institutional analysis approach to the study, the research team has drawn the conclusion that institutional, contractual and policy factors adversely affect Hong Kong's OHSW statistics. This paper highlights the fact that many of these factors are not under Hong Kong contractor's control. However, there is always opportunity to improve performance and a series of potential initiatives are proposed that target industry-wide issues. An overarching issue for a company is the balance between the systems it operates and the culture within which it operates. A key issue in project-based organisations is to operate with rigid flexibility throughout the business. The goal is rigid conformance to safety standards but flexibility in how these standards are achieved. This characteristic is typical of high reliability organisations.

Keywords: *Construction Industry OHSW Roadmap; Hong Kong Contractor; Institutional Analysis; Policy; Safety Leadership.*

1. THE CONTEXT

The industrial accident rate in Hong Kong has steadily declined over the past 20 years, but has plateaued in recent years with no noticeable improvement over the past 5 years. Much of the improvement has been in the public sector with the private sector obviously lagging far behind. More worryingly, the fatality rate has been flat for over 15 years. This clearly highlights a level of under reporting of accidents in that accidents and fatalities are in a roughly constant proportion to one another. These trends and issues have been corroborated by informal discussions with the insurance industry. The research presented here was undertaken in collaboration with a major Hong Kong contractor through interviews and observations on site and in head office. A whole range of personnel were interviewed from directors through project managers, supervisors and workers in order to

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deliver a balanced picture of the current state of the industry. A 360 degree safety climate survey was conducted to validate findings and this will be reported in due course

This study has three objectives:

1. To explain why there is continuing poor Occupational Health & Safety and Wellbeing (OHSW) performance in Hong Kong despite a range of initiatives (Note: This paper does not address the wellbeing issues due to space limitations);
2. To describe the context (and reasons) for the poor performance;
3. To make recommendations for change in the Hong Kong industry.

Generally, different projects exhibit their own safety culture and climate but have the same objectives for OHSW performance. However, to achieve these objectives project directors place different emphases on particular aspects of the safety management system and they do employ different operating procedures. This seems to be an appropriate reaction to the differing institutional backgrounds in which they operate. An overarching principle is the balance between the system and the culture within which it operates. A key issue in project-based organisations is to operate with rigid flexibility throughout the business. That is to be flexible in the way one goes about achieving goals but rigid in the standards that one sets for these goals. This is a difficult task as it is based essentially on people and their competence and their attitudes to implementing standards, essentially a behavioural approach from top to bottom in the organisation. Hence, this is much more difficult than introducing the same safety management system across the whole of the business in that it entails a sophisticated and mature safety management system, which takes into account different cultures, different ecologies and different demographics.

Hence, the systems will not be identical as they operate in different cultures. Typically, Singapore is a highly structured society; The Philippines is somewhat chaotic but exhibits a high power distance; workers in Malaysia may be considered as laid back as they may in Indonesia but Indonesia has a strong, clan culture; Hong Kong is considered to be the leader in construction management because of its "can-do attitude" but its workers are regarded by managers as risk takers.

Thus, any new initiatives must be based upon an understanding of these different cultures and the institutions that govern society. Also, demography, age, education and discipline of the workforce, must be taken into account in implementing standards and incentives to work safely must fit within these differing contexts. There is no one size fits all approach to improving OHSW performance.

The approach to accident prevention and safety enhancement in Hong Kong needs serious, fundamental change. Current poster campaigns and safety initiatives pay lip service to the need to improve safety through **leadership and management of the whole design and construction process**. We see a visible presence of safety propaganda but no tangible improvements in performance.

There is a widely held view in Hong Kong that safety on site is purely the contractor's responsibility. That is not the case. It is accepted worldwide that **responsibility for safety lies with the client** first and foremost and through client leadership becomes a joint responsibility of the whole project team (Lingard *et al*., 2009 and Sherratt, 2014).

Now is not the time for tinkering with a range of minor initiatives; the problem is urgent, as evidenced by the number of fatalities over the past 10 years averaging over 23 per annum and showing no significant downward trend (Hong Kong Housing Authority, 2019). Fundamentally the problem lies with **Safety Leadership. Major clients in the industry must drive change** in order to enable **Safety in Design** to be properly implemented in all projects. This requires truly collaborative working and establishing health and safety as the top priority in design, construction, maintenance and use of new facilities.

2. ISSUES ADDRESSED IN THE STUDY

This research was based on one contractor that operates in Hong Kong but also has projects in other parts of South East Asia. The overarching objective was to assess how and why performance in Hong Kong differed from performance in other parts of the region – the Hong Kong malaise.

2.1 ISSUE 1

When a business works on different projects in different countries, there is a difference in **safety management maturity** in each project. This comes about because the **institutional context** in each country is different and projects operate under different:

- legislation and codes of practice,
- professions with different governance,
- expectations, norms and values,
- processes and routines,
- levels of training, competence and degree of specialisation, and
- cultural differences (of all kinds).

Thus standards, expectations and practices are inevitably different. The differences cannot be readily controlled by any of the individual projects (nor any other multinational organization).

This context creates a barrier to the effective transfer of good practice across projects. This is normal and to be expected. Thus, because of the breadth of geography, institutions and cultures across regional projects, each will exhibit its own unique level of **safety management maturity**. This range of maturity also applies to different sites within the same country. The goal of a mature business should be to create a **high reliability organisation** (Koh *et al*, 2013) that is resilient and can achieve "best in class" performance in all contexts. This is the challenge facing the Hong Kong based contractor.

2.2 ISSUE 2

Change cannot be brought about without a clear understanding of context. This study sprang from the fact that the safety metrics in Hong Kong appear to have plateaued. In Hong Kong, institutional issues work against effective management of OHSW. Governance of the industry, client attitudes and expectations, the tendering and bidding system, extensive sub-contracting and the use of piece-rate payment systems, and the role and goals of organisations such as the Labour Department create an unreceptive environment for OHSW improvement. Furthermore, there is an inherent lack of **safety leadership** at this institutional level. Overseas projects operate in a context that is in many ways more benign than that in Hong Kong. The contexts may not be as sophisticated as Hong Kong but they can be more conducive to control of OHSW in these business units.

2.3 ISSUE 3

The following discussion addresses the institutional context first and foremost. Without change in the context and the exercise of leadership at the institutional level initiatives at project level will never be fully effective. The Hong Kong industry context is addressed first, then the project context.

3. A CONSTRUCTION INDUSTRY ROADMAP FOR CHANGE IN HONG KONG

The time is ripe for a fundamental change in the way that the industry conducts its business, starting with the **tendering and bidding system** by incorporating provisions for **adequate time to incorporate safety into design**. The **ageing workforce** lacks **competence in certain key skills** and is in **short supply**. Thus, **demand must be matched with labour supply** otherwise new safety initiatives will be futile. **Subcontracting** needs to be governed at this institutional level by an accreditation system that rewards safe performance, not lowest price. The governance structures of the industry must change and more use made of relational contracts to enable **collaborative design and construction**, including **early contractor involvement**. **Client leadership** is essential in order to drive this change and refresh the industry's approaches and attitudes. **This task cannot be achieved by an individual contractor;** it has to be a collective push for change.

3.1 INDUSTRY ROADMAP FOR AN INCIDENT FREE ENVIRONMENT

The Hong Kong construction industry is in urgent need of a **vision for the future that is incident free**. In order to achieve this, we need **visible leadership and a roadmap** to direct the industry to this objective. There are a number of key elements missing in the way construction is undertaken in Hong Kong that make it very difficult for individual contractors to improve safety and health performance. Individual contractors' initiatives are thwarted by the inertia of the institutional context in which they operate. This context must be changed and directed by an industry roadmap for an incident free environment which must address the following issues:

There is no driving mechanism for **Safety in Design**. Clients demand neither a design management coordinator nor a design risk register and construction design management for safety is not mandated;

The **bidding system** leads to risk taking by the bidder and price cutting and the workforce feels the pressure of this risk-taking;

Consequently, safety management on site has become a firefighting exercise, it is **reactive rather than proactive**;

Safety starts with design but at top levels within organisations there is a **lack of comprehension and understanding** of how OHSW works. Particularly, major clients and consultants do not recognise the health and safety problems in the same way that contractors and workers do;

There is **little incentive to self-manage projects**. The maintenance of a direct labour force is not economically viable for contractors in this competitive market. The use of piece rate payment systems leads to risk taking by construction workers;

There is a reluctance to prosecute workers for obvious breaches of legislation and in-house safety rules. This lack of sanction fuels the **risk-taking propensity** of some construction workers;

Hong Kong as a whole exhibits the cultural trait of "**Eastern Pragmatism**", which involves adapting behaviour to situation, context and time. Thus, an attitude exists where rules are there to be broken and practices change to suit the individual. This goes against many of the tenets of effective safety management practice.

At the **strategic level** of the industry, there is a lack of **vision and leadership**. The mechanisms that are used to procure construction are outdated and adversarial. There is a distinct lack of collaboration across the industry and institutionalised barriers exist to learning and informing on ways to design safety into projects. **BIM** is not being used to its full potential in this respect and this is mainly because we have neither **Integrated Project Delivery** (IPD) nor **Early Contractor Involvement** (ECI) (Lingard *et al*, 2014). This situation points to the need to move towards collaborative and relational procurement, in the whole supply chain. This requires adoption of modern forms of construction contract, such as NEC, and a more rational approach to bidding is required. Only then will **Safety in Design** be achievable. Today, there is an urgent need to manage the demand generated by the industry so as to match the supply capacity: this means projects must be brought to the market more slowly.

At this institutional level, what is required is an industry roadmap that maps out a route to industry change that will in turn cascade down to the company and project level. This will stimulate change in attitudes and working practices, build competences and lead to a safer and healthier industry. A **strategic level roadmap** is presented below in Figure 1. Initiatives that can be undertaken by the contractor are expanded upon below.

4. THEORETICAL BASIS FOR THE STUDY

This study has taken a theoretically based, institutional analysis approach in order to provide a credible academic basis for the propositions put forward in this study and to provide a framework in which the "real" situation can be explored in the interviews and site visits

Institutional issues include different cultural values within the domains of government, workers and clients and different expectations, requirements and industry governance. These are mainly things that are outside of the control of the contractor in that they are inherent to the worker and his culture or are products of the economic, political and social climate of the location. These are, in the main, beyond the immediate, short-term control and influence of the contractor and have to be dealt with as such.

Contractual issues relate to bidding, employment, payment, employee's compensation insurance and other factors and are under the control of the contractor in some way but not entirely so;

Policy issues reflect the attitude of legislators, government and other stakeholders and are not under the control of the contractor but the contractor may well influence these issues, in the longer term rather more often than immediately. Issues such as labour importation, OHSW training and inspection regimes come under this category. In Hong Kong, bodies such as the OSHC and CIC that provide training for industry improvement and over, which the contractor has no control are relevant here. These have the potential to impact negatively on OHSW management in Hong Kong;

Internalisation refers to the ability of the contractor to internalize, specify and manage certain functions, such as training, and so drive performance above the norm of the industry as a whole. As far as OHSW training, education and management goes Hong Kong contractors score highly on these aspects.

The basis of this study, in layman's terms, focuses on the high level of incident reporting as not necessarily reflecting poor safety management but as a result of institutional and policy issues which are not under individual contractor' control. These are bigger industry issues that will take time to resolve. Examples of how this can happen are the BuildSafe initiative in USA (a private sector driven initiative, see Metropolis Group Inc., 2019) and the management of OHSW for the London Olympics infrastructure (a public sector driven initiative, Olympic Delivery Authority (ODA), see Engineering News Record, 2019). At present, there is no institutional and policy drive to approach OHSW in this way in Hong Kong. Obvious champions for change and key institutional players in this respect are the Construction Industry Council (CIC), the Occupational Safety and Health Council (OSHC) and the government's Labour Department. There are opportunities to improve OHSW performance in Hong Kong but the major barriers to improvement in Hong Kong are institutional and policy issues; overcoming these will require long term planning and adjustment by all parties and changes in culture in client organisations and government bodies

5. WHY DO WE NEED A ROADMAP?

Effective safety management lies in a complex series of processes that must be implemented in order to deal with safety issues in a whole range of situations that may arise within an industry or on a particular site. If we are to keep our industry and our sites safe, we need a roadmap that will lead to institutional and organisational maturity in the construction industry. The roadmap needs to be generic so that it can be applied in different cultures and at different stages of development. Thus, what is proposed here is a safety roadmap for the Hong Kong construction industry.

When a company works on numerous different projects at any point in time there is inevitably a variability of safety maturity in each project that creates a barrier to the effective transfer of good practice across the organisation. This is normal and to be expected. If one accepts this premise that because of the breadth of distance, institutions and cultures across projects, each will exhibit its own unique level of safety maturity. It is already accepted within the contractor management that traditional quantitative measures of safety performance, lag measures, only determine the level of past performance but provide little insight into strategies that may be successful or are transferable amongst other projects. The traditional lag indicators give no insights into prevailing values, behaviours and beliefs in the construction industry. Thus, if it is recognised that effective safety performance is predicated upon both qualitative and quantitative data assimilation and analysis, then it is necessary to provide a framework that is common across the whole organisation that can be used to guide and direct safety measures. A safety roadmap provides this framework and indicates both destination and waypoints on the way that need to be followed in order to reach this final destination.

The roadmap construct applies both to organisations and to industries. The Hong Kong construction industry, through the CIC, needs to develop its own Road Map in order to reach this, perhaps not articulated by CIC as yet, destination. Zero fatalities should be a target destination in the first instance.

6. WHAT ARE THE PRINCIPLES BEHIND THE ROADMAP?

Section 3 clearly lays out the issues identified as contributing to poor OHSW performance in Hong Kong. The aim of the roadmap should be to address the issues raised above. Thus, along with the roadmap there has to be a system whereby contractors, subcontractors and designers are certified in terms of their safety performance. This system must differentiate between good and bad performers in terms of OHSW and the administering body have powers to remove certification. An overarching principle should be a focus on discouraging piece rate payment systems.

There needs to be a change of approach amongst the institutional players who must become more proactive in the way they address prosecutions and industry engagement. CIC's Construction Industry Performance Report lists three OHSW KPIs, the third of which is "Number of summonses convicted per HK$100m gross value of construction works". Such a KPI sends completely the wrong message to the industry. Indeed, key performance indicators should include a reduction in prosecutions and an improvement in the industry's accident statistics. A key set of metrics should include:

- Reduction in incident rate annually;
- Reduction in fatality rate annually;
- Reduction in the number of contractor prosecutions;
- Appropriate level of worker prosecutions;
- Increased competence in and engagement with the key players.

At this institutional level what is required is an industry roadmap that maps out a route to industry change that will in turn cascade down to the company and project level. This will stimulate change in attitudes and working practices, build competences and lead to a safer and healthier industry.

7. INSTITUTIONAL MATURITY

The purpose of the roadmap is to provide a framework for assessing the development of institutional maturity. This is necessary in order to ensure that the industry is heading on the right route to its ultimate destination that is zero fatalities and an incident free environment.

The roadmap helps on the journey already started to move from a static industry adopting *ad-hoc* responses and initiatives to one with a sense of direction and purpose. The roadmap allows for a combination of qualitative and quantitative assessment with a series of metrics that are suitable for the journey. Underlying the roadmap is the sense of being able to feel how good safety is. The roadmap also recognises different businesses, different construction sites, different subcontractors and different project managers, as well as different stages in projects, all lead to the need to follow a route that leads to the same outcome but may pass different waypoints. However, all routes lead to the same destination: incident free construction. The roadmap is presented in Figure 1.

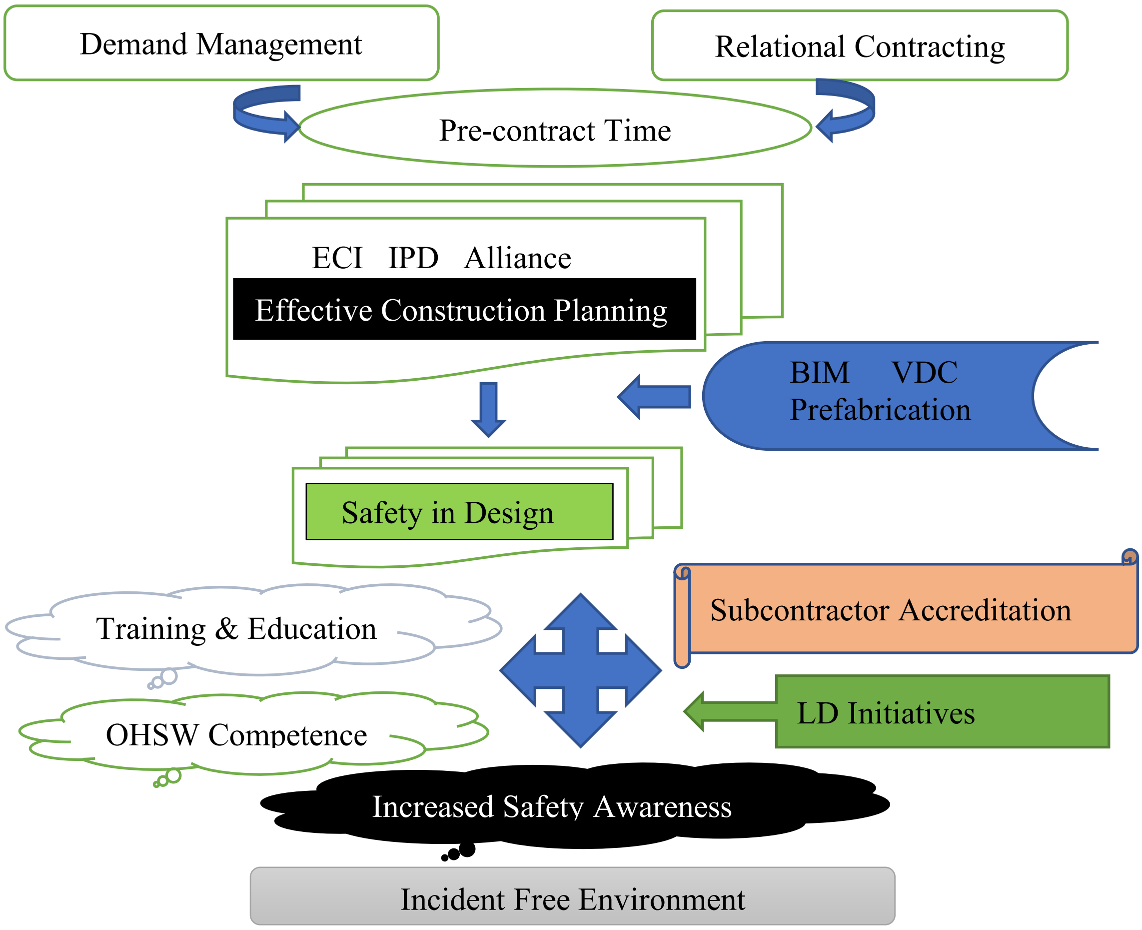

Figure 1: Hong Kong construction industry safety roadmap

8. THE WAY FORWARD

8.1 TENDERING AND BIDDING

The **tendering and bidding process** must be reviewed in order to allow time and resources to plan for safety effectively and to fairly assess contractors' safety records. Projects spend an enormous amount of time in the planning and outline design phase and then are rushed into the bidding and award process with infeasibly short construction periods being specified. This allows no proper time for value engineering, programme planning, method statements and risk analysis. These tasks should take place concurrently with design and there is evidence from USA, Australia and UK that early contractor involvement, collaborative contracting and virtual design and construction all contribute to safety improvements. These trends are pushing the industry in developed countries to proper **IPD** (integrated project delivery) which achieves time, budget quality and safety and health goals. Integrated teams provide solutions which are innovative and which individual teams on their own would not come up with.

8.2 EARLY CONTRACTOR INVOLVEMENT

By making **early appointments** of key players in a project, we achieve more effective planning, coordination and cooperation that addresses commercial and health and safety issues and provides an integrated approach to risk management where health and safety, technical, financial, time and environmental risks can all be addressed and balanced in an open forum. In the long term, this will raise the competence of designers in respect of safety and health. The motto adopted in London 2012 was "**only build things once**" and this reflected the vision of the leadership of the integrated team and its focus on safety first. This would allow for a very specific focus on safety and health in bid assessments.

8.3 POLICY CHANGE

Overarching this structural change, there needs to be a policy change in that output of the industry needs to be managed in order to match the labour force constraints that Hong Kong has at the moment. By stretching industry capacity, safety and health suffer. The same applies to the pace of construction: Hong Kong Housing Authority slowed the pace of construction of their products in the late 90s and saw an improvement in safety performance.

Client Leadership is essential for any such initiatives to succeed. Not only does the client have to initiate change in the procurement process but the client must be more involved and competent and should expect regular updating of all aspects of construction phase plans. Safe working must be rewarded in order for it to become the norm. This applies at both the **organizational and individual level**.

8.4 EMPLOYMENT PRACTICES

We have only two alternatives, either a comprehensive subcontractor registration system or employment of direct labour.

If we adopt the former approach, it is necessary to devise, implement and maintain a system whereby subcontractors are assessed on their various levels of performance, particularly safety and health, in order to maintain their registration. This is a carrot and stick approach. The other alternative is to encourage major contractors to take on their own direct labour force. This requires consideration by the industry as a whole, led by Development Bureau and the CIC, as to the feasibility of encouraging more direct labour to be employed by Hong Kong contractors. Project Level Issues

There is a whole range of factors that affect health and safety performance at the individual level. These are factors, which directly affect decisions and actions on a day-to-day basis. They include work pressure, team working, risk perception, and fatigue.

8.5 WORK PRESSURE

Work pressure leads to negative consequences for individuals. An example of this is the continued use of **piece rate systems** in the Hong Kong construction industry. This applies pressure to the individual worker either from his own personal goals or from work group pressure. The piece rate payment system is synonymous with subcontracting.

8.6 TEAM WORKING

An area which needs attention in Hong Kong is how people discuss, share, communicate and follow-up safety and health information and good practice. **Collaborative team working** should be encouraged in order to ensure that each and every participant looks after their own and other's safety and health issues.

8.7 RISK PERCEPTION

A recurring theme in discussion of safety and health on Hong Kong construction sites is **risk perception**, the way in which workers perceive and understand hazards and risks. This is essentially an individual issue. Dealing with a risk can be done by **compliance or perception**. For repeat risk takers, there should be no tolerance. A **three strikes and out** policy has been shown to be effective worldwide.

8.8 FATIGUE

It is now well known that the physical health and well-being of the ageing workforce in Hong Kong is poor, **fatigue** is a serious problem on Hong Kong construction sites workers should be empowered to take rests whenever they feel it is necessary and they should also be in a position to **refuse to work** if they believe the situation is dangerous.

9. CONCLUSIONS

This paper has presented a rationale for analysing OHSW in the construction industry. From this analysis a roadmap for OHSW improvement has been developed. The methodology adopted can be used in different cultural contexts but the roadmaps developed will be different dependent on industry maturity.

10. REFERENCES

Engineering News Record [Online], 2019, Available from: http://enr.construction.com/business_management/safety_health/2012/0730-london-olympics-construction-is-safest-in-recent-times.asp [Accessed 16 October 2019].

Hong Kong Housing Authority [Online], 2019, Available from: https://www.housingauthority.gov.hk/mini-site/site-safety/en/publications/performance-statistics/index.html [Accessed 16 October 2019]

Koh, T.Y., Tuuli, M.M. and Rowlinson, S., 2013. A relational approach to high reliability organising for construction project safety: a conceptual framework. In: Smith, S.D and Ahiaga-Dagbui, D.D (Eds.) *Proceedings of the 29th Annual Association of Researchers in Construction Management (ARCOM2013) Conference* (pp.369-379). 2-4 September 2013, Reading, UK.

Lingard, H., Pirzadeh, P., Blismas, N., Wakefield, R. and Kleiner, B., 2014. Exploring the link between early constructor involvement in project decision-making and the efficacy of health and safety risk control. *Construction Management and Economics*, 32(9), pp.918-931.

Lingard, H., Blismas, N., Cooke, T. and Cooper, H., 2009. The model client framework: resources to help Australian Government agencies to promote safe construction. *International Journal of Managing Projects in Business,* 2(1), pp.131-140.

Metropolis Group, Inc. [Online], 2019, Available from: https://metropolisny.com/2019/02/save-the-date-for-the-2019-build-safe-live-safe-conference/, [Accessed 16 October 2019].

Sherratt, F., 2014. Exploring 'Zero Target' safety programmes in the UK construction industry. *Construction Management and Economics*, 32(7-8), pp.737-748.

Shivanthi, B.K.C., Devapriya, K.A.K. and Pandithawatta, T.P.W.S.I., 2019. Disputes between main contractor and subcontractor: Causes and preventions. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 286-296. DOI: doi.org/10.31705/WCS.2019.29. Available at: https://2019.ciobwcs.com/papers

DISPUTES BETWEEN MAIN CONTRACTOR AND SUBCONTRACTOR: CAUSES AND PREVENTIONS

B.K.C. Shivanthi[1], K.A.K. Devapriya[2] and T.P.W.S.I. Pandithawatta[3]

ABSTRACT

Disputes free subcontract is a key to success of modern construction industry which largely depends on subcontracting. Since this effort has to be made on the expense of time and cost, which can be used otherwise to add more value to the project, it is vital to decide an effective mechanism to mitigate subcontract disputes. Considering the need for addressing this fact, this paper aims to investigate causes of subcontract disputes and effective prevention measures. Mixed approach was followed in order to achieve the aim of the study. Thus, a preliminary survey was conducted to validate literature findings and a questionnaire survey was carried out with contractor and subcontractor representatives to identify causes of subcontract disputes and prevention measures. The findings of the preliminary survey were analysed using content analysis technique and data captured through questionnaire survey was evaluated using relative important index and weighted mean. Incompleteness of the contract was identified as the primary reason of disputes in subcontracts. Further, financial issues, risks and uncertainties, collaborative conflicts, opportunistic behaviours of contracting parties and wrong practices also have a significant impact on occurrence of disputes. Proper contract management and proper site management which includes scheduling and effective project management practices were identified as the most effective prevention measures. The contract administrators should identify the things they should necessarily address in the contract and project managers in dispute prevention regards should consider time and cost constraints to prioritize effective prevention measures.

Keywords: *Causes of Disputes; Disputes; Dispute Prevention Mechanisms; Sub-contracts.*

1. INTRODUCTION

Success of any construction project is measured using four basic dimensions, namely time, cost, quality and stakeholder's satisfaction (Long *et al*., 2004). However, in present construction world, it can be seen that two more dimensions have joined to determine the success of a project. According to the modern view, safely executed and dispute free projects which meets time cost quality requirements are identified as successful projects (Zack, 2016). Chang and Chang (2004) identified, satisfaction of parties, who involve in projects as a performance indicator of the project success. However, due to uncertainties of technology, budget and development process construction industry has become more dynamic. Further, a construction project is an effort of a team consists of client,

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consultant, contractor and subcontractor organizations to bring the conceptual project into a material reality within a limited time period (Cherns and Bryant, 1984). This environment has made the industry inevitable of disputes which affect the success of a project. Therefore, it is clear that disputes remain to be an unavoidable factor in constructions due to its complexity and uniqueness. Further, it impacts time, cost and quality measures of a project to a considerable extent and ultimately to the success of the entire project (Jaffar *et al*., 2011). Therefore, it would be helpful if causes of disputes can be identified more systematically. Most of the researches that have been conducted on this area, do not seem to be helpful in making decisions regarding dispute avoidance and mitigation. Hence, this research paper intends to identify underlying causes of disputes between subcontractors and the main contractor and to identify most effective mechanisms to avoid or mitigate these causes.

2. LITERATURE FINDINGS

Disputes are unavoidable within the construction industry (Cheung and Pang, 2012). The adversarial nature of the industry contributes to origin and growth of disputes (Cheung *et al*., 2006). Most of the disputes occur due to unclearly assigned risks, which can be turned into disputes with improper resolution (Acharya *et al*., 2006). Though some of the literature sources have not distinguished conflicts and disputes as two different words, many have identified these as two separate terminologies. A conflict is a long-term more entrenched issue whereas a dispute is a short-term issue that is readily resolved (Burton, 1990). Moreover, conflicts are manageable to an extent of avoiding disputes and unmanaged conflicts can grow into disputes which needs costly (Cakmak and Cakmak, 2014).

2.1 CAUSES OF DISPUTES IN CONSTRUCTION PROJECTS

Construction disputes have distinct characters and thus sources of disputes vary from project to project (Hohns, 1979). However, the author further proposed the five primary sources of construction disputes as existence of errors in the contract documents, cost estimation errors, changed condition, consumer reaction and people involved. Acharya *et al*. (2006) by researching the Korean construction industry has proposed six critical conflicting factors. They are differing site condition, local people obstructions, differences in change order evaluation, errors and omissions in design, excessive quantity of work and double meanings in specification. Mitkus and Mitkus (2014) has presented a different view after evaluating many literatures. According to authors ninety percent of conflicts are occurred due to poor communication process. Further, authors argued that unpredictable site conditions will not create disputes, if parties to the contract agree on risk bearing in advance. If the agreement is unclear about this fact, that means the communication has not happened properly hence it will make conflicts. Moreover, as per Mitkus and Mitkus (2014), unfair behaviour and effects of psychological defences are other two factors that make conflicts.

Harmon (2013) has identified some other causes of disputes. As per author, the size and duration of the project, the complexity of the contract documents, changed conditions, poor communication, limited resources, financial issues, inadequate design, labour issues, and force majeure events are the causes of conflicts. Moreover, Harmon (2013) has described limited resources such as time, money, labour, materials and/or equipment as triggers of conflicts. Moreover, the findings of the author have been affirmed by Chang and Ive (2003), where they identify that disputes occur over the attributes of construction works unspecified in the contract and opportunistic intention to take advantage of one party's defencelessness. Mitropoulos and Howell (2001) have also presented a similar kind of idea in their model for understanding, preventing and resolving project disputes. Accordingly, contractual problems, opportunistic behaviours and uncertainties are the major causes of disputes.

Considering all these causes of disputes, Cheung and Pang, (2012) elaborated a new categorization for causes of disputes. According to authors, incompleteness of the contract is the primary cause of disputes. However, the authors also agreed to the fact that it is impossible to prepare a complete contract document since construction projects face vast uncertainties. Moreover, task and people factors have been identified by authors as fuel of disputes and have categorized all disputes under two categories namely contractual and speculative. Hence the categorization of the Cheung and Pang, (2012) was used. Accordingly, three main groups of disputes were identified as incompleteness of contract, task factors and people factors. Other factors which cannot categorize under any of these groups were identified under the category named other.

3. RESEARCH METHODOLOGY

Initially a preliminary survey was conducted in the form of semi-structured interviews to identify major causes of disputes and effective prevention mechanisms. Moreover, experts were requested to rank each attribute considering the probability of causing dispute of each attribute and effectiveness of respective prevention mechanisms. This ranking was used to weight each attribute. Table 1 represents the details and qualifications of each expert. It was identified that all five experts have been representatives of contractor and subcontractor in different projects.

Table 1: Profile of the interviewees

Reference	Discipline	Designation	Experience (Years)
E1	Contractor	Manager contract administration	13
E2	Contractor	Manager contract administration	19
E3	Contractor	Chief quantity surveyor	11
E4	Consultant	Director	26
E5	Consultant	Director	45

Then the questionnaire was prepared as an online form and sent to the respondents to identify most critical factors that cause disputes and to recognise effective prevention measures. For the purpose of this research, a sample of fifty respondents from C1 and C2 contractor organisations and forty respondents from MEP subcontractors were selected by using purposive sampling technique.

RII was used to analyse ratings given by respondents to find most critical attributes of disputes between main contractor and subcontractor and applicable prevention methods. RII was tabulated using equation (01).

$$\sum w/AN = (5n5+4n4+3n3+2n2+1n1)\ /\ 5N \qquad (01)$$

Where w is the weighting given to each factor by the respondent ranging from 1 to 5, A is the highest weight, N is the total number of samples, n5 total no of respondents who gives 5 to a certain attribute. Then the weighted mean was calculated for each factor considering the RII as the marks to each attribute of a factor and the mean of experts score as the weight (wi). Further, the weighted mean was calculated for each factor group (Fm) by considering factor weighted mean value (Wm) as the marks of each factor and mean of each attribute weight as factor weight (Fw).

Factor weighted mean:

$$Wm = (\sum(wi*RII)) / (\sum wi) \qquad (02)$$

Factor group weighted mean:

$$Fm = (\sum(Fw*Wm) / \sum Fw \qquad (03)$$

Weight of each factor group:

$$wi = (\sum_{i=0}^{n} wi)/n \qquad (04)$$

where, wi = weight of each attribute

4. RESEARCH FINDINGS

4.1 MAJOR CAUSES OF DISPUTES AND EFFECTIVE PREVENTION MEASURES

Foremost objective of this research paper is to identify causes of disputes between main contractor and subcontractor which have a high probability of turning into disputes. According to the analysis it was found out that both contract incompleteness and task factors have the highest weighted mean of 0.8. This means that incompleteness of the contract and task factors such as risks and uncertainties and collaborative conflicts are the major causes of disputes. Moreover, if these factors exist in the project there is a high probability of occurring disputes. Factors categorized under other factor category got a score of 0.7 which means factors such as wrong practices, unavailability of resources and project issues also affect to the occurrence of disputes to a considerable extent. The weighted mean of people factors was noticeably low which was 0.1. Each factor group was analysed in detail, considering the attributes of each factor to gain a comprehensive idea about what actually contributes for disputes and what are the effective prevention mechanisms.

4.1.1 Analysis of Contract Incompleteness Factors that Cause Disputes

Table 2 presents the contract incompleteness factors that have arranged in descending order of weighted mean of factors. Moreover, each attribute within the factor has been arranged in descending order of RII of each factor. Accordingly, ambiguity of the contract document is the major reason which contributes to the disputes in subcontracts of Sri Lankan construction industry. This was also stressed by E2 in the preliminary interview. According to E2 ambiguities of contractual agreements may cause interpretational difficulties. Construction parties with different interest may try to interpret liabilities and obligations in different ways, when the document itself open to more than one interpretation.

Table 2: Analysis of contract related factors that cause disputes

Factor Group	*F*m	Factor	*Wm*	Attributes	RII
Contract incompleteness	0.8	Ambiguity	0.808	The scope of work is unclear	0.82
				The specification is unclear	0.79
		Deficiency	0.753	Rules of variations are not addressed	0.81
				The drawings provide insufficient details	0.71
		Defectiveness	0.736	The details in the drawings are inconsistent	0.75
				Some items are missing from the contract bills	0.72
		Inconsistency	0.725	The drawings are inconsistent with the contract bill	0.77
				The drawings contradict with the specification	0.68
		Non-compliance with legal requirements	0.609	VAT qualifications are not fulfilled	0.63
				Legislation issues	0.62
				Taxation issues	0.58

Moreover, according to Table 2, factors such as deficiency, defectiveness and inconsistency of contract document have weighted means between 0.75 and 0.70. This means lack of information, defects of information given and inconsistencies throughout the contract document have a high contribution to the occurrences of disputes in subcontracts. However, non-compliances with legal requirements have quite less weighted mean when comparing with the other factors.

a) Prevention mechanisms for contract incompleteness factors

Clearly written contract with no ambiguity has been identified as the most effective way of avoiding disputes arises due to contract incompleteness (refer Table 3). However, most experts said that this option is not that easy and practical due to limitations such as time available, information available and cooperate level of design parties. However, the parties involve in contract documentation should try their best to avoid the ambiguities.

Table 3: Prevention mechanisms for contract incompleteness

Avoidance mechanisms	RII
Clearly written contract with no ambiguity	0.90
Follow proper contract process,	0.89
Sign MoU after clarifying details if necessary	0.87
Use standard contracts	0.86
Corresponding subcontracts	0.86
Reasonable time allowance for the design team to produce clear and complete contract documents with no or minimum errors and discrepancies	0.84
Efficient quality control techniques and mechanisms during the design process to minimize errors, mismatches, and discrepancies in contact documents,	0.83
Read the contract several times before signing it to understand any unclear clauses and	0.81

Avoidance mechanisms	RII
Use special contracting provisions and practices that have been used successfully on past project	0.74
Check the compliance with legal requirements of each party	0.74
Let a third party to read contract documents before the bidding stage	0.70

4.1.2 Analysis of Task Factors that Cause Disputes

Causes of task factors are also contribute to the occurrence of disputes to a considerable extent and it has same impacts as issues related to the contract incompleteness (refer Table 4). Moreover, it is clear that collaborative conflicts or clashes between the responsibilities of parties contribute to disputes to a greater extent. Construction process is a collaborative task and each party depend on others. When one party fails to do his part on required manner or in according to the contract requirement disputes can occur if these issues are not addressed on timely manner. Out of the collaborative conflicts, contractor delays progress payment has got the highest RII value.

Table 4: Analysis of task related factors that cause disputes

Factor Group	*F*m	Factor	*Wm*	Attributes	RII
Task Factors	0.8	Collaborative Conflicts	0.776	Contractor delays progress payment	0.84
				Slow progress of subcontractor	0.84
				Contractor fails to meet milestones on time	0.83
				Contractor fails to issue instructions on time	0.82
				Engineer fails to provide adequate site investigation details	0.77
				Architect fails to issue instruction within time	0.75
				Client request changes unreasonably	0.75
				Nominated supplier delays in works	0.74
				Consultant fails to give information within due time	0.74
				Client requests acceleration unreasonably	0.74
				Nominated subcontractor delays in works	0.73
		Risk and Uncertainties	0.734	Shortage of labour	0.8
				Shortage of materials	0.79
				Variations	0.79
				Force majeure events	0.77
				Fluctuations in material price	0.64
				Fluctuations in labour cost	0.6

The results of the analysis can be explained through the perspectives of the experts. Experts identified collaborative issues as more crucial factors of disputes. In construction industry subcontractors procure the services of suppliers on credit basis and payments to labours and staff done at the end of the month, when the subcontractor receives the interim payments. Hence, if the payments get delay subcontractor cannot continue the work and it will disrupt the works. This will subsequently cause disputes on site. Moreover, risks and uncertainties, which are considered as unavoidable features of constructions, also have a significant impact on subcontract disputes. Out of the risks and uncertainties, shortage of labour and material have a significantly high RII value. This means if a material or labour shortage occur, there is a high probability of dispute occurrence. Variations also scored a high value for RII. According to E1, not having written communication system is the main reason to the disputes relates with variations. However, fluctuations of labour prices and material prices have scored a lesser value. The reason was explained by E2. The expert stated that "generally parties come to an agreement on price fluctuations at the beginning of the project or they keep contingencies to cover these uncertainties". But E3 mentioned that, when there is no proper agreement and when the profit margin of subcontractor is low, issues will arise with price fluctuations. This is mainly because of the subcontractor's inability to manage the cash flow as expected.

a) Prevention mechanisms for tasks factors

Prevention mechanisms for tasks factors are provided in Table 5. Using standard contracts has been identified by the respondents as the most effective mechanisms to avoid disputes relates to risks and uncertainties. According to E1 within the Sri Lankan context, many contractors does not use standard contract forms for small scale subcontracts and use own preferred formats of contract. As a result of that, there is a high chance that these ad hoc formats do not cover all the risks and uncertainties that may arise. Appropriate allocation of risks and cost allowances for potential risks have also gained a high weight. However, the weight obtained by risk sharing is comparatively low.

Table 5: Prevention mechanisms for tasks factors

Factor group	Avoidance mechanisms	RII
Risks and Uncertainties	Using standard contracts	0.84
	Allocating risks appropriately	0.78
	Cost allowances for potential additional costs in uncertainty areas	0.76
	Risk assessment and identify actions to address them	0.75
	Conducting constructability review	0.75
	Risk sharing	0.66
Collaborative conflicts	Record keeping	0.88
	Proper supervision	0.87
	Proper documentation	0.87
	Follow good communication procedures	0.87
	Adhere to proper contract administration procedures	0.85
	Disputes resolving tools should be implemented contractually.	0.84
	The use of conflicts resolution techniques at site level	0.83
	Improve the communication of plans from planners to users	0.77
	Appoint a dispute resolution expert (DAB)	0.77
	Establish reliable production management process	0.76

To avoid disputes, cause from collaborative conflicts, record keeping, proper supervision, proper documentation and following good communication procedures have been identified as important mechanisms. Appointing dispute resolution expert or Dispute Adjudication Boards (DAB) has not been recognized much by respondents. According to the opinions of E2, industry considers DAB as an additional cost to the project. This high cost associate with the DAB process might be the reason for the low RII value.

4.1.3 Analysis of other Factors that Cause Disputes

According to Table 6, availability of resources namely financial issues of contractor and subcontractor have a high contribution to the disputes. According to E2, if the contractor waits to pay subcontractor until he receives his payments from employer, subcontractor will not be able to do his procurement on time. If contractor plans to do payment in such a way, he should select financially capable subcontractor at the beginning. Moreover, sometimes contractor delays payment to the subcontractor to receive the interest of money deposited by employer. Not having written communication has been stressed as the most serious wrong practice out of many wrong practices. The probability of happening disputes due to complexity of the project is rather low. According to the experts, this is mainly because the parties accept the project complexity and adjust their selves quickly to work on it.

Table 6: Analysis of other causes of disputes

Factor Group	Fm	Factor	Wm	Attributes	RII
Other	0.6	Unavailability of Resources	0.757	Financial issues of contractor	0.80
				Financial issues of subcontractor	0.73
		Wrong Practices	0.733	Not having written communication	0.87
				Not having a proper agreement	0.70
				Not evaluating bids properly	0.70
				Awarding contract to the lowest bid	0.67
		Project Issues	0.564	Limitation of the site and environment	0.65
				Complexity	0.47

a) Prevention mechanisms for other factors

Prevention mechanisms for other factors are provided in Table 7.

Table 7: Prevention mechanisms to other factors

Avoidance mechanisms	RII
On time payments	0.92
Have procurement systems align with the project attributes	0.85
Proper evaluation before selecting parties	0.84
Do not select only based on lowest bid	0.81
Regular discussions with respective parties	0.75

On time payments has been identified by the respondents as the most critical factor in avoiding disputes. According to E4, subcontractors are generally paid when main contractor get the payment. Hence, payment delays by any party to the contract may affect the project seriously. Therefore. every one of the projects should not delay their liabilities related to payments without any proper reason. Procurement systems align with the project attributes has been identified as the second most effective mechanism to avoid disputes. "Avoid selection of subcontractors solely based on lowest bid" got a low RII value. This means the industry accept the fact that competitive bidding process will lead to a lesser number of disputes. As per E5, after selecting a set of equally competent sub-contractors, cost is the only basis which provide a criterion to evaluate them. Using this kind of legitimate selection method always reduce the number of disputes within the project.

4.1.4 Analysis of People Factors that Cause Disputes

The overall weighted mean of people factors is considerably low which is only 0.1. However, as per the findings opportunistic behaviours and other attributes have obtained a significantly high RII values (0.75-0.70) and affective conflicts had obtained a considerably low RII value (0.47) (refer Table 8). This implies that emotional features of parties do not create a considerable impact on origins of disputes. Since the opportunistic behaviours are manageable through provisions of contract it is avoidable before turning into a dispute. However, having high RII values demonstrates the difficulty or the inability to prepare a contract document to cover all these aspects. Moreover, majority of the experts agree that domestic subcontractors cause less disputes due to long-term relationships.

Table 8: Analysis of people related factors that cause disputes

Factor Group	Fm	Factor	Wm	Attributes	RII
People Factors	0.1	Opportunistic behavior	0.751	Contractor rejects outright monetary claim submitted by the subcontractor	0.83
				Contractor rejects outright extension of time claim submitted by the subcontractor	0.82
				Subcontractor over claims costs for progress acceleration	0.76
				Subcontractor purposely works below the specified standard	0.71
				Subcontractor purposely fails to disclose the specification of the materials used	0.7
				Subcontractor purposely fails to notify omission of items in the contract bills of quantity	0.67
		Other	0.731	Poor communication	0.84
				Capability level of staff to manage the process	0.76
				Cooperate level of parties	0.69
				Interpersonal skills	0.59
		Affective Conflicts	0.47	Excessively neat or overly exact attributes are displayed by member(s) of the project team	0.49
				Psychological distress such as fear, sadness, anger, and guilt are displayed by member(s) of the project team	0.47
				Emotions such as dominance, assertion, bullying, and forcefulness are displayed by member(s) of the project team project team	0.46

a) Prevention mechanisms for people factors

When analysing people factors that contribute to the causes of disputes (refer Table 9), it is clear that opportunistic behaviours of parties makes a higher contribution than others. Hence, most prevention mechanisms were directed to avoid these opportunistic behaviours of contracting parties. Proper record keeping and documentation process will massively help to prevent disputes relates to opportunistic behaviour as it gives a written evidence about the things happened in the site. Promote relations at multiple levels has get the least RII value in the prevention factor list. According to E3, it is not practical to manage relations at multiple levels and it is always advisable to have single point communications to avoid disputes.

Table 9: Prevention mechanisms to people factors

Avoidance mechanisms	RII
Record keeping and documentation	0.87
Keep each other informed about their actions during the project	0.85
Assign managers and superintendents with strong cooperative skills and attitudes	0.84
Parties to the contract should take proactive steps to foster a cooperative attitude towards dispute avoidance	0.81
Quality management	0.77
Fair contract and resolution process	0.77
Selecting parties who have work together in previous projects or based on their reputation	0.76
Set up joint training in negotiations and problem-solving	0.73
Discuss interests and expectations	0.69
Conduct teambuilding to develop common project goals and processes (Partnering)	0.67
Promote relations at multiple levels	0.55

5. CONCLUSIONS

With the advanced and sophisticated clients' requirements it has become more difficult for the contracting firms to undertake a project single-handedly, due to the limited number of resources. Therefore, construction product is a collaborative effort of different specialists. However, if a dispute occurs between these specialists and the main contractor, it will be harmful to the progression of the project. Therefore, it is vital to have a proper understanding about strategies and prevention mechanisms to avoid any dispute between these parties. As per the findings of this research, attributes that come under the contract incompleteness factors and task factors are the causes that have the highest probability to turn into disputes. Attributes that come under people factors are the lowest probable causes of disputes. Clearly written contracts with no ambiguities, proper contract processes, signing MoU after clarifying details, using standard contracts and corresponding subcontracts were identified as most effective preventing mechanisms of disputes related to contract incompleteness. Moreover, using standard contracts, appropriate allocation of risks and cost allowances for uncertain areas were identified as the most suitable avoidance mechanisms for disputes related to risks and uncertainties. Further, to avoid disputes relate to collaborative conflicts, record keeping, proper supervision, proper documentation and good communication procedures were recognised as effective prevention mechanisms. Moreover, it was identified that affective conflicts such as dominance, assertion and bullying do not have a considerable high probability to cause a dispute. Further, different mechanisms to avoid disputes should be done at different stages of the project and some mechanisms should be continued throughout the project.

6. 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), pp.543-566.

Burton, J. W., 1990. *Conflict: Resolution and Prevention*. St. Martin's press.

Cakmak, E. and Cakmak, P. I., 2014. An Analysis of Causes of Disputes in The Construction Industry Using Analytical Network Process. *Procedia-Social and Behavioural Sciences*, 109, pp.183-187.

Chan, A.P. and Chan, A.P., 2004. Key performance indicators for measuring construction success. *Benchmarking: an international journal*, *11*(2), pp.203-221.

Chang, C. Y. and Ive, G., 2003. Discussion of "Model for Understanding, Preventing, and Resolving Project Disputes" by Panagiotis Mitropoulos and Gregory Howell. *Journal of Construction Engineering and Management*, 129(3), pp.231-232.

Cherns, A.B. and Bryant, D.T., 1984. Studying the client's role in construction management. *Construction management and economics*, *2*(2), pp.177-184.

Cheung, S. O. and Pang, K., 2012. Anatomy of Construction Disputes. *Journal of Construction Engineering and Management*, 139(1), pp.15-23.

Cheung, S. O., Yiu, T. W. and Yeung, S. F., 2006. A Study of Styles and Outcomes in Construction Dispute Negotiation. *Journal of Construction Engineering and Management*, 132(8), pp.805-814.

Harmon, K., 2003. Conflicts Between Owner and Contractors: Proposed Intervention Process. *Journal of Management in Engineering*, 19(3), pp.121-125.

Hohns, H. M., 1979. *Preventing and Solving Construction Contract Disputes*. Van Nostrand Reinhold Company.

Jaffar, N., Abdul, T. and Shuib, M. N., 2011. Factors of Conflict in Construction Industry: A Literature Review. *Procedia Engineering*, 20, pp.193-202.

Long, N. D., Ogunlana, S., Quang, T. and Lam, K. C., 2004. Large Construction Projects in Developing Countries: A Case Study from Vietnam. *International Journal of Project Management*, 22(7), pp.553-561.

Mitkus, S. and Mitkus, T., 2014. Causes of Conflicts in a Construction Industry: A Communicational Approach. *Procedia - Social and Behavioural Sciences*, 110, pp.777-786.

Mitropoulos, P. and Howell, G., 2001. Model for Understanding, Preventing, And Resolving Project Disputes. *Journal of Construction Engineering and Management*, 127(3), pp.223-231.

Zack, J., 2016. *Delivering Dispute Free Projects - Does Partnering Help?.* Navigent Construction Forum.

Ranga, M.K.G.T., Mallawarachchi, H. and Withanage, K.T., 2019. Effective partner selection model for construction joint ventures in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 297 -307. DOI: doi.org/10.31705/WCS.2019.30. Available at: https://2019.ciobwcs.com/papers

EFFECTIVE PARTNER SELECTION MODEL FOR CONSTRUCTION JOINT VENTURES IN SRI LANKA

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ABSTRACT

Construction Joint Venture (CJV) is a response to the complex and competitive environment which characterised the nature of construction industry. However, various disputes arose in CJVs which impede the successful completion of the construction project especially as a result of the ineffective partner selection. Nevertheless, the literature thus far has failed to provide an effective partner selection for the CJVs since none of the studies subjected to partner selection in CJVs. Hence, the research is aimed to investigate the existing practice of partner selection in order to develop a model for avoiding disputes in CJVs in Sri Lanka. Three rounds of Delphi survey were conducted through the adoption of quantitative approach with the participation of experts who have plenty of experience and adequate knowledge on CJVs. The identified joint venture (JV) partner selection criteria from literature synthesis were the base for the adoption of the CJV partner selection criteria developed using the relative importance index. Consequently, effective CJV partner selection model was proposed based on the effect of dispute avoidance. The concern of literature and industry experts proved the absence of the standard partner selection criteria for the CJVs. However, guidelines for selecting partners provided in tender documents were followed by only contractors in order to fulfil the required criteria merely towards winning the project. Thus, the partner selection model proposed in this research provides a basis to select the most appropriate and the best partner for CJVs by evaluating all particular skills and capacities which may avoid having the future disputes.

Keywords*: Construction Joint Ventures; Disputes; Partner Selection; Selection Model.*

1. INTRODUCTION

Creating JVs is a response to the challenges of complex business environment in order to succeed in this global arena (Tatoglu, 2000). Hence, the JV approach is necessitated for construction organisations for fulfilling their desire to enter new construction markets around the world (Mohammed, 2003). Thus, due to the growing scale and complexity of construction projects, organizations have begun to set up CJVs to utilize the resources of

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partners (Zhao *et al*., 2013). However, Habib and Burnett (1989) found that managing the JV has proven to be particularly difficult. CJVs are identified as one of common sources cause conflicts in construction industry (Kumaraswamy, 1997).

If conflicts are not well managed, they turn in to disputes (Cakmak and Cakmak, 2014). Disputes that occurred in CJVs may cause project delays, undermine team spirit, increase project costs, and damage continuing business relationships (Cheung andSuen, 2002). Disputes are main factor which prevent the successfully completion of the construction project (Cakmak and Cakmak, 2014). The dispute avoidance is the best technique to deal with the disputes (Kumaraswamy, 1997). However, potential reason for dispute occurrence in any JV is the differences between partners (Williams and Lilley, 1993; Munns *et al*., 2000). In order to gain success towards the JVs, the paramount importance lies with the selection of an appropriate partner (Williams and Lilley, 1993). Thus, Gale and Luo (2004) identified that the selection of a suitable partner is the most crucial factor and the first step leading JVs towards success after deciding to form a JV. Furthermore, Geringer (1991) demonstrated that partner selection is an important variable in the formation and operation of JVs. Therefore, Habib and Burnnet (1989) argued that JVs should select partners carefully much like a marriage (Geringer, 1991).

Even though partner selection has been recognised as a critical factor that affect to the disputes in construction industry, none of researches have been explored on the disputes in CJVs. Hence, literature gap remaining on the partner selection method on CJV especially as a method of avoiding disputes. Therefore, the purpose of this research is to propose a partner selection model for CJVs with the aim of assisting construction firms to prevent the disputes that adversely affect to the performance of the firms.

2. LITERATURE SYNTHESIS

2.1 CONSTRUCTION JOINT VENTURES

The desktop literature on CJVs in building and construction unveils that there is no consentient definition for CJVs (Hong and Chan, 2014). Thus, the scope and definition of CJV are not internationally standardised (Prasitsom and Likhitruangsilp, 2012). Ashley (1980) defined that "CJV is a partnership of contractors who have formed a business alliance for the purpose of undertaking a project" (p.267) only respect to CJVs formed by contractors. Girmscheid and Brockmann (2009) specified that CJVs are non-equity alliances which are based on contracts and non-ownership relationships. However, CJV differs from the concept of alliance as it is based on project agreements (Badger *et al*., 1993). By collaborating and analysing all related circumstances of CJVs, in this research the CJV can be defined as a temporary project based contractual arrangement or agreement between two or more parties of construction such as AEC firms for operating and obligating specific construction project.

2.2 PARTNER SELECTION IN CONSTRUCTION JOINT VENTURES

The detailed partner-selection process is considered as an important role in ensuring continued cooperation between the two companies (Williams and Lilley, 1993). The choice of the most suitable partner is vital to the partner selection process (Hitt *et al*., 2000) since performance outcomes of the JV will be more significantly considerably influenced by the nature of the chosen partner (Geringer, 1991; Glaister and Buckley, 1997). Furthermore, specific chosen partner can affect in the entire mix of available skills and resources, the operating policies and procedures, and the short- and long-term viability of JV (Geringer, 1991).

2.2.1 Partner Selection Criteria

Several criteria need to be considered while choosing partners for a particular project (Ozorhon *et al*., 2007). Two-fold typology of partner selection criteria as task related and partner related criteria is introduced by Geringer (1991) for partner selection as task related criteria and partner related criteria. The task related and partner related dimensions are distinguished in partner selection criteria for providing better understanding on partner selection process and procedures used by firms to select partners (Tatoglu, 2000). In particular, criteria associated with operational skills and resources that JV requires for competitive success are considered as task related criteria and criteria associated with efficiency and effectiveness of partners' cooperation treated as partner related criteria (Geringer, 1991).

Almost all researchers who have studied on JV partner selection such as Al-Khalifa and Peterson (1999), Glaister, 1999, Glaister and Buckley (1997) and Tatoglu (2000) use the two-fold typology that Geringer (1991) introduced as a base in reviewing. Therefore, the partner selection criteria stated in Table 1 is adopted in this research.

Table 1: Partner selection criteria

Task related partner selection criteria	Partner related partner selection criteria
• Access to technology	• Experience in technology applications
• Access to knowledge of production process	• International experience
• Access to knowledge of local culture	• Financial status/resources
• Access to knowledge to local market	• Management in depth
• Access to regulatory permits	• Partner's ability to negotiate with government
• Access to labour	• Relatedness of partner's business
• Access to product itself	• Complementarity of partner's resource contribution
• Access to distribution channels	• Established marketing and distribution system
• Access to materials/natural resources	• The partner company's size or structure
• Access to links with major buyers	• Trust and compatibility between the top management teams
• Access to brand names	• Degree of local favourable past association between partners
• Access to capital	• Reputation
• Partner's ability to raise funds from local institutions	• Partner's national or corporate culture

Sources: Geringer (1991); Glaister and Buckley (1997); Tatoglu (2000)

As per Table 1, the partner related criteria which comprised of thirteen number of task-related criteria and thirteen number of partner-related criteria was selected for this research based on the criteria reviewed by the authors above-stated. However, all the criteria Table 1 includes, result of the criteria that introduced by Geringer (1991), Glaister and Buckley (1997) and Tatoglu (2000).

3. RESEARCH METHODOLOGY

Quantitative techniques applied for this research as the research is aimed to identify partner selection criteria that effect on dispute avoidance. Delphi technique was adopted as data collection technique which provides collaborative data at the aim of obtaining most reliable census from group of experts. The expert panel for carrying out the Delphi questionnaire survey was selected through convenience sampling method in non-probability sampling technique as according to cost/time basis approach since the research has to be done in limited cost and time constraints. Thus, 30 experts were selected from the construction industry including Project Managers (6), Contract Administrators (5), Quantity Surveyors (12) and Engineers (7), who have more than five years of working experience in the construction industry especially in CJVs. Kincaid (2003), Skulmoski *et al*. (2007) and Xia and Chan (2012) stated that three round Delphi is typical and usually used by most of researches. Thus, three or more rounds are required only for the researches which are conducted by heterogeneous sample (Skulmoski *et al*., 2007). Furthermore, Delbecq *et al*. (1975) demonstrated that two or three iteration Delphi is sufficient for most research. Table 2 illustrates the entire format of the tree Delphi rounds in terms of instrument, purpose, experts and database.

Table 2: Format of Delphi rounds

	Round one	Round two	Round three
Instrument	Questionnaire 1	Questionnaire 2 And CJV Partner selection model	CJV Partner selection model
Purpose	Gathering partner selection criteria which are applied in Sri Lankan CJVs	Ranking CJV partner selection criteria on dispute avoidance	Developing and validating CJV partner selection model
Number of experts selected	30	30	30
Data base for the design of Questionnaire/ model	Literature review	Results gained from round one	Results gained from round two questionnaire survey

In Delphi round one and two, the questionnaires were used to collect the data. Thus, the results of round one was validated in round two and results of round two validated in round three through the model. The purposes of every round were pointed out how the objectives of the research are accomplished with proceeding Delphi rounds. The data collected through questionnaire surveys in Delphi method and document reviews were analysed using relative importance index (RII). RII was used as an analysis technique for questionnaire responses, which has been used by many researchers to determine the relative significance of the attributes (Tayalan *et al*., 2014). RII is calculated using equation (01).

$$RII = \frac{\Sigma W}{A \times N}, (0 - index < 1) \qquad (01)$$

Where, w = weighting given to each factor by the respondents; A = highest weight; N = total number of respondents.

In the research, the criteria's RII values more than 0.80 considered as 'Most Important', more than 0.6 recognized as 'Important', more than o.4 considered as 'Somewhat important', more than 0.2 considered as 'Little important' and values less than 0.2 considered as 'Not important' which obtained from using Five-Likert scale (Anuruddhika *et al*., 2016).

4. DATA ANALYSIS AND FINDINGS

4.1 INVESTIGATING THE EXISTING PRACTICE OF PARTNER SELECTION: DELPHI ROUND ONE

The current practice of partner selection investigated through the questionnaire survey results that obtained by the experts on evaluating the base used to select the partners (refer Table 3), the disputes arisen due to ineffective partner selection and exploring documents that they used to select partners.

Table 3: Existing partner selection practice

Base of CJV partner selection	Number of responses	Percentage of responses (%)
Previous experience	28	93.33%
Contacts	27	90.00%
Other	0	0%
Contacts and previous experience	27	90.00%
Non response	2	6.67%

According to Table 2, it is confirmed that the Sri Lankan CJVs are not practised any standard process for partner selection in forming CJVs as the contacts and previous experience cannot be considered as proper partner selection practice. Therefore, it is established that providing a CJV partner selection model is an essential need for the construction industry. As a result of not practising standard procedure to select partners, various disputes are arisen in the CJVs due to the ineffective partner selection. The common disputes occurred in CJVs due to inefficient partner selection which was contented by the experts are listed in Table 4.

Table 4: Common disputes occurred in CJVs

Reasons	Disputes
Inefficient partner selection	• Disputes about the scope of works • Disputes regard to work and profit sharing • Clash of cooperate culture /Cultural disputes • Financial disputes • Disputes about the intended capabilities and actual capabilities of the partner • Disputes on coordination • Disputes with clients due to inappropriate partners • Dispute arising in Construction stage regards to responsibility matrix • Dispute arising regards to warranties and undertaking

Hence, it is confirmed that effective partner selection leads to dispute avoidance of CJVs since more disputes occurred due to the inefficient partner selection. Thus, the experts demonstrated that ineffective partner selection affects every project circumstance interrupting effective project completion. Moreover, the disputes that occurred due to ineffective partner selection effect all aspects of the project; time, cost and quality. Hence, practising effective partner selection, the project can be completed in a profitable and dispute avoidable nature as the CJV performance is enhanced. Although it is found that no any standard guidelines practised by the construction organisations in order to select the partners for the CJVs, the guidelines provided in the tender documents are fulfilled by contractor organisations in selection of CJV partners. Thus, it is essential adhere criteria as according to the tender documents of projects especially in funded projects and public projects in order to win the project. The guidelines that provided by the tender documents can be listed as Asian Development Bank (ADB) guidelines, National Procurement Agency (NPA) guidelines, guidelines on government tender procedure and world bank guidelines. However, these guidelines are limited to contractor organisations as well the tender guidelines only used in CJVs which form to bid for projects. Therefore, it demonstrates that any standard guideline of organisation which can be used for forming CJVs in any circumstance is not practised by the organisation to select the CJV partners.

4.2 IDENTIFICATION OF PARTNER SELECTION CRITERIA APPLIED IN CONSTRUCTION JOINT VENTURES: DELPHI ROUND ONE

In the same Delphi round, the gathered JV partner selection criteria (refer Table 1) were surveyed, analysed and ranked on the applicability in the CJVs. The findings of the survey are presented in Table 5.

Table 5: Applicability of JV partner selection criteria in CJVs

Category	Partner Selection Criteria	RII	Rank
Task related criteria	Access to capital	0.87	1
	Access to technology	0.85	2
	Access to links with major clients	0.80	3
	Access to regulatory permits	0.78	4
	Partner's ability to raise funds from local institutions	0.77	5
	Access to materials/natural resources	0.73	6
	Access to transportation	0.72	7
	Access to product itself	0.70	8
	Access to brand names	0.69	9
	Access to labour	0.68	10
	Access to knowledge to local market	0.35	11
	Access to knowledge of local culture	0.33	12
	Access to knowledge of production process	0.32	13
Partner related criteria	Financial status/resources	0.94	1
	Management in depth	0.88	2
	Experience in technology applications	0.85	3

Category	Partner Selection Criteria	RII	Rank
	Reputation	0.84	4
	Complementarity of partner's resource contribution	0.83	5
	Degree of favourable past association between partners	0.79	6
	The partner company's size or structure	0.75	7
	Partner's national or corporate culture	0.74	8
	Trust and compatibility between the top management teams	0.73	9
	Established marketing and distribution system	0.69	10
	Partners ability to negotiate with government	0.61	11
	International experience	0.33	12
	Relatedness of partner's business	0.32	13

According to Table 5, access to capital is the top rank in task-related criteria, showing the highest RII (0.87). Subsequently, access to technology and access to link with major clients are the top ranks donates to RII of 0.85, 0.80 in sequence. In task-related criteria, access to knowledge of production process has the lowest rank contributed to lowest RII (0.32) values. Thus, the partner-related criterion of financial status/ resources is the highest rank in partner-related criteria showing RII of 0.94. Further financial status/ resources is the topmost criteria of all partner selection criteria which takes highest RII values of analysis. Relatedness of partner's business is given the lowest rank in partner-related criteria due to its lowest RII (0.32) values. The criteria which have more than RII value 0.60 are selected for the Delphi two round considering the lesser values other criteria have. Since the criteria which have RII values more than 0.4 comprised of 'most important', 'important' and 'somewhat important' criteria, the selected partner selection criteria for Delphi round two are comprised above-stated criteria, not including 'little important' and 'not important' criteria.

4.3 EVALUATION OF PARTNER SELECTION CRITERIA ON DISPUTE AVOIDANCE: DELPHI ROUND TWO

The analysis of selected partner selection criteria in Delphi round one in term of applicability in CJVs on dispute avoidance is illustrated in Table 6.

According to Table 6, the topmost partner selection criteria of the task-related criteria is exacted by the criterion of access to capital with the highest RII value (0.73). Access to transportation is the lowermost criteria that effects avoiding disputes in CJVs respect to having lowest RII value (0.45) in task-related criteria. Besides this criterion can be considered as the minimally effected criterion to dispute avoidance in CJVs compared to all task-related and partner-related criteria. In partner-related criteria, the topmost criterion is obtained by financial status/ resources regard to its RII value of 0.87. The partner-related of financial status/resources, experience in technology applications and complementarity of partner's resources are having high WMR and RII values rather than the task-related criteria. Hence these criteria become topmost criteria in partner selection which effects dispute avoidance in CJVs. Established marketing and distribution system is the bottom criterion which has 0.48 RII value. The criteria that have RII values more than 0.6 which considered as 'important' criteria selected for the model development of research.

Table 6: Evaluation of partner selection criteria on dispute avoidance

Category	Partner Selection Criteria	RII	Rank
Task-related criteria	Access to capital	0.73	1
	Partner's ability to raise funds from local institutions	0.69	2
	Access to materials/natural resources	0.65	3
	Access to technology	0.62	4
	Access to brand names	0.60	5
	Access to regulatory permits	0.59	6
	Access to links with major clients	0.58	7
	Access to labour	0.55	8
	Access to product itself	0.47	9
	Access to transportation	0.45	10
Partner-related criteria	Financial status/resources	0.87	1
	Experience in technology applications	0.86	2
	Complementarity of partner's resource contribution	0.81	3
	Degree of favourable past association between partners	0.75	4
	Partners ability to negotiate with government	0.74	5
	Management in depth	0.73	6
	Reputation	0.72	7
	Partner's national or corporate culture	0.68	8
	Trust and compatibility between the top management teams	0.67	9
	The partner company's size or structure	0.58	10
	Established marketing and distribution system	0.48	11

4.4 DEVELOPMENT AND VALIDATION OF PARTNER SELECTION MODEL: DELPHI ROUND THREE

Table 7 demonstrates the developed partner selection model for CJVs in construction industry. Hence, the model was developed with regards to the minor changes supposed in the validation by the experts.

Table 7 depicts the partner selection model that developed from the analysis of the criteria are arranged in a successive manner based on the dispute avoidance in CJVs. Thus, the RII value obtained from the data analysis and the percentages which gained from the selected criteria's RII values shown in Table 7. Hence, the effect of disputes avoidance regard to each criterion is delivered in terms of RII and percentage from the partner selection criteria model contained. Therefore, adhering to the model, the organisation gains the ability to value the dispute avoidance that CJV can encounter in terms of the criteria which they used for the CJV partner selection.

Table 7: Construction joint venture partner selection model

Partner Selection Model		
	RII	**Percentage**
Task-related criteria		
Access to capital	0.73	7%
Partner's ability to raise funds from local institutions	0.69	7%
Access to materials/natural resources	0.65	6%
Access to technology	0.62	6%
Access to brand names	0.60	6%
Partner-related criteria		
Financial status/resources	0.87	9%
Experience in technology applications	0.86	9%
Complementarity of partner's resource contribution	0.81	8%
Degree of favourable past association between partners	0.75	7%
Partners ability to negotiate with government	0.74	7%
Management in depth	0.72	7%
Reputation	0.70	7%
Partner's national or corporate culture	0.68	7%
Trust and compatibility between the top management teams	0.67	7%
Total	**10.09**	**100%**

5. CONCLUSIONS AND RECOMMENDATIONS

CJV is a popular collaborative form of establishment in the construction industry due to the numerous benefits it accumulates in order to sustain in the competitive complex business environment. The partner selection is a crucial step in CJV formation as the success of the CJV highly depends on it. The partner selection global practice of JV was comprehensively analysed through literature and the JV partner selection criteria which are in general context of JVs gathered from the current literature. Based on the JV partner selection criteria of the research gained as literature outcome, the CJV applied partner selection criteria developed in Delphi round one. In addition, the existing partner selection process identified in same round. Therefore, it was confirmed that any standard or regular guideline or criteria not practised by the construction organisations to select CJV partners. However, the contractor organisations adhere to the CJV partner requirements of tender documents when provided in order to bid for a project. Thus, the disputes arisen due to ineffective partner selection identified confirmed that the effective partner selection lead a CJV to dispute avoidance.

As a result of Delphi round two, the partner selection criteria evaluated on the dispute avoidance in CJVs and effective partner selection criteria for model development was gained accomplishing the objectives of the research. Therefore, in order to provide effective CJV partner selection for construction industry, an effective partner selection model is developed as an ultimate outcome of the research together with the expert validation in Delphi round three. The model was presented as an effective partner selection model for CJVs with the aid of experts' suggestions that encountered through the validation for the betterment of the construction industry. Thus, this partner selection model will be a guideline for CJVs in order to succeed in the construction industry where no any standard or effective guideline was found. Accordingly, the partner selection model proposed in the research provides a base to select the most appropriate and best partner evaluating his all particular skills and capacities together with avoiding disputes in CJVs.

6. REFERENCES

Al-Khalifa, A. K., and Peterson, S. E., 1999. The partner selection process in international joint ventures. *European Journal of Marketing*, 33(11/12), pp.1064-1081.

Anuruddhika, M. M. C., Perera, B. A. K. S., and Rodrigo, M. N. N., 2016. Management of delays in design and build projects undertaken in Sri Lanka, In *Proceedings of the Conference on the International Institute for Infrastructure Resilience and Reconstruction*, pp.191-198.

Ashley, D. B., 1980. Construction joint ventures. *Journal of the Construction Division*, 106(3), pp.267-280.

Badger, W. W., Mulligan, D. E., Carter II, J. P., Gay, S. W., Held, M. S. and Markham, C. S., Harvard System [online]. 1993. *Alliances in International Construction*, Available from https://books.google.lk/books?id=VXnk5tDBVoC&pg=PP5&lpg=PP5&dq=%22Alliances+in+International+Construction%22&source=bl&ots=9GXM3Uaoki&sig=2eu7zLDTUiM4OaauU778BXVE0YY&hl=en&sa=X&ved=0ahUKEwjHuOWvnIDUAhXFMI8KHcRxCDQQ6AEIIzAB#v=onepage&q&f=false

Cakmak, E., and Cakmak, P. I., 2014. An analysis of causes of disputes in the construction industry using analytical network process. *Procedia-Social and Behavioral Sciences*, 109, pp.183-187.

Chan, D. W. M., and Kumaraswamy, M. M., 1997. A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, 15(1), pp.55-63.

Cheung, S. O., and Suen, H. C., 2002. A multi-attribute utility model for dispute resolution strategy selection. *Construction Management and Economics*, 20(7), pp.557-568.

Delbecq, A. L., Van de Ven, A. H., and Gustafson, D. H., 1975. *Group techniques for program planning: A guide to nominal group and Delphi processes*. Glenview, Illinois: Scott, Foresman and Company.

Gale, A., and Luo, J., 2004. Factors affecting construction joint ventures in China. *International Journal of Project Management*, 22(1), pp.33-42.

Geringer, J. M., 1991. Strategic determinants of partner selection criteria in international joint ventures. *Journal of International Business Studies*, 22(1), pp.41-62.

Girmscheid, G. and Brockmann, C., 2009. Inter-and intraorganizational trust in international construction joint ventures. *Journal of Construction Engineering and Management*, 136(3), pp.353-360.

Glaister, K. W., 1999. Strategic motives and selection criteria in international joint ventures: perspectives of UK firms and foreign firms. *International Business Organization*, pp.156-175, UK: Palgrave Macmillan.

Gunduz, M., Nielsen, Y., and Ozdemir, M., 2013. Quantification of delay factors using the relative importance index method for construction projects in Turkey. *Journal of Management in Engineering*, 29(2), pp.133-139.

Habib, G. M., and Burnett, J. J., 1989. An assessment of channel behaviour in an alternative structural arrangement: The international joint venture. *International Marketing Review*, 6(3).

Hitt, M. A., Dacin, M. T., Levitas, E., Arregle, J. L., and Borza, A., 2000. Partner selection in emerging and developed market contexts: Resource-based and organizational learning perspectives. *Academy of Management Journal*, 43(3), pp.449-467.

Hong, Y., and Chan, D. W. M., 2014. Research trend of joint ventures in construction: a two-decade taxonomic review. *Journal of Facilities Management*, 12(2), pp.118-141.

Kincaid, S. O., 2003. Web-based courses in human services: A comparison of student and faculty perceptions of factors that facilitate or hinder learning. *Digital Abstracts International*, 64(07).

Kumaraswamy, M. M., 1997. Conflicts, claims and disputes in construction. *Engineering, Construction and Architectural Management*, 4(2), pp.95-111

Mohammed, S., 2003. Performance in international construction joint ventures: Modeling perspective. *Journal of Construction Engineering and Management*, 129(6), pp.619-626.

Munns, A. K., Aloquili, O. and Ramsay, B., 2000. Joint Venture negotiation and managerial practices in the new countries of the former Soviet Union. *International Journal of Project Management*, 18(6), pp.403-413.

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), pp.799-806.

Prasitsom, A. and Likhitruangsilp, V., 2012. Design of administrative structures for construction joint ventures. In *Joint ventures in construction contract 2: Contract, governance, performance and risk*, pp.29-40. Available from: https://www.icevirtuallibrary.com/doi/pdf/10.1680/jvc2012.2.57838.0003

Skulmoski, G.J., Hartman, F.T. and Krahn, J., 2007. The Delphi method for graduate research. *Journal of Information Technology Education: Research*, *6*(1), pp.1-21.

Tatoglu, E., 2000. Western joint ventures in Turkey: strategic motives and partner selection criteria. *European Business Review*, 12(3), pp.137-147.

Williams, R. G., and Lilley, M. M., 1993. Partner selection for joint-venture agreements. *International Journal of Project Management*, 11(4), pp.233-237.

Xia, B. and Chan, A. P., 2012. Measuring complexity for building projects: A Delphi study. Engineering, *Construction and Architectural Management*, 19(1), pp.7-24.

Zhao, X., Hwang, B. G. and Yu, G. S., 2013. Identifying the critical risks in underground rail international construction joint ventures: Case study of Singapore. *International Journal of Project Management*, 31(4), pp.554-566.

Fasna, M.F.F. and Gunatilake, S., 2019. Energy retrofits to enhance energy performance of existing buildings: A review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 308-319. DOI: doi.org/10.31705/WCS.2019.31. Available at: https://2019.ciobwcs.com/papers

ENERGY RETROFITS TO ENHANCE ENERGY PERFORMANCE OF EXISTING BUILDINGS: A REVIEW

M.F.F. Fasna[1] and Sachie Gunatilake[2]

ABSTRACT

Inefficient buildings use three to five times the energy as efficient buildings. Herein, improving the Energy Efficiency (EE) of buildings, specifically existing buildings that account for a large part of the building sector, has become a major priority. Energy Retrofits (ER) are identified as the main approach to enhance energy performance of buildings to achieve energy reduction targets. Yet, a general lack of awareness exists with respect to ER, types of ER and the possible ER measures through which building EE could be enhanced. Thus, the aim of this paper is to fill this research gap by critically reviewing the relevant literature on ER. With the intention of avoiding the misperceptions on the concept of ER, the paper first analysed various definitions of ER provided by different authors. This had made it clear that in addition to enhancing EE, ER also result in upgraded functionality, improved architectural quality, increased aesthetic value, reduced resource consumption, decreased CO_2 emissions and improved indoor air quality. Besides, based on the critical review of literature, the paper also discusses different types of ER that could be adopted to retrofit a particular building and different ER measures that could be used to retrofit different building elements/systems. The findings of this study could be used by practitioners as a basis in understanding the available ER types and measures for the buildings that would be of use in making effective decisions during their endeavours to enhance the EE of existing buildings.

Keywords: *Definition; Energy Efficiency (EE); Energy Retrofits (ER); Existing Buildings; Retrofit Measures; Retrofit Types.*

1. INTRODUCTION

Among the energy end-use sectors, improving the Energy Efficiency (EE) of buildings has become a major global priority (Bertone *et al*., 2018). This is because, buildings account for almost half of the worldwide energy consumption, together with resultant Greenhouse Gas (GHG) emissions (Liang *et al*., 2016). Thus, to reach the emissions reduction targets and to enhance the sustainability of the built environment, a shift has to be made towards more energy efficient practices (Rydin *et al*., 2012).

Within the context of built environment, EE is all about using less energy for operations (i.e. for heating, cooling, lighting and other appliances), without impacting the health and comfort of its occupants (Ruparathna *et al*., 2016). ESMAP (2014) and Hendron (2013) had disclosed ‘improved design and construction’ techniques that reduce heating, cooling, ventilating, and lighting loads; ‘active management of energy use’; and ‘ER’ i.e. building upgrades and replacement of energy-using equipment, as the key EE

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improvement approaches to enhance the energy performance of the buildings (i.e. both new and existing buildings) (refer Figure 1). As existing buildings encompass the largest segment of the built environment (Zhou *et al*., 2016) and have a huge potential for energy saving (Xu *et al*., 2013), improving the EE of existing buildings is perceived as a crucial step in minimising overall energy use (Panthi *et al*., 2017) and improving the energy performance (Mohareb and Kennedy, 2014).

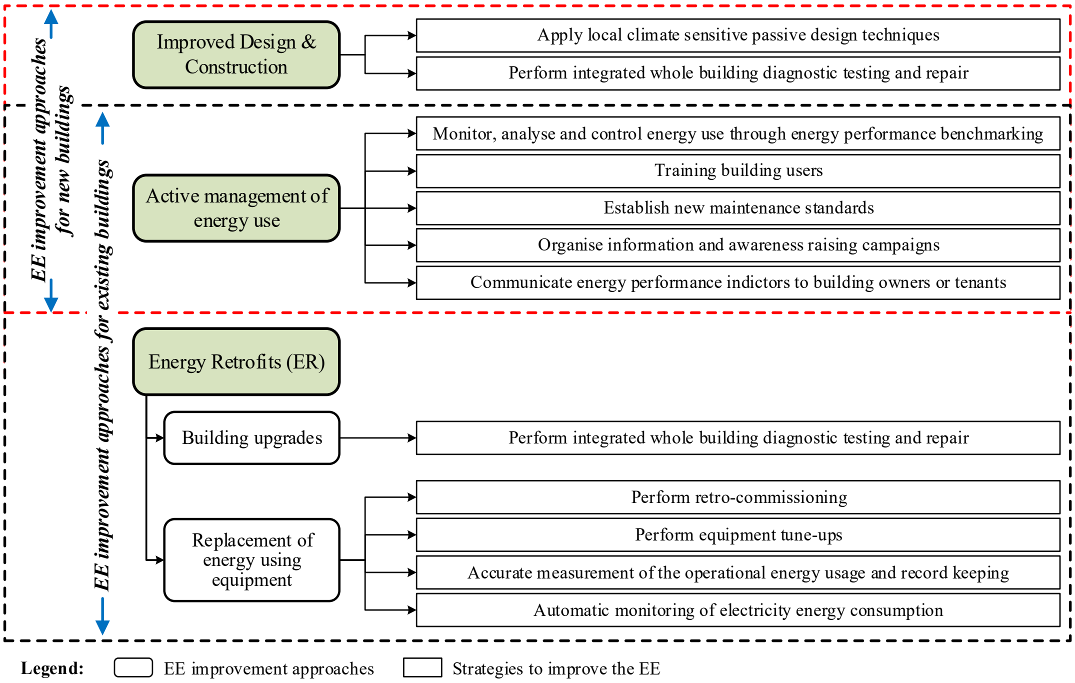

Figure 1: EE improvement approaches to enhance the EE of buildings (Source: Adapted from BASF, 2009; Escrivá-Escrivá, 2011; ESMAP, 2014; Hendron, 2013)

Various studies have made evident that among the two main approaches to enhance the EE of existing buildings, energy consumption in existing buildings can be reduced significantly through adopting ER (Chidiac *et al*., 2011; Sesana *et al*., 2016). Hence, retrofitting existing buildings is considered as the key approach to achieve energy reduction targets (Liang *et al*., 2015) and sustainability in the built environment (Liang *et al*., 2015; Ma *et al*., 2012) at relatively low cost and high uptake rates (Ma *et al*., 2012). However, still there appear to be confusions around conceptualization of ER, ER types and the respective measures that could be adopted under each ER type to enhance energy performance of the built environment. Hence, this paper is aimed at reviewing the existing literature to identify and explore the concept of ER, different types of ER, and available ER measures to enhance the energy performance of the existing buildings. Using these findings as a basis, this paper conceptualises the different ER types and measures that could incentivise the practitioners in determining and implementing the suitable types of ER and measures for a particular built environment.

2. RESEARCH METHODOLOGY

A systematic literature review is a vital research methodology that is capable of, synthesizing the existing body of knowledge; creating new knowledge on a wider scale than is possible with empirical studies; and identifying new agendas for future research (Denyer and Tranfield, 2009). This study utilized systematic literature review to achieve the aforementioned aim. The methodology adopted to do the systematic literature review is shown in Figure 2, which is found to be in line with the suggestions of Denyer and Tranfield (2009) and Mostafa *et al*. (2016).

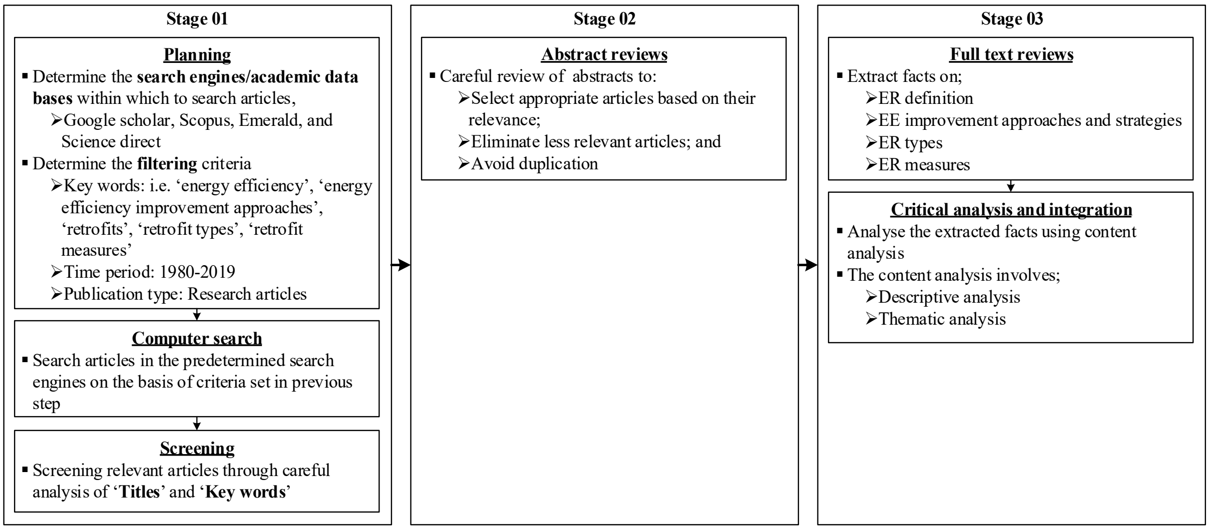

Figure 2: Research process followed to do the systematic literature review

As depicted in Figure 2, this study followed three stages. The intention of the first two stages were to select appropriate research outputs for the review while the third stage was focused on extracting all the needed facts from the derived articles and synthesising accordingly. Among the available search engines, 'Google Scholar', 'Scopus', 'Emerald', and 'Science direct' were selected for this study, as these domains have been widely used in similar reviews (e.g. Yang *et al*., 2009). This had also ensured that adequate research outputs were captured for the review. Though there are other numerous alternative terms for retrofits identified in literature including 'commercial property retrofit' (Dixon *et al*., 2014), 'sustainable retrofit' (Swan *et al*., 2013), 'EE retrofit' (Xu *et al*., 2015), and 'green retrofit' (Alm *et al*., 2005; Liang *et al*., 2015; Liang *et al*., 2016), the basic search term adopted to retrieve the research publications under this study was 'retrofit'. Search was conducted for the period from year 2000-2018. By following the three stages indicated in Figure 2, this study derived a total of 90 articles appropriate for this study. The articles were analysed using code based content analysis.

3. ER DEFINITIONS AND PERSPECTIVES

When discussing the upgrade of a property's physical characteristics to improve its environmental performance, the terms 'modernisation', 'retrofit' and 'refurbishment' are all used within the literature (Jenkins, 2010). This has led to some confusions regarding the clear-cut difference between retrofit and refurbishment. To avoid such confusions, Kolokotsa *et al*. (2009) have defined both terms clearly in a literal sense. According to them, the term 'refurbishment' implies the necessary modifications needed to return a building to its original state, whereas 'retrofit' includes the necessary actions that will improve the building's energy and/or environmental performance.

As highlighted by Dixon (2014), in academic literature, there has been much debate over the meaning of 'retrofit' and its distinction since different authors have used different terminologies (refer Section 2). Out of the 90 selected articles, 16 were found to have provided definitions for ER (refer Table 1). These definitions were analysed with the intention of setting clear boundaries for the concept of ER.

Table 1: Definitions for ER

Source	Definitions for ER
Alm *et al*. (2005)	The process of renovating the systems and structure of a building to improve efficiency, reduce resource consumption, and create improved Indoor Air Quality (IAQ)
Ashrafian *et al*. (2016)	The modifications done to the existing building systems and equipment to enhance the energy performance of the buildings
Brown *et al*. (2014)	Upgrade of the building fabric, systems or controls to improve the energy performance of the property
Energy Efficient Buildings Hub [EEBH] (2012)	An optimally engineered improvement designed for a particular building based on its unique energy usage profile and potential for energy savings, costs of proposed energy saving solutions, potential for increased asset valuation, available financial incentives and resources, owner and occupant needs, and other factors
Han *et al*. (2006), Sun and Liu (2007), Xu *et al*. (2009), (2015)	Projects aimed at reducing the operational energy use in buildings through building envelope improvement and mechanical systems upgrades, while preserving the comfort of the indoor environment (i.e. reduce energy expenditures and minimises emissions)
Jafari and Valentin, (2017), Syal *et al*. (2014)	Physical or operational change in a building, its energy-consuming equipment, or its occupants' energy-use behavior to reduce its amount of energy consumption, and thereby to convert the building to a lower energy consuming facility
Jaggs and Palmer (2000)	Actions that allow an upgrade of the building's energy and environmental performance to a higher standard than was originally planned Changing or modifying building systems to achieve an improved and desired energy performance
Liang *et al*. (2016)	Incremental improvement of the fabric and systems of a building with the primary intention of improving EE and reducing carbon emissions
Shanghai Con-struction and Transportation Commission (2008)	Approaches to improve the building envelope and equipment systems, that reduces building energy use while maintaining the comfort of the building's indoor environment
Swan *et al*. (2013)	Upgrades to the fabric or systems of a property that may reduce energy use or generate renewable energy
Tryson (2016)	Making changes to the elements or components of a building
Wilkinson (2011)	The induced modernisation and improvement of an existing structure/building due to its degradation and the need to improve EE, architectural appeal and Indoor Environmental Quality (IEQ) for the benefit of the community

According to Chunduri (2014), the main aim of ER is to save energy or reduce the usage of energy by changing or modifying the systems, equipment or parts of the building. The analysis of many of the definitions given in Table 1 affirms this viewpoint. However, a few authors like Jafari and Valentin (2017) and Syal *et al*. (2014) had stated that making changes to occupants' energy-use behavior with the intention of reducing energy consumption would also fall within the scope of ER. But, according to ESMAP (2014), this should be considered as a separate EE improvement approach (refer Figure 1). According to Wilkinson (2011), making modifications or upgrades to the existing structure owing to its degradations is also called as ER if it results in enhanced EE. This appear to be contradicting with the perspectives of rest of the authors. By critically reviewing the definition domain of 'retrofit', this study had defined ER as, *"any type of upgrade or alterations made to an existing building, either to its elements or systems, with the primary intention of improving its energy performance"*.

It is vivid from the definitions of ER in existing literature that in addition to the enhancement in EE, ER also results in upgraded functionality (Kalc, 2012), improved the architectural quality (Kalc, 2012; Wilkinson, 2011), increased aesthetic value (EEBH, 2012; Kalc, 2012), reduced resource consumption (Alm *et al*., 2005), decreased CO_2 emissions (Liang *et al*., 2016) and improved IAQ (Alm *et al*., 2005; Shanghai Construction and Transportation Commission, 2008; Sun and Liu, 2007; Wilkinson, 2011; Xu *et al*., 2009, 2015).

4. ER TYPES AND MEASURES

ER is an area with a broad scope ranging from minor alterations to major retrofit projects (refer Chunduri, 2014). So far numerous authors have identified various types of ER that can be adopted to enhance building energy performance (Ma *et al*., 2012). These have been classified in various ways based upon different criteria (refer Chunduri, 2014). Review of literature made it clear that, even though different authors have classified ER in different ways on the basis of different criteria or perspectives, it is still possible to find some commonalities and overlaps among these categories despite the terminology being used. Figure 3 portrays the classification of ER types along with the criteria considered by previous authors as well as the other criteria that can also be a basis in stemming the same classification.

Analysis revealed different terms used by authors such as, existing building commissioning, shallow retrofits, retro commissioning, lite retrofits, and quick wins are all interchangeable with one another. Similarly, standard or staged retrofits, medium scale retrofits, partial retrofits, rational paybacks, and conventional retrofits are ascertained as the substitutable to medium retrofits. Correspondingly, whole building retrofit, comprehensive scale retrofits, integrated design, substantial retrofits, comprehensive retrofits, deep measures and deep energy retrofits are found to be identical with deep retrofits. Hence, it is possible to derive that despite these classifications, ER can be classified mainly in to three types as shallow, medium and deep retrofits, on the basis of 'energy saving', 'effort', 'cost', 'number of building systems', 'payback period', 'scale of the project', and 'parties involved'. Table 2 provides a snapshot of the types of ER along with their unique features compiled from the review of literature.

Detailed evaluations of the classifications given in Table 2 disclosed that even though shallow retrofit is the easiest type of retrofit to be implemented, it provides comparatively lower energy savings. Further, it made it clear that deep retrofit is a combination of many shallow and medium retrofits covering several systems of the building (PNNL and PECI, 2011) and focused on achieving higher energy savings compared to shallow and medium retrofit measures by incorporating a whole-building approach (SEAI, 2015).

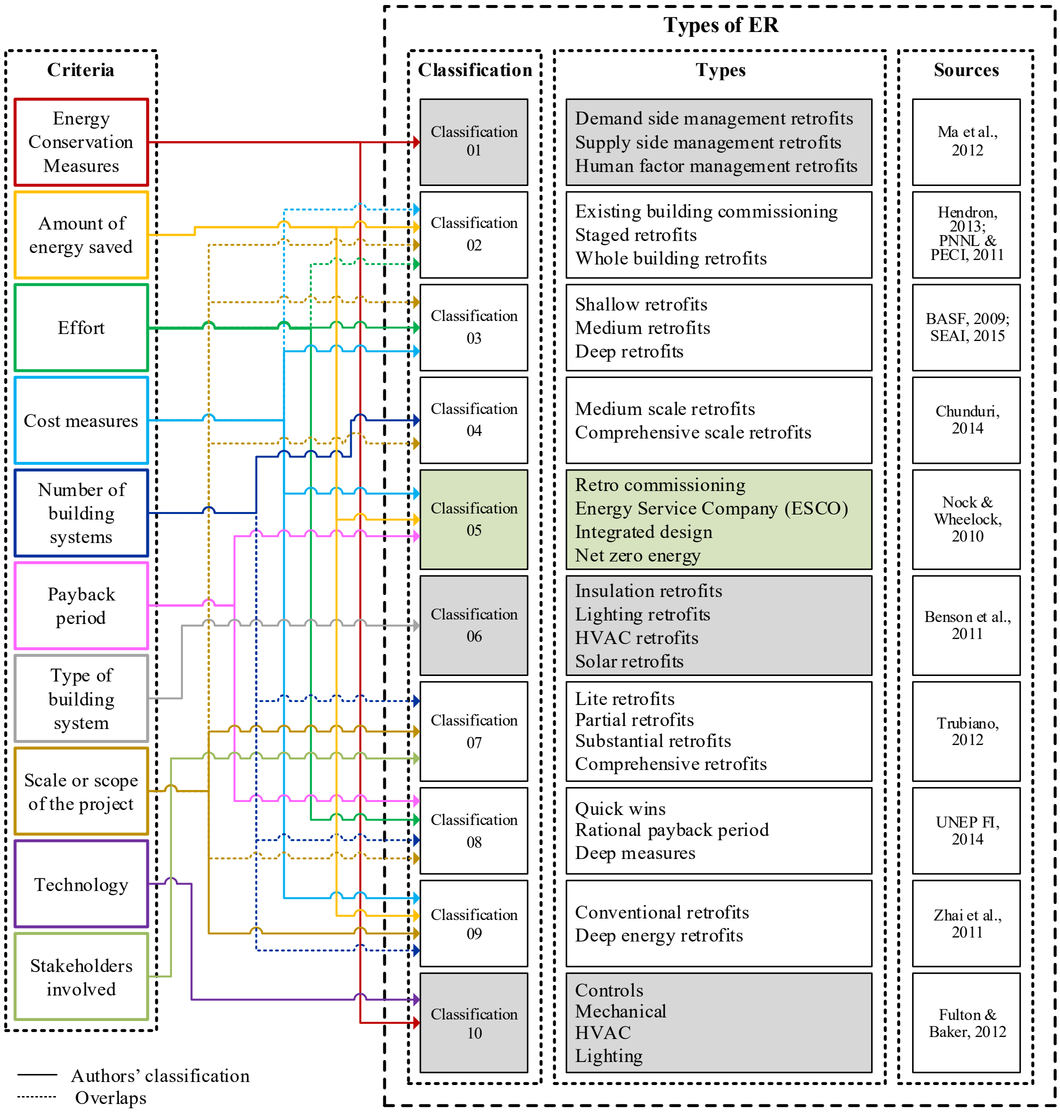

Figure 3: Classifications of ER types based on different criteria

Among the derived classifications of ER (refer Figure 3), Nock and Wheelock (2010) had classified ER into four (i.e. retro commissioning, ESCO, integrated design, and net zero energy) on the basis of energy saving, cost and payback (i.e. classification 6). Among these ER types, the retro commissioning and integrated design are found to be similar to shallow and deep retrofits respectively. It had been ascertained from the literature review that ESCO is a type of stakeholder who tend to execute ER project, while net zero energy is merely an outcome rather an ER type. By considering these facts, in this study the classification of ER by Nock and Wheelock (2010) has not been included.

Table 2: Comparison of shallow, medium, and deep retrofits

Criteria	**ER types**		
	Shallow	**Medium**	**Deep**
Energy saving	Up to 15% [5]	15-45% [3, 5, 9]	45% - 60% [2, 3, 4, 5, 9]
Effort	Measures are relatively easy to install [3, 6]		More difficult to implement [3, 5, 6]

Criteria	ER types		
	Shallow	Medium	Deep
Cost	Very low upfront cost [3, 4, 5, 6]	Require lower investment costs [4]	High upfront cost [2, 3, 5, 6]
Number of building systems		2 or more [7] but is limited to 2-7 [2]	7 or more [2]
Payback	Slightly over one year and less than 2 years [8]	Less than 5 years [3] (i.e. 4-5 years [1])	Longer payback [2, 5] i.e. more than 5 years
Scale or scope	Limited to retro-commissioning [7, 8] (i.e. repair damaged equipment, weather strip doors and windows, improve control strategies etc. [4])	Adopts a system approach i.e. upgrade or replacement of building systems [1] (An integrated design approach is adopted to some extent [4, 7])	Focuses on multiple building systems [2, 9] and adopt an integrated design approach [2, 3, 4, 7] Involves whole-building analysis [2, 3, 6, 8]
Parties involved	Sub-contractors or building system suppliers (Design or engineering professionals or general contractors are not involved) [7]	One or no design & engineering professional(s), with or without the participation of the general contractor [7]	All members of the Architecture, Engineering & Construction community – design & engineering professionals as well as a general contractor/ project manager [7]

[1] BASF, 2009; [2] Chunduri, 2014; [3] ESMAP, 2014; [4] Hendron, 2013; [5] PNNL and PECI, 2011; [6] SEAI, 2015; [7] Trubiano, 2012; [8] UNEP FI, 2014; [9] Zhai *et al*., 2011

As there are different types of retrofit projects as shown in Figure 3, the ER measure(s) to be used under one project may differ from another. Simply, ER measures (also referred to as ‘ER options’, ‘ER technologies’, and ‘ER actions’) are the actions that can be applied to reduce the energy consumption of buildings (Chidiac *et al*., 2011) and thereby promote building EE and sustainability (Ma *et al*., 2012). Currently, a wide range of technological options or solutions are available to increase the EE of buildings (International Finance Corporation Sri Lanka [IFCSL], 2013; Kolokotsa *et al*., 2009; Mitalidou, 2015; Sri Lanka Energy Managers Association [SLEMA], 2009; Sri Lanka Sustainable Energy Authority [SLSEA], 2008).

As per Xu and Chan (2010), three key retrofit measures for building ER projects are building envelope refurbishment, energy consumption equipment replacement, and Energy Management Systems (EMS) improvement. Hence, it is clear that ‘building envelope’, ‘building services/systems’ and ‘EMS’ are the key areas to be focused when identifying the common ER measures. As building systems like Heating, Ventilation and Air-conditioning (HVAC) and lighting are the dominant energy consuming systems in buildings (Abu-Bakar *et al*., 2015), during retrofitting priority should be given for lighting and HVAC systems to gain sufficient energy consumption reduction. Thus, during literature review, under ‘building services/systems’ focus was given towards identifying the ER measures relating to lighting and HVAC systems improvements, as has been highlighted by Doukas *et al* (2009).

Review of literature disclosed that while selecting the suitable ER measure(s) several key criteria should be considered (e.g. Ma *et al*., 2012; Menassa and Baer, 2014; Mondrup *et* *al*., 2014). Figure 4 conceptualises the modified classification of different ER types and common ER measures that could be adopted under ER projects and different criteria to be considered to determine the most suitable ER measures.

As shown in Figure 4, depending on the selected type of ER project, the most suitable ER measure(s) should then be selected. For instance, if HVAC or lighting retrofit is selected under ‘demand side management retrofits’ (i.e. intended to reduce overall energy demand of a building) or ‘medium retrofits’, one or few of the ER measures pertinent to the respective building systems to be selected as illustrated in Figure 4. Equally, if an organisation decides to move on with shallow retrofits, among these elicited list of ER measures low cost measures to be selected, while in case of deep retrofits high cost measures that could offer significant savings could be selected, as has been highlighted by SEAI (2015).

As per Duah *et al*. (2014), to make an informed decision about the most suitable ER measure(s) for a particular building having sufficient and sound knowledge on these retrofit measures is found to be crucial for the building owners and Facilities Managers (FMs). Within this context, it is believed that this developed conceptual framework would facilitate the practitioners.

5. CONCLUSIONS AND THE WAY FORWARD

This study provided a full picture of the available EE improvement approaches to enhance the energy performance of buildings along with the respective strategies that could be adopted under each approach (refer Figure 1). Among these derived key EE improvement approaches, building retrofits is ascertained as the best opportunity to improve the EE of the existing buildings. It was revealed that the key intention of ER is to enhance the energy performance of existing buildings mainly through making upgrades or alterations to the building elements or systems. Besides, the paper presents different types of ER projects that would be of use for a particular organisation to determine the suitable type of ER project to be adopted depending on their needs and context. Further, a comprehensive list of different ER measures that can be used enhance the EE of different ‘building elements’, ‘building services/systems’ and ‘EMS’ were also being compiled through the review of articles pertinent to the study arena and presented in this paper (refer Figure 4).

The findings of this study could help industry practitioners to have a better understanding of ER types, possible ER measures, and criteria to be considered in determining the suitable ER measure(s), which would be of use for them during their endeavours to enhance the energy performance of their facilities. Though through compiling different literature sources, the possible ER measures could be identified (refer Figure 4), the level of energy cost reduction and other benefits that could be gained through each of such measures is not well known, which is found to be crucial to make fruitful decisions. Hence, assessing the level of energy saving that could be gained through each of the ER measures found to be a worthy research area.

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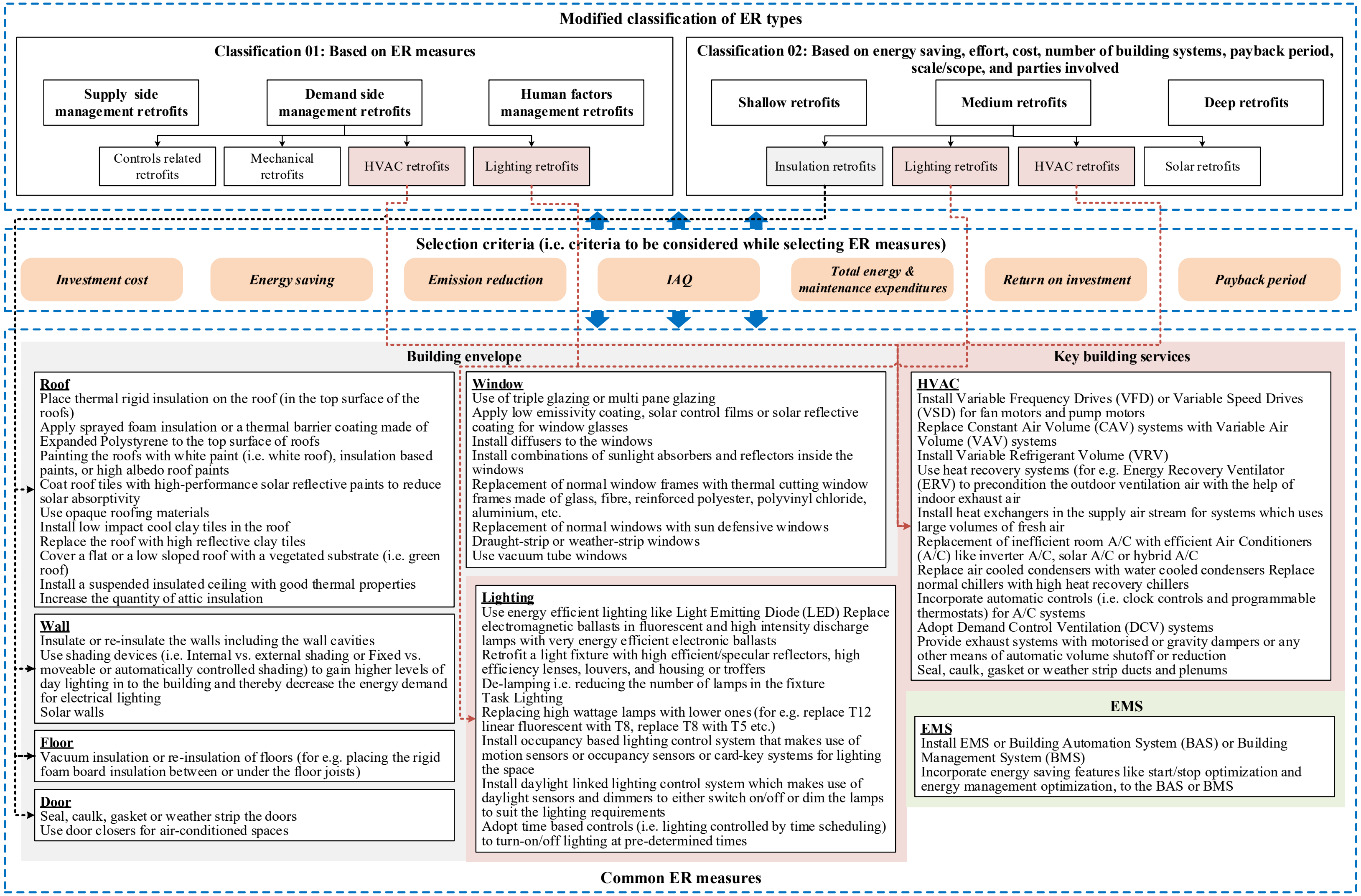

Figure 4: An overview of the modified types of ER, common ER measures and selection criteria

7. REFERENCES

Abu Bakar, N.N., Hassan, M.Y., Abdullah, H., Rahman, H.A., Abdullah, M.P., Hussin, F. and Bandi, M., 2015. Energy efficiency index as an indicator for measuring building energy performance: A review. *Renewable and Sustainable Energy Reviews*, 44, pp.1-11.

Alm, E., Boland, I., Cobb, V., Eaton, E., Newcomer, M., Pajkowska, J., Zeller, A., 2005. Workshop in applied earth system policy analysis. In *Final Workshop Report*. New York, NY: Columbia University.

Ashrafian, T., Yilmaz, A.Z., Corgnati, S.P. and Moazzen, N., 2016. Methodology to define cost-optimal level of architectural measures for energy efficient retrofits of existing detached residential buildings in Turkey. *Energy and Buildings*, 120, pp.58-77.

BASF, 2009. *Improving the performance of existing commercial buildings: The chemistry of sustainable retrofits [white paper]*. Available from: http://www.construction.basf.us/files/pdf/BASFSustainableRetrofit_whitepaper.pdf

Benson, A., Vargas, E., Bunts, J., Ong, J., Hammond, K., Reeves, L., Duan, P., 2011. *Retrofitting commercial real estate: current trends and challenges in increasing building energy efficiency*. Available from: https://www.ioes.ucla.edu/wp-content/uploads/retrofitting-commercial-real-estate.pdf

Bertone, E., Stewart, R.A., Sahin, O., Alam, M., Zou, P.X., Buntine, C. and Marshall, C., 2018. Guidelines, barriers and strategies for energy and water retrofits of public buildings. *Journal of Cleaner Production*, 174, pp.1064-1078.

Brown, P., Swan, W. and Chahal, S., 2014. Retrofitting social housing: reflections by tenants on adopting and living with retrofit technology. *Energy Efficiency*, 7(4), pp.641-653.

Chidiac, S.E., Catania, E.J., Morofsky, E. and Foo, S., 2011. Effectiveness of single and multiple energy retrofit measures on the energy consumption of office buildings. *Energy*, 36(8), pp.5037-5052.

Chunduri, S., 2014. *Development of planning and design phases of an integrative building life-cycle process model for advanced energy retrofit projects*. Thesis (PhD). Available from https://etda.libraries.psu.edu/files/final_submissions/9943

Denyer, D. and Tranfield, D., 2009. Producing a systematic review. In D. A. Buchanan and A. Bryman (Eds.), *The Sage Handbook of Organizational Research Methods* (pp. 671-689). Thousand Oaks, CA: Sage Publications.

Dixon, T., 2014. Commercial property retrofitting. *Journal of Property Investment & Finance*, 32(4), pp.443-452.

Dixon, T., Britnell, J. and Watson, G.B., 2014. *'City-wide' or 'City-blind?' an analysis of emergent retrofit practices in the UK commercial property sector* (ISSN 2052-1618). PSRC Retrofit 2050, Cardiff.

Doukas, H., Nychtis, C. and Psarras, J., 2009. Assessing energy-saving measures in buildings through an intelligent decision support model. *Building and Environment*, 44(2), pp.290-298.

Duah, D.Y., Ford, K. and Syal, M., 2014. Expert knowledge elicitation for decision-making in home energy retrofits. *Structural Survey*, 32(5), pp.377-395.

Energy Efficient Buildings Hub [EEBH], 2012. *Energy Efficient Buildings Hub Five-Year Plan*. Philadelphia, PA: EEBH.

Energy Sector Management Assistance Programme [ESMAP], 2014. *Improving energy efficiency in buildings* (Knowledge series 019/14). Available from: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/ESMAP_Energy_Efficient_MayoralNote_2014.pdf

Escrivá-Escrivá, G., 2011. Basic actions to improve energy efficiency in commercial buildings in operation. *Energy and Buildings*, 43(11), pp.3106-3111.

Fulton, M. and Baker, J., 2012. *United States building energy efficiency retrofits – Market sizing and financing models*. Available from: http://web.mit.edu/cron/project/EESP-Cambridge/Articles/Finance/Rockefeller%20and%20DB%20-%20March%202012%20-%20Energy%20Efficiency%20Market%20Size%20and%20Finance%20Models.pdf

Han, Z., Liu, C. and Sun, J., 2006. Research on commercial patterns of China existing building energy retrofit based on energy management contract. In *Proceeding of International Conference for Enhanced Building Operations (ICEBO)*. Shenzhen, China.

Hendron, B., 2013. *Advanced Energy Retrofit Guide Practical Ways to Improve Energy Performance - Grocery stores*. Available from: https://www.nrel.gov/docs/fy13osti/54243.pdf

International Finance Corporation Sri Lanka [IFCSL], 2013. *Ensuring sustainability in Sri Lanka's growing hotel industry*. Available from: https://www.ifc.org/wps/wcm/connect/30f331004fddd89eb9d8ff23ff966f85/Mapping+Report+++Ensuring+Sustainability+in+Sri+Lanka%E2%80%99s+Hotel+Industry.pdf?MOD=AJPERES

Jafari, A. and Valentin, V., 2017. An optimization framework for building energy retrofits decision-making. *Building and Environment*, 115, pp.118-129.

Jaggs, M. and Palmer, J., 2000. Energy performance indoor environmental quality retrofit - a European diagnosis and decision making method for building refurbishment. *Energy & Buildings*, 31(2), pp.97-101.

Jenkins, D.P., 2010. The value of retrofitting carbon-saving measures into fuel poor social housing. *Energy Policy*, 38(2), pp.832-839.

Kalc, I., 2012. *Energy Retrofits of Residential Buildings – Impact on Architectural Quality and Occupant's Comfort*. Master's thesis. Norwegian University of Science and Technology, Trondheim, Norway).

Kolokotsa, D., Diakaki, C., Grigoroudis, E., Stavrakakis, G. and Kalaitzakis, K., 2009. Decision support methodologies on the energy efficiency and energy management in buildings. *Advances in Building Energy Research*, 3(1), 121-146.

Liang, X., Peng, Y. and Shen, G.Q., 2016. A game theory based analysis of decision making for green retrofit under different occupancy types. *Journal of Cleaner Production*, 137, pp.1300-1312.

Liang, X., Shen, G. and Guo, L., 2015. Improving Management of Green Retrofits from a Stakeholder Perspective: A Case Study in China. *International Journal of Environmental Research and Public Health*, 12(11), pp.13823-13842.

Ma, Z., Cooper, P., Daly, D. and Ledo, L., 2012. Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, 55, pp.889-902.

Menassa, C.C. and Baer, B., 2014. A framework to assess the role of stakeholders in sustainable building retrofit decisions. *Sustainable Cities and Society*, 10, pp.207-221.

Mitalidou, C., 2015. *Energy Efficiency in historic buildings*. Master's thesis. International Hellenic University, Thessaloniki, Greece. Available from https://repository.ihu.edu.gr/xmlui/bitstream/handle/11544/12468/Dissertation_MITALIDOU_Signed.pdf?sequence=1

Mohareb, E.A. and Kennedy, C.A., 2014. Scenarios of technology adoption towards low-carbon cities. *Energy Policy*, *66*, pp.685-693.

Mondrup, T.F., Karlshøj, J. and Vestergaard, F., 2014. Building Performance Simulation tools for planning of energy efficiency retrofits. In: Arfvidsson, J., Harderup, L., Kumlin, A. and Rosencrantz, B. (eds.), *10th Nordic Symposium on Building Physics*. Lund, Sweden: Lund University.

Mostafa, S., Chileshe, N. and Abdelhamid, T., 2016. Lean and agile integration within offsite construction using discrete event simulation. *Construction Innovation*, *16*(4), pp.483-525.

Pacific Northwest National Laboratory [PNNL] and PECI, 2011. *Advanced energy retrofit guide: Practical ways to improve energy performance - Office buildings*. Available from: https://www.pnnl.gov/main/publications/external/technical_reports/pnnl-20761.pdf

Panthi, K., Das, K. and Abdel-Salam, T., 2017. Sustainability and cost assessment of coastal vacation homes for energy retrofits. *Built Environment Project and Asset Management*, 7(2), pp.185-198.

Nock, L. and Wheelock, C., 2010. Energy Efficiency Retrofits for Commercial and Public Buildings. Available from: https://paceworx.com/wp-content/uploads/srm/pdf/whitepapers/Energy_Efficiency_Retrofits_Pike_Research_Jun09.pdf

Ruparathna, R., Hewage, K. and Sadiq, R., 2016. Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. *Renewable and Sustainable Energy Reviews*, 53, pp.1032-1045.

Rydin, Y., Turcu, C., Chmutina, K., Devine-Wright, P., Goodier, C., Guy, S. and Wiersma, B., 2012. Urban energy initiatives: the implications of new urban energy pathways for the UK. *Network Industries Quarterly*, 14(3), pp.20-23.

Sesana, M.M., Grecchi, M., Salvalai, G. and Rasica, C., 2016. Methodology of energy efficient building refurbishment: Application on two university campus-building case studies in Italy with engineering students. *Journal of Building Engineering*, 6, pp.54-64.

Shanghai Construction and Transportation Commission, 2008. *Evaluation Standard of Energy Efficiency for Existing Building* (DG/TJ 08-2036-2008).

Sri Lanka Sustainable Energy Authority (SLSEA), 2008. *Code of practice for energy efficient buildings in Sri Lanka*. Colombo, Sri Lanka: SLSEA.

Sri Lanka Energy Managers Association (SLEMA), 2009. *Energy management guide*. Colombo, Sri Lanka: Sri Lanka Sustainable Energy Authority (SLSEA).

Sun, J.Y. and Liu, C.B., 2007. Obstacle identification and solution on energy efficient retrofit for existing buildings. *Low Temperature Architecture Technology*, *5*, pp.130-131.

Sustainable Energy Authority of Ireland (SEAI), 2015. *Unlocking the Energy Efficiency Opportunity - Summary for policymakers*. Available from: https://www.seai.ie/resources/publications/Unlocking-the-Energy-Efficiency-Opportunity-Summary-for-Policymakers.pdf

Swan, W., Ruddock, L. and Smith, L., 2013. Low carbon retrofit: attitudes and readiness within the social housing sector. *Engineering, Construction and Architectural Management*, 20(5), pp.522-535.

Syal, M., Duah, D., Samuel, S., Mazor, M., Mo, Y. and Cyr, T., 2014. Information Framework for Intelligent Decision Support System for Home Energy Retrofits. *Journal of Construction Engineering and Management*, 140(1), p.04013030.

Trubiano, F., 2012. *Integrated design roadmap for advanced energy retrofit*. Philadelphia, PA: Penn Design - University of Pennsylvania.

Tryson, L., 2016. *Commercial buildings & the retrofit opportunity*. Available from: https://www.contractingbusiness.com/commercial-hvac/commercial-buildings-retrofit-opportunity [Accessed 11 May 2016]

United Nations Environment Programme - Finance Initiative (UNEP FI), 2014. *Commercial Real Estate - Unlocking the energy efficiency retrofit investment opportunity*. Available from: http://www.unepfi.org/fileadmin/documents/Commercial_Real_Estate.pdf

Wilkinson, S., 2011. Sustainable retrofit potential in lower quality office stock in the central business district. In *Proceedings of the Management and Innovation for a Sustainable Built Environment Conference, 20-23 June* 2011. Amsterdam, Netherlands.

Xu, P.P. and Chan, E.H., 2010. Towards low carbon building: sustainable building energy efficiency retrofit (BEER) under energy performance contracting (EPC) mechanism. In *First International Conference on Sustainable Urbanization (ICSU 2010), 15-17 December 2010*. Hong Kong.

Xu, P.P., Chan, E.H. and Lam, T.I., 2009. A framework for Energy efficiency retrofits of existing buildings (EEREB) in China. In *Proceedings of CRIOCM 2009 International Research Symposium on Advances of Construction Management and Real Estate, 29 Oct - 01 Nov 2009*. Nanjing, China.

Xu, P., Chan, E.H.W., Visscher, H.J., Zhang, X. and Wu, Z., 2015. Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: analytic Network Process (ANP) approach. *Journal of Cleaner Production*, 107, pp.378-388.

Xu, P., Chan, E.H.W. and Lam, P.T., 2013. A conceptual framework for delivering sustainable building energy efficency retrofit using the Energy Performance Contracting (EPC) in China. *Journal of Green Building*, 8(1), pp.177-190.

Yang, J., Shen, G.Q., Ho, M., Drew, D.S. and Chan, A.P.C., 2009. Exploring critical success factors for stakeholder management in construction projects. *Journal of Civil Engineering and Management*, *15*(4), pp.337-348.

Zhai, J., LeClaire, N. and Bendewald, M., 2011. Deep energy retrofit of commercial buildings: a key pathway toward low-carbon cities. *Carbon Management*, 2(4), pp.425-430.

Zhou, Z., Zhang, S., Wang, C., Zuo, J., He, Q. and Rameezdeen, R., 2016. Achieving energy efficient buildings via retrofitting of existing buildings: a case study. *Journal of Cleaner Production*, *112*, pp.3605-3615.

Amarasinghe, S.D.I.A. and Chandani, H., 2019. Essential stakeholder contributions for establishing Life Cycle Assessment (LCA) in the construction industry: A desk study. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 320-329. DOI: doi.org/10.31705/WCS.2019.32. Available at: https://2019.ciobwcs.com/papers

ESSENTIAL STAKEHOLDER CONTRIBUTIONS FOR ESTABLISHING LIFE CYCLE ASSESSMENT (LCA) IN THE CONSTRUCTION INDUSTRY: A DESK STUDY

S.D.I.A. Amarasinghe[1] and Chandanie Hadiwattage[2]

ABSTRACT

In recent times, Life Cycle Assessment (LCA) has been evolved in globally as an analytical tool that systematically and holistically investigates cumulative environmental impacts associated with the entire building lifecycle from its cradle-to grave. Moreover, LCA approach has become a well-rooted concept internationally as a decision making tool due to the collaborative activities between main five (05) stakeholders i.e. academia, government, construction industry, civil society, and the natural environment. In contrast, it is difficult to find evidence on the application of LCA in Sri Lankan construction industry. Also, there is increasing interest in applying LCA, as Sri Lankan construction industry has been criticised due to the environmental pollution with the escalation of upcoming building projects. Hence, this study aimed to conduct a desk study by reviewing existing literature to disclose the activities, which the developed countries followed to integrate LCA into construction practice pertaining to aforesaid five stakeholder's contributions. Literature findings highlighted that, academia have to undertake and disseminate fact-based and comprehensive research on the field of LCA in order to popularize the concept of LCA while government bodies, construction industry, civil society and natural environment have to take actions to embed LCA to the environmental regulations and environmental planning as a core element to take voluntary actions to build ecologically sustainable constructions by using LCA as a decision making technique. Environmental modeling software packages have to be introduced as a collaborative activity of academia, construction industry and natural environment to make it possible to integrate LCA to the construction industry.

Keywords: *Academia; Civil Society; Construction Industry; Government; Life Cycle Assessment; Natural Environment.*

1. INTRODUCTION

At present, building constructions have become a foremost threat for environment, as the construction sector accounts for 40% energy consumption, 33% of GHG (Green House Gas) emissions, 30% of raw material usage, 25% of water consumption, 25% of solid waste generation and 12% of land use globally (Mills, 2009). Due to the speedy developments in the construction industry, the upward trend in adverse environmental

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influences will continue in the future (Robertson *et al*., 2012), along with critical economic and social influences.

In order to address these challenges, ecological considerations (i.e. energy saving, reduction of material usage, reduction of construction waste generation and emissions control, etc.) are required to be amalgamated into decisions made by a variety of parties (i.e. contractors, consultants, engineers, government bodies, general public, environmentalists, etc.), who are involved in the process of building constructions (Eckerberg and Nilsson, 2013). Subsequently, different methods and tools have come into practice which address the aforesaid ecological considerations to alleviate undesirable environmental problems (Atmaca, 2016). Examples include LCA, Environmental Impact Assessment (EIA) and Ecological Footprint, etc. (Buyle *et al*., 2013).

Amongst, aforementioned tools, Basbagill *et al*. (2013) have found that, the LCA can be applied to construction industry in order to predict, how a building or any other structure would perform throughout its lifetime. Moreover, LCA can be defined as a systematic set of processes, which targets to quantitatively evaluate the potential environmental burdens affixed with building lifecycle by recognizing and quantifying all environmental inputs (i.e. raw material, water and energy) and environmental outputs (i.e. atmospheric emissions, solid waste generation and waterborne waste) (Chau *et al*., 2015).

On the other hand, LCA seems to be utilised rapidly in developed countries with increased attention towards constructing more environmentally friendly constructions (Guinee *et al*., 2011). Confirming the above view, LCA has been mostly engaged in the construction sector in developed countries such as; Europe, North America, Japan, and Korea (Islam *et al*., 2015). Supportively, prevailing literature indicates significant evidence of an extensive amount of LCA being conducted in developed counties rather than in developing countries (Ortiz *et al*., 2009). It can be proved that, LCA has been successfully integrated in the construction industry in developed countries as a result of collaborative activities between main five (05) stakeholders such as; academia, government, construction industry, civil society, and the natural environment (Szalay, 2007). Accordingly, required contribution from aforementioned five (05) stakeholders to integrate LCA to the construction industry in developing countries successfully, is worthy to be examined.

2. RESEARCH METHODOLOGY

Desk study research method is selected to achieve the aim of this research. A desk study can be identified as searching information using prevailing resources such as; published papers, analytical reports and other publications (Crisp, 1981). Moreover, a desk study can be identified as a secondary data used research method, which is used to review previous research findings for the purpose of gaining a comprehensive understanding on a relevant research field (Bingham *et al*., 2012). When consider about the aim of this research, desk study was carried out to identify essential contributions from stakeholders (i.e. academia, government, construction industry, civil society, and the natural environment) to establish LCA enabled construction industry in the local context. Hence, a thorough review of the existing literature published in the last ten (10) years on LCA was undertaken. Thereafter, results of the study are significant since it recognizes the essential contributions of aforesaid stakeholders to establish LCA in the construction industry in a developing country like Sri Lanka.

3. LITERATURE REVIEW

3.1 INCORPORATING CYCLE ASSESSMENT INTO CONSTRUCTION INDUSTRY PRACTICE

LCA can be identified as an analytical method that systematically and holistically investigates, compiles and evaluates potential environmental burdens attributed with products, processes or an activity by ascertaining and quantifying material usage, energy consumption and environmental releases during the lifecycle of the product (Rønning and Brekke, 2014). Implementation of LCA is ruled by ISO 14041-14043 standards and the implementation process is structured into four fundamental steps such as, Goal and Scope Definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment (LCIA), and Interpretation (Chau *et al*., 2015). Moreover, LCA enables the quantification of cumulative environmental impacts attached along the entire life cycle from "cradle to grave" (Rønning and Brekke, 2014). LCA allows to prioritise, optimisation efforts based on an accurate information, so LCA is driven to the construction industry by incorporating proactive ecological concerns such as design and management implications which is able to optimize resource usage, energy consumption and waste generation over the entire lifecycle (Zhang *et al*., 2014). Accordingly, with the use of LCA, decision-makers can take the decisions that will resultant least negative impacts into the environment to create sustainable world (Fedkin, 2017).

However, existing literature shows significant evidences that an extensive amount of LCA have been conducted in developed counties rather than in developing countries (Ortiz *et al*., 2009; Saunders *et al*., 2013). Confirming the above view, LCA has been mostly engaged in the construction sector in developed countries such as; Europe, North America, Japan, and Korea (Islam *et al*., 2015). Accordingly, it was proved that LCA is not a novel concept in the developed countries (Edirisinghe, 2013). Number of studies have divulged various reasons that encourage the adoption of LCA to the construction industry in developed countries, Dewulf *et al*. (2009) highlighted that construction industry in developed countries actively participate in organising workshops, publishing scientific papers and several handbooks (i.e. International Reference Life Cycle Data System Handbook (ILCD)) on LCA, which encourage the application of LCA within construction industry. Moreover, government bodies promote the utilisation of LCA by incorporating LCA into policies and regulations such as Construction Products Regulation (CPR), European Commission on Integrated Product Policy (IPP) and in the certification schemes for sustainable building constructions (Kogler and Goodchild, 2017). Szalay (2007) further elaborated that, academia, government, construction industry and environmentalists are collaboratively involved in developing different LCA data bases such as ATHENA for US and Canada and GaBi and SimaPro for Europe to facilitate LCA in redeveloped countries. Increasing awareness on environmental sustainability coupled with pressures from numerous stakeholders such as government, environmental activist and civil society to protect environment have keen in introducing LCA (Singh *et al*., 2010). It is proved that, LCA has been successfully integrated in the construction industry in developed countries as a result of collaborative activities between main five (05) stakeholders such academia, government, construction industry, civil society, and the natural environment. Hence, it is very much critical to further identify the essential contributions from aforementioned stakeholders in order to implement LCA within construction industry. Table 1 indicates the identification of a contribution from stakeholders to integrate LCA for the construction industry.

Table 1: Contribution from stakeholders to establish LCA for the costruction industry

Required contributions from stakeholders to establish LCA for the construction industry	**Responsible Stakeholders**					**Reference Code**
	Academia	**Government**	**Construction industry**	**Civil society**	**Natural environment**	
Integration of LCA into an environmental policy, legislation and environmental planning as a motivation mechanism to promote sustainable development		✓	✓		✓	3, 10, 14
Encourage the use of LCA	✓	✓	✓	✓	✓	10
Organization of workshops and forums on LCA	✓	✓	✓	✓	✓	10
Standardisation of LCA guides and handbooks specially for construction industry	✓	✓	✓			9, 10, 12
Organization of platform to co- ordinate LCA practitioners, scientists, and users, for the continuous improvement of LCA	✓	✓	✓	✓	✓	10
Appearance of scientific journals on LCA	✓					10
Development of regional specific LCI tools and energy simulation tools	✓	✓	✓		✓	2, 8, 9, 10, 11, 12
Increase the accuracy of LCA results by using accurate LCA data instead of using deterministic values	✓	✓	✓			1
Enrich the existing literature and knowledge on LCA by undertaking more LCA related research activities	✓		✓			1, 5
Integrate Building Information Modeling (BIM) with LCI tools, energy simulation software, sensitivity analysis software and Maintenance, Repair and Replacement (MRR) scheduling to increase interoperability	✓	✓	✓			4, 13, 14
Development of Hybrid LCA frameworks and approaches	✓	✓				3
Provision of guidance to the LCA practitioners	✓	✓	✓	✓	✓	3, 5
Increase interest on environmental sustainability		✓	✓	✓	✓	5, 12
Encourage the use of LCA tools	✓	✓	✓		✓	5
Development of LCI data bases for new innovative materials	✓	✓	✓		✓	8
Commitment from top management to implement LCA		✓				8
Implement policy governance measures in order to encourage building developers and designers to apply LCA in early design stage			✓		✓	8
Implementation of environmental reporting and management systems		✓	✓		✓	9

Required contributions from stakeholders to establish LCA for the construction industry	Responsible Stakeholders					Reference Code
	Academia	Government	Construction industry	Civil society	Natural environment	
Urge the use of the Environmental Product Declarations (EPD) based on LCA	✓	✓	✓		✓	6, 7, 9
Use of streamlined LCA	✓	✓	✓	✓	✓	9, 14
Provision of subsidies for the reduction of environmental impacts		✓	✓			6, 12, 14
Development of reporting and communication mechanism for LCA result	✓	✓	✓		✓	13
Development of a national open access databases	✓	✓	✓		✓	13
Encourage eco-design of new building construction and rehabilitation of existing buildings	✓	✓	✓	✓	✓	7

(Sources: 1- Aktas and Bilec, 2012; 2- Azari, 2014; 3- Bilec *et al*., 2009; 4- Bilec *et al*., 2006; 5- Blengini, 2009; 6- Bribián *et al*., 2009; 7- Bribián *et al*., 2011; 8- Chau *et al*., 2015; 9- Erlandsson and Borg, 2003; 10- Grundel and Dahlstrm, 2016; 11- Khasreen *et al*., 2009; 12- Malmqvist *et al*., 2011; 13- Takano *et al*., 2014; 14- Zuo *et al*., 2017)

3.2 STAKEHOLDER INVOLVEMENT TO ESTABLISH LIFE CYCLE ASSESSMENT IN CONSTRUCTION INDUSTRY

Table 1 indicates that each stakeholder has to contribute individually or collectively to integrate LCA into construction industry. Further, there is a need for developing bilateral and multilateral relationships between stakeholders for LCA integration to the construction industry.

Accordingly, Grundel and Dahlstrm (2016) specified that promoting multidisciplinary coordination by organizing platforms to gather research bodies, industry professionals, LCA specialists and the government bodies can be identified as one of the major contribution of academia, government and building industry for the continuous improvement of LCA integration to the construction industry. Relevant environmental laws, policies and regulations required to be formulated by the government with the help of construction industry to encourage building designers and developers to apply LCA at the initial stage of building construction (Chau *et al*., 2015). Grundel and Dahlstrm (2016) explained regional specific LCA databases have to be developed as a collaborative process between academia, building industry, government for the purpose of enhancing credibility of LCA results. Moreover, BIM can be used to assists in information management and communication between different stakeholders throughout the project lifecycle. Integration of both BIM and LCA facilitate real time data capturing ability at any time. Hence stakeholders such as academia, government, construction industry and natural environment have to contribute their effort in integrating LCA with BIM (Zuo *et al*., 2017). Aktas and Bilec (2012) argued that it is important to provide priority to conduct LCA based research activities by the academia and government cooperatively. Construction industry have to be actively participated in organising workshops and publishing guidelines and handbooks on LCA in order to popularise and implement the LCA (Dewulf *et al*., 2009). Moreover, civil society, construction industry and environmentalists (natural environmnt) have to increase their interest in developing more and more green buildings. As, erection of green buildings require complete LCA to assess harmful environmental impacts during the entire lifecycle.

Hence, it can be said that the process of successful LCA integration to the construction industry is needed to create win-win situation among all related stakeholders; such as academia, construction industry, government, civil society, and natural environment. Therefore, LCA integration to the construction industry can be identified as a collaborative and disseminated innovative processes rather than simple activity. When considering Sri Lanka as a developing county numerous views emphasize that LCA implementation and adaptation has been limited in the construction industry (Edirisinghe, 2013). Even though, it has emerged as a requirement in integrating LCA concept to Sri Lankan construction industry as a solution to reduce increasing adverse environmental impacts. As, Dissanayake (2016) has revealed that 40% of GHG emission, and 30% of solid waste generation are immense contributors to the atmospheric pollution contributed by the building sector in Sri Lanka. Accordingly, for the purpose of providing better assistance to the wide-spread adoption of LCA in Sri Lankan construction industry, Figure 1 was developed based on the findings from a desk study to highlight the essential contributions from five (05) prominent stakeholders to establish LCA within Sri Lankan construction industry.

According to Figure 1, LCA integration to the construction industry consists a variety of implications that cannot be handled by a single stakeholder due to the lack of competences and resources**.** Hence the collaborative activities between stakeholders can be identified as a way of integrating LCA into the construction industry, as resources and capabilities are disseminated among a wide network of stakeholders (e.g. academia, industry, construction industry, society, and natural environment). Hence, stakeholders need to collaboratively act with each other for the successful LCA integration through mutual interactions.

4. CONCLUSIONS

Environmental issues seemingly become more complex, unpredictable and multistate, and affect a wide variety of stakeholders and demanding novel technical solutions, new collaborations and societal transformations. Consequently, LCA came into practice as a remedy to mitigate possible environmental impacts generated by the construction industry. Moreover, global environmental needs and targets of reducing adverse environmental impacts generated by the building sector can be achieved by integrating LCA with the help of main five (05) stakeholders such as; academia, government, construction industry, civil society, and the natural environment. Though, holistic assessment of LCA have been disregarded in Sri Lankan context, due to the lack of contribution from main five (05) stakeholders in the society. LCA integration to the built environment is extremely important for Sri Lankan context. As, Sri Lankan building sector is stepping into a mega building avenue in the next few years with the escalation of upcoming projects e.g. Megapolis and Port City. However, despite its major contribution to the economic growth, construction industry has generated huge environmental impacts. Hence, LCA is currently novel, essential, and trendy, concurrently.

Academia

- Organization of forums and platform to co-ordinate LCA practitioners
- Appearance of scientific journals on LCA
- Development of regionalized LCA databases
- Standardisation of LCA
- Undertake LCA related research activities
- Integrate BIM with LCA
- Provision of guidance to the LCA practitioners
- Use of the Environmental Product Declarations (EPD) based on LCA
- Make society aware on LCA
- Use of streamlined LCA
- Development of a national open access databases
- Encourage the use of LCA

Government

- Integration of LCA into an environmental regulations and environmental planning
- Organization of forums and platform to co-ordinate LCA practitioners
- Standardisation of LCA
- Development of regionalized LCA databases
- Integrate BIM with LCA
- Provision of guidance to the LCA practitioners
- Increase interest on environmental sustainability
- Make society aware on LCA
- Implementation of environmental reporting and management systems
- Use of the Environmental Product Declarations (EPD) based on LCA
- Use of streamlined LCA
- Provision subsidies for the reduction of environmental impacts
- Development of building specific LCA tools
- Development of a national open access databases
- Encourage the use of LCA

Construction Industry

- Encourage the use of LCA
- Integration of LCA into an environmental regulations and environmental planning
- Organization of forums and platform to co-ordinate LCA practitioners
- Standardisation of LCA
- Development of regionalized LCA databases
- Undertake LCA related research activities
- Integrate BIM with LCA
- Provision of guidance to the LCA practitioners
- Increase interest on environmental sustainability
- Implementation of environmental reporting and management systems
- Use of the Environmental Product Declarations (EPD) based on LCA
- Make society aware on LCA
- Use of streamlined LCA
- Provision subsidies for the reduction of environmental impacts
- Development of building specific LCA tools
- Development of a national open access databases

Civil Society

- Encourage the use of LCA
- Organization of forums and platform to co-ordinate LCA practitioners
- Provision of guidance to the LCA practitioners
- Incorporate LCA into strategic environmental planning
- Increase interest on environmental sustainability
- Use of the Environmental Product Declarations (EPD) based on LCA
- Make society aware on LCA

Natural Environment

- Encourage the use of LCA
- Integration of LCA in to an environmental regulations and environmental planning
- Organization of forums and platform to co-ordinate LCA practitioners
- Development of regionalized LCA databases
- Standardisation of LCA
- Undertake LCA related research activities
- Increase interest on environmental sustainability
- Provision of guidance to the LCA practitioners
- Use of the Environmental Product Declarations (EPD) based on LCA
- Make society aware on LCA
- Use of streamlined LCA
- Implementation of environmental reporting and management systems
- Development of building specific LCA tools
- Development of a national open access databases

Figure 1: Summary of essential contributions from stakeholders to establish LCA for the construction industry

The outcomes of this research explain the essential contribution from the each of the related stakeholders (e.g. academia, industry, construction industry, civil society, and natural environment), which will need to drive LCA integration to the construction industry. Hence, identified essential contribution would be highly important to the domain of LCA application, since there has been lack of research in the area towards integrating LCA to Sri Lankan construction industry. Deliverables of this study can be used to understand the each of the stakeholder contribution towards the successful LCA implementation to the construction industry in Sri Lanka. Subsequently, the creation of a LCA enabled environment with the help of five (05) prominent stakeholders in the society will motivate to apply LCA as a decision making tool, to assess environmental impacts generated throughout the entire building lifecycle. Finally, it is recommended to conduct further study to identify significance of each stakeholder contribution to the LCA implementation for construction industry.

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6. REFERENCES

Aktas, C.B. and Bilec, M.M., 2012. Impact of Lifetime on US Residential Building LCA Results. *The International Journal of Life Cycle Assessment*, 17(3), pp.337-349.

Atmaca, A., 2016. Life Cycle Assessment and Cost Analysis of Residential Buildings in South East of Turkey: Part 1—Review and Methodology. *The International Journal of Life Cycle Assessment*, 21(6), pp.831-846.

Azari, R., 2014. Integrated Energy and Environmental Life Cycle Assessment of Office Building Envelopes. *Energy and Buildings*, 82, pp.156-162.

Basbagill, J., Flager, F., Lepech, M. and Fischer, M., 2013. Application of Life-Cycle Assessment to Early Stage Building Design for Reduced Embodied Environmental Impacts. *Building and Environment*, 60, pp.81-92.

Bilec, M., Ries, R., Matthews, H.S. and Sharrard, A.L., 2006. Example of a Hybrid Life-Cycle Assessment of Construction Processes. *Journal of Infrastructure Systems*, 12(4), pp.207-215.

Bilec, M.M., Ries, R.J. and Matthews, H.S., 2009. Life-Cycle Assessment Modeling of Construction Processes for Buildings. *Journal of Infrastructure Systems*, 16(3), pp.199-205.

Bingham, I.J., Hoad, S.P., Lang, B., Philpott, H., Stobart, R., Thomas, J., Barnes, A.P., Ball, B.C., Knight, S. and Kightley, S., 2012. *Desk study to evaluate contributory causes of the current yield plateau in wheat and oilseed rape.* Home Grown Cereals Authority (HGCA) Project Report No. 502.

Blengini, G.A., 2009. Life Cycle of Buildings, Demolition and Recycling Potential: A Case Study in Turin, Italy. *Building and Environment*, 44(2), pp.319-330.

Bribián, I.Z., Capilla, A.V. and Usón, A.A., 2011. Life Cycle Assessment of Building Materials: Comparative Analysis of Energy and Environmental Impacts and Evaluation of the Eco-Efficiency Improvement Potential. *Building and Environment*, 46(5), pp.1133-1140.

Bribián, I.Z., Usón, A.A. and Scarpellini, S., 2009. Life Cycle Assessment in Buildings: State-of-the-art and Simplified LCA Methodology as a Complement for Building Certification. *Building and Environment*, 44(12), pp.2510-2520.

Buyle, M., Braet, J. and Audenaert, A., 2013. Life Cycle Assessment in the Construction Sector: A Review. *Renewable and Sustainable Energy Reviews*, 26, pp.379-388.

Chau, C.K., Leung, T.M. and Ng, W.Y., 2015. A Review on Life Cycle Assessment, Life Cycle Energy Assessment and Life Cycle Carbon Emissions Assessment on Buildings. *Applied Energy*, 143, pp.395-413.

Crisp, D.T., 1981. A Desk Study of the Relationship between Temperature and Hatching Time for the Eggs of Five Species of Salmonid Fishes. *Freshwater Biology*, 11(4), pp.361-368.

Dewulf, J., Van der Vorst, G., Versele, N., Janssens, A. and Van Langenhove, H., 2009. Quantification of the Impact of the End-of-Life Scenario on the Overall Resource Consumption for a Dwelling House. *Resources, Conservation and Recycling*, 53(4), pp.231-236.

Dissanayake, R. 2016. *Green Buildings for Sustainable Built Environment in Sri Lanka* (Unpublished doctoral dissertation).

Eckerberg, K., and Nilsson, M. 2013. *Environmental Policy Integration in Practice: Shaping Institutions for Learning*. London, England: Routledge.

Edirisinghe, J., 2013. Life Cycle Assessment of a Ceramic Tile Produced in Sri Lanka. *ARPN Journal of Science and Technology*, 3(11), pp.02-12.

Erlandsson, M. and Borg, M., 2003. Generic LCA-Methodology Applicable for Buildings, Constructions and Operation Services—Today Practice and Development Needs. *Building and Environment*, 38(7), pp.919-938.

Fedkin, M. 2017. Technology for Sustainability Systems. Available from: http://www.e-education.psu.edu/eme807/node/690 [Accessed 10 April 2019].

Grundel, I. and Dahlström, M., 2016. A Quadruple and Quintuple Helix Approach to Regional Innovation Systems in the Transformation to a Forestry-Based Bioeconomy. *Journal of the Knowledge Economy*, 7(4), pp.963-983.

Guinee, J.B., Heijungs, R., Huppes, G., Zamagni, A., Masoni, P., Buonamici, R., Ekvall, T. and Rydberg, T., 2010. Life Cycle Assessment: Past, Present, and Future. *Environmental Science & Technology*, 45(1), pp.90-96

Islam, H., Jollands, M. and Setunge, S., 2015. Life Cycle Assessment and Life Cycle Cost Implication of Residential Buildings: A Review. *Renewable and Sustainable Energy Reviews*, 42, pp.129-140.

Khasreen, M., Banfill, P.F. and Menzies, G., 2009. Life-Cycle Assessment and the Environmental Impact of Buildings: A Review. *Sustainability*, 1(3), pp.674-701.

Kogler, K. and Goodchild, R., 2006. The European Commission's Communication Integrated Product Policy: Building on Environmental Life-Cycle Thinking. *Governance of Integrated Product Policy*, pp.70-77.

Malmqvist, T., Glaumann, M., Scarpellini, S., Zabalza, I., Aranda, A., Llera, E. and Díaz, S., 2011. Life Cycle Assessment in Buildings: The ENSLIC Simplified Method and Guidelines. *Energy*, 36(4), pp.1900-1907.

Mills, E., 2011. Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions in the United States. *Energy Efficiency*, 4(2), pp.145-173.

Ortiz, O., Castells, F. and Sonnemann, G., 2009. Sustainability in the Construction Industry: A Review of Recent Developments Based on LCA. *Construction and Building Materials*, 23(1), pp.28-39.

Robertson, A.B., Lam, F.C. and Cole, R.J., 2012. A Comparative Cradle-to-Gate Life Cycle Assessment of mid-rise Office Building Construction Alternatives: Laminated Timber or Reinforced Concrete. *Buildings*, 2(3), pp.245-270.

Rønning, A. and Brekke, A., 2014. Life Cycle Assessment (LCA) of the Building Sector: Strengths and Weaknesses. *Eco-Efficient Construction and Building Materials* (pp.63-83). Woodhead Publishing.

Saunders, C. L., Landis, A. E., Mecca, L. P., Jones, A. K., Schaefer, L. A., and Bilec, M. M. 2013. Analyzing the Practice of Life Cycle Assessment: Focus on the Building Sector. *Journal of Industrial Ecology*, 17(5), pp.777-788.

Singh, A., Berghorn, G., Joshi, S. and Syal, M., 2010. Review of Life-Cycle Assessment Applications in Building Construction. *Journal of Architectural Engineering*, 17(1), pp.15-23.

Szalay, Z., 2007. *Life Cycle Environmental Impacts of Residential Buildings* (Unpublished doctoral dissertation). Budapest University of Technology and Economics, Hungary.

Takano, A., Winter, S., Hughes, M. and Linkosalmi, L., 2014. Comparison of Life Cycle Assessment Databases: A Case Study on Building Assessment. *Building and Environment*, 79, pp.20-30.

Zhang, Z., Provis, J.L., Reid, A. and Wang, H., 2014. Geopolymer foam Concrete: An Emerging Material for Sustainable Construction. *Construction and Building Materials*, 56, pp.113-127.

Zuo, J., Pullen, S., Rameezdeen, R., Bennetts, H., Wang, Y., Mao, G., Zhou, Z., Du, H. and Duan, H., 2017. Green Building Evaluation from a Life-Cycle Perspective in Australia: A Critical Review. *Renewable and Sustainable Energy Reviews*, 70, pp.358-368.

Nibras, S.M., Abeynayake, M., Gowsiga, M. and Dilakshan, R., 2019. Facilities management value addition in corporate social responsibility. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 330-339. DOI: doi.org/10.31705/WCS.2019.33. Available at: https://2019.ciobwcs.com/papers

FACILITIES MANAGEMENT VALUE ADDITION IN CORPORATE SOCIAL RESPONSIBILITY

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ABSTRACT

Corporate activities have a major impact on society environment, thus the concern and pressure on corporate activities become a recurrent theme. Especially, the operations of corporates in the built environment is highly violated with the well-being of employee, customer, society, and environment. To overcome the impacts of the built environment operation, corporates need to adopt an effective management practice within the built environment as a part of their social responsibility. Facilities Management (FM) is a profession, which manages the built environment effectively. Therefore, this research aimed at assessing the value addition of FM in social responsibilities of the corporates through effective built environment management practices. Initially, situational analysis was conducted to identify the existing CSR practices in Sri Lanka and then the FM value added practices in key areas of CSR were found to achieve the aim. A qualitative research approach was adopted and seven (07) semi-structured expert interviews were carried out for data collection and two (02) interviews were carried out to validate the findings. The results of the content analysis revealed that CSR practices are relatively at a low level in Sri Lanka. As well as, most of FM professionals are involved in the operational and tactical level function. However, facilities managers perform energy management, water management, waste management, asset management and maintenance management, health and safety, stakeholder management, compliance management, risk management, procurement and contract management and workplace management roles in an organisation. Throughout those FM practices, part of CSR of an organization could be fulfilled.

Keywords: *Built Environment; Corporate Social Responsibility, Facilities Management; Social Well-being.*

1. INTRODUCTION

The corporates are the major key driver of global development where they generate a large number of goods and services, employment and economic benefits to the countries (Feijoo *et al*., 2014). However, the intention of profit making in business activities lead to negative impacts such as environmental pollution, resource depletion, health and safety issues and poverty in the society (Martinez, 2012). Also, corporate activities are violated with society (Supanti et *al.,* 2015). Hence to minimise those issues, CSR concept was developed in early 1950 and its demand is continuously increasing due to the

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globalisation and adverse effect of competition among the corporates (Jamali and Mirshak, 2007). CSR is defined as a set of activities undertaken by the corporates in order to show their social and environmental commitment to neighbourhoods (Marrewijk, 2003). The CSR concept is not a philanthropic responsibility, it discusses environmental, employee, legal, ethical and community development responsibilities of the corporates (Turker, 2009). Central Bank of Sri Lanka (CBSL) reported that the corporate sector is the major revenue creator and employment provider in the Sri Lankan economy (2015). However, their social and environmental consideration for the well-being of society is at a low level (Rajmanthri, 2005). The CSR concept exists as a new concept in Sri Lanka, not all corporates are following it due to the lack of knowledge in areas of CSR (Rathnasiri, 2003). Further, there is a requirement of a contribution of the professionals in the company to eliminate the social and environmental impact of the corporates. In that respect, some of FM activities are having a great potential for ensuring social well-being through effective built environment management (Conely, 2017). FM functions such as health and safety, energy and water management and workplace management have great potential to add value in social and environmental responsibility of the corporates (Jensen *et al*., 2014). Moreover, FM professionals can take a strategic role in CSR initiation of the company for delivering an effective strategic plan to CSR policy (Redlein *et al*., 2015). Nevertheless, the involvement of facilities managers in the CSR initiation and policy creation is rare in the current practice. Although FM has great potential to add value on CSR (Jensen *et al*., 2012) on the contrary, there is no research has been so far undertaken on value addition of FM in CSR (Jensen, 2010). Hence, the aim of this research is to address this gap by review the FM value addition in the social and environmental well-being of society through the built environment management of corporates. The structure of the paper launches with a literature review related to significant concepts of the study. Then it presents the method used in achieving the aim of the study and finally, it presents the discussion on research findings together with conclusions and the recommendations.

2. LITERATURE REVIEW

"CSR is the obligations of businessmen to pursue those policies, to make decisions, or to follow those lines of action which are desirable in terms of the objectives and values of our society" (Bowen, 1953). It is businesses taking care of their society, environment and interaction with their stakeholders which is used as a tool to businesses show their role in society and reputation (Lichtenstein *et al*., 2004). Moreover, the definitions vary due to the differentiation in the country, business culture and social, ethical behaviours and used different areas to describe the CSR. Table 1 illustrates the areas of CSR discussed in the definitions. Conclusively, it has concluded that six (06) main areas which are health and safety and welfare of employees, environment protection, ethical behaviour, legal compliance, economic development and philanthropic responsibilities of the companies. The first and foremost responsibility of an organisation toward its employee is to ensure their safety and satisfaction in the workplace (Montero *et al*., 2009). Moreover, the organisations should have health and safety policies, workplace monitoring practices, proper training programmes, providing entertainment facilities to reduce stress and tired of employees in order to improve the employees' health and safety at the workplace (Peloza and Shang, 2011).

Table 1: Definitions of CSR

Authors	Areas					
	Community	Economic	Legal	Ethical	Philanthropic	Environmental
Frederick (1960)	√	√		√		
Carroll (1979)		√	√	√	√	√
Maignan (2001)	√	√	√		√	√
Sharma and Mehta (2012)		√	√		√	√
Lindgreen and Swaen (2010)	√	√	√	√	√	√

Corporate activities are highly contributed to the Green House Gas emission (2008), and it pollutes water reservoirs, groundwater, fauna and flora and biodiversity by releasing wastewaters, solid waste and chemicals (Gadenne *et al*., 2009). Thus, CSR emphasise to follow the energy efficient, water conservation, renewable energy usage, waste management practices and plantation programs to protect the environment (Lyon and Maxwell, 2008).

Then, the ethical responsibility emphasises business owners need to create a set of terms to carry out the business activities without doing harm to society. Even though it does not enforce by the law, the organisation creates its own value and norms to treat the employee, customers, suppliers, competitors and debtors fairly and respectively (Lantos, 2001). Further, corporates have a responsibility to respect and follow the legal regulation because law and regulations are created to ensure the well-being of society by avoiding harmful activities of peoples and firms (Chen, 2011). The legal responsibility includes the compliance of labour practices with labour law and health and safety regulations, following environmental regulations when operating the plant and waste disposal, compliance with the contract and property laws (Guay *et al*., 2004). The economic responsibility is to emphasise being a profitable organisation maximise shareholder value, strategies for competitive advantage and use of human and natural resources to achieve economic objectives through social activities (Garriga and Mele, 2004). Also, it as integrity, corporate governance and economic development of the community, transparency, prevention of bribery and corruption, payments to national and local authorities, use of local suppliers, hiring local labour and similar areas (Asemah *et al*., 2013). Moreover, philanthropic responsibilities are the volunteer responsibilities of the enterprise (Lambooy, 2014). It includes donations of goods and services, volunteering activity, the involvement of the enterprise in the community development (Nurn and Tan, 2010).

The above discussed responsibilities are closely related to the built environment of the corporates. Hence, managing built environment to reduce the social and environmental impacts is the social responsibility of an organisation (Lyon and Maxwell, 2008). In that respect, FM is an emerging profession to support the core business of the organisation by effective management of facilities, people, workplace and technology in the built environment (Chotipanich, 2004), and it is a rapidly growing sector over the years due to the increased importance for managing support services to meet the needs of the core business (Musa and Pitt, 2009). Further, the role of FM in the organisations enhances the business continuity through the effective management of support services to core business function (Junghans and Olsson, 2014). International Facilities Management Association (IFMA, 2017) defined, FM is a profession that encompasses multiple disciplines to ensure the functionality of the built environment by integrating people, place, process and technology. The term multiple disciplines cover a wide range of activities such as real estate management, engineering and maintenance, risk management, health and safety, human resource management, environment and sustainability, contract management and utility management (Kamaruzzaman and Zawawi, 2010). Further, facilities managers are engaging with customers, employees, service partners and the community to manage economic, environmental and social impact of the organisation and to deliver stakeholder value in community based FM (Alexander and Brown, 2006). In addition, Isa and Kamaruzzaman (2017) argued that FM functions are closely related to the value management because owners can gain benefits for their investment in the building development when it lasts a long time and functioning with the cost effective operation and maintenance. In that respect, CSR is an area where FM is expected to have great potential to add value in terms of environment aspect together with social aspect (Jensen *et al*., 2014).

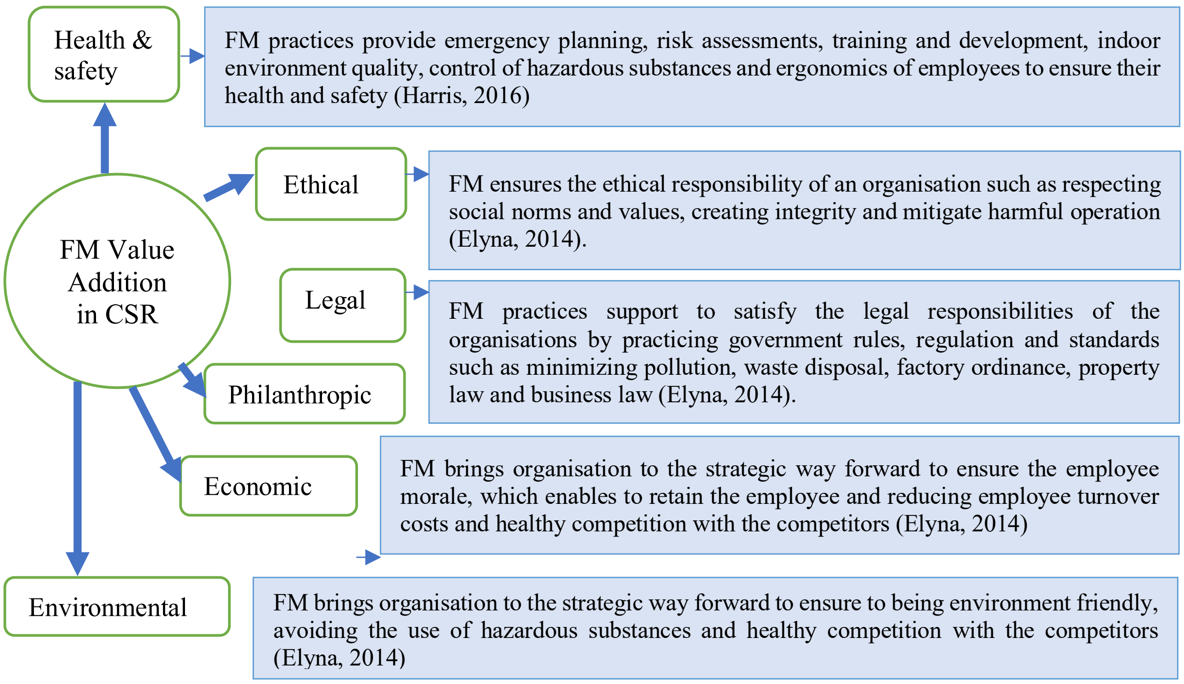

Figure 1:FM value addition in CSR

3. RESEARCH METHODOLOGY

The aim of the study is to review the FM value addition in the social and environmental well-being of society through the built environment management of corporates. Agreeing with the nature of this study, a qualitative approach was chosen due to its holistic view of the research problems and qualitative researches are well structured, transparent and easy to understand. Accordingly, semi structured interview was selected as the data collecting tool to reach and explore complete and clear answers for any new research topics (Creswell, 2008). Expert interviews, are most suitable techniques in case of there are no enough researches and data available for the study (Hamza, 2014) with semi structure interview format, which is provided with an opportunity to the interviewee for acknowledging own views regarding the social issue (Saunders, 2009) were selected. The details of the experts are shown in Table 3. All three (03) experts of CSR were selected from the socially responsible companies in Sri Lanka and who have engaged in CSR practices. The FM experts who engaged in the built environment. Collected data were analysed by content analysis method by using NVivo12 software. Finally, the research findings were validated with two (02) expert interviews.

Table 3.: Details of selected organisations

Expertise	Interviewee	Sector	Designation	Experience
CSR	S_A	Retail and Finance	Senior Commercial Manager	10 Years
	S_B	CSR consultancy service	Knowledge Management and Corporate Engagement Officer	8 years
	S_C	Telecommunication	Human Resource Manager	8 years
FM	F_A	FM Service Provider	Head of Business	8 years
	F_B	FM Service Provider	General Manager (FM)	24 years
	F_C	Office	Facilities Manager and Deputy head of Corporate Service	7 years
	F_D	Hospital sector	Quality Assurance Coordinator	8 years

4. RESEARCH FINDINGS AND DISCUSSION

This section discusses the finding of this study of FM value addition in areas of CSR into six (06) subs heading namely Health and Safety and Welfare of Employees, Environmental protection, Ethical Responsibility, Legal compliance responsibility, Economic responsibility and Philanthropic responsibility.

4.1 FM VALUE ADDITION IN AREAS OF CSR

While FM support to the core business function of the companies, the experts highlighted that FM has a significant role to add value in CSR. FM is not only adding value to the economic viability of the organisation, but also delivering social and environmental value too. “Do you think FM practices can influence social well-being? If yes, briefly describe it” through this question, the views about CSR of FM professionals understood. F_A specified, CSR is about what businesses are adding value to its employees, customers, environment and the society beyond the goods and service they provide. In addition, F_C and F_D noted, “CSR is about companies voluntarily taking responsibility for the social and environmental impact of their operation”. Moreover, F_B statement evidenced that the companies have responsibilities to fulfil the expectation of the society beyond the owner’s benefits. Additionally, all four of them were agreed with the FM has a significant role to add value in CSR. F_A stated that FM is not only adding value to the economic viability of the organisation, but also delivering social and environmental value too. However, most of them are seeing FM as a property management practice in Sri Lanka. Further, F_B stated as, FM supported to enhance the well-being of the community, even though they do not have a CSR policy through energy saving, water conservation and waste management. In addition, F_C statement also similar with F_A statement, the impact of the FM practices is not only extended within the organisation and its building but also impact the society and environment. To identify the FM value addition on the CSR, the data was collected under the six areas of the CSR as mentioned above and each area is described below.

4.1.1 Health and Safety and Welfare of Employees

The professional behaviour of FMs ensure the rights of employees and avoid any potential situation for employee violations. F_A stated that role of FM in health and safety is vital to ensure the well- being of employees and F_B mentioned that in the built environment, facilities managers are the most competence professionals in this area. All the FM experts were mentioned the same practices of FM in employee health and safety. However, only F_A and F_B mentioned the avoidance of employee violations under the health and safety practices and explained, in line with professional ethical standards of the facilities manager, have to perform their role where they ensure the rights of employees and avoid any potential situation for the employee violations. Also, F_A ensuring employee health and safety is a part of legal obligation as well as the social responsibility of the businesses. In addition, F_B and F_C stated facilities managers have a major part in this area due to having responsibility of policy creation and compliance with the local and international regulatory requirements. Apart from that, all the interviewees were discussed about hazard identification and elimination, workplace monitoring, emergency preparedness practices during the fire, chemical exposure and blasting, employee training and stakeholder communication functions of FM. Added to that, F_D listed following as the responsibility of FM which has to disclose the accident information in the built environment as part of social responsibility.

4.1.2 Environmental Protection

"Sustain of the environment is important for well- being of the human and animals in the planet" stated by F_B and F_D argued about releasing GHG emission, wastage of resources and excessive energy uses are the main reason for the global warming and which are handle and recorded by FM professionals. As said by the CSR experts, companies should have a clear environmental policy to ensure the effectiveness of environmental protection process. Alike, FM experts were noticed that FMs have a major role in the environmental policy creation in the organisations. According to S_B, "corporate built environment is highly contributed to climate change by consuming high energy, GHG emission and pollute the air and water reservoirs. Therefore, organisations are concerned with the environment protection as their social responsibility". FM experts were discussed how FM practices are contributed to minimise the environmental effect of organisations activities. In that respect, F_B and F_C mentioned eco-friendly purchasing practices which are selecting less carbon or carbon neutral materials, reusable and recyclable products, less energy usage and environmentally friendly dispose products for manufacturing and end-use purposes. Additionally, compliance with the environmental management standards and regulatory practices of facilities managers such as environment protection license, monitoring and reporting, environmental impact assessment, energy audits were mentioned.

4.1.3 Ethical Responsibility

The FM profession highly deal with the employees, suppliers, contractors and other facility related parties in the society for organisation purposes. Therefore, facilities managers have a responsibility to ensure the rights of employees such as workplace safety, equality, and fair wages and work hour. Also, they support to the organisation toward the clients through the fair dealing with the clients by avoiding any harms to their properties. Further, ethical responsibility is to avoid harmful activities to society. F_C defined ethical responsibility as "behaving fairly and transparently with the employee, customers, suppliers and society" and F_A said, even though FM has no any relationship with organisation's customers, it is linked with the employee and society. Moreover, F_A and F_C were stated that generally violation of employees is occurred in the workplaces due to the different behaviours and disciplines of employees. Therefore, facilities managers using different methods to identify the potential for the employees' violations and resolve it in the early stage to ensure the rights of other employees in the organisation. The CSR experts defined ethical responsibility as doing good things to society. Further, mentioned as avoiding environmental harmful activities as an ethical responsibility because it causes a negative impact on society. Similarly, all FM experts noticed that FM practices are eliminated those environmental harmful operations in the built environment. In addition, F_B and F_D stated the main function of the FM is integrating people, place, process and technology for the functionality of a built environment. Hence, people are important part of FM. Thus, fulfilling expectations and respecting the cultural and social values are important to facilities managers in order to ensure the social responsibility of the organisation toward the community.

4.1.4 Legal Compliance Responsibility

Legal responsibility of corporates discussed respect and compliance with local and international standards, rules and regulation which are enacted by the government to direct the business activities in an ethical way. Corporate activities are generally linked with different laws and FM practices ensure the compliance of the corporate built environment activities along with the law and regulation. Thus, facilities managers create health and safety policies and environmental policies as per the requirement of local and international standards and regulation and practicing it standards manner. F_A and F_B stated that facilities managers are managing the health and safety of the built environment in order to secure the peoples from the hazards. Moreover, F_C indicated that those health and safety management practices are designed based on the local and international standards and regulatory requirements. Further interviewee F_D mentioned that facilities managers are ensuring mechanical and electrical services are complied with the standards, obtaining license and certificates regarding air and water quality, implementing health and safety standards and following the regulatory guidance for ensuring the safety of employees, customers and visitors. In addition, according to F_D FMs must aware of the environmental problems and create the solution in accordance with the standards and regulations. Further, F_A and F_B stated that FMs are carried out the environmental assessments, obtaining an environment protection license, monitoring and reporting practices as part of compliance with the standards. Moreover, contract management activities were mentioned by F_B, F_C and F_D and in addition, they specified that facilities managers are entered into the facilities related contracts on behalf of client or owners with different service providers. They have a responsibility to keeping this contractual relation without breaching any obligations, bribery and corruption as well. Moreover, F_A, F_B and F_D were stated the real estate property management role of FM, which ensure the compliance with areas of property law such as ownership, tenancy, possession, leasing, property rights and dispute solution. Further, documentation practices of facilities managers enable the availability of records as per the legal requirements.

4.1.5 Economic Responsibility

The foremost economic responsibility of corporate is to be a profitable organisation due to their responsibility to provide economic benefits to its owners, employees, creditors and society. F_A and F_D only discussed the FM role in the economic responsibility of CSR. In that respect, interviewee F_A and F_D argued that FM has consisted of a different economy related disciplines such as prepare more accurate future capital budgets, finding solutions to specific problems in the built environment, controlling capital resources required to support operations, reduction in procurement cost, saving in energy consumption of the facility and improvement of overall work environment with more flexible and cost effective which enable to profit maximization of the company. Therefore, facilities management support to the economic responsibility of the companies in terms of profit maximization. In addition to that, FM practices ensure the efficient use of the human, physical, financial and technology resources of the organizations. So, FM support to the economic responsibility in terms of cost saving, risk avoiding and efficient use of resources. However, interviewee F_B and F_C did not mention the FM role in economic responsibility.

4.1.6 Philanthropic Responsibility

According to all four FM experts' statements, FM does not have any value addition in the philanthropic responsibility of the company. Because, philanthropic activities include donations, public welfare, education and the environment-based volunteer activities of the company. Therefore, FM practices not related to philanthropic activities.

5. CONCLUSIONS

According to the CSR experts, corporates have a responsibility to concern the social issues along with the profit maximisation and have become the main element of economic development and human resource development in Sri Lanka. However, corporates activities have a major impact on the society and environment. Thus, there is a need for socially responsible business operation among the corporates. According to the finding, there is a lack of knowledge and practices regarding the CSR among the Sri Lankan corporate sectors. Thereby, most of the organisations follow CSR as a philanthropic activity. When considering the social and environmental impact of the corporates' built environment performance, it has a significant effect on employee health and safety, environmental pollution, energy and water conservation, resource depletion, employee violations, legal negligence and sustainability. In addition, CSR experts revealed few companies are following energy saving, waste management and water efficiency for their profit maximization purposes, not for the social conservation. Further, corporates are not giving priority to the environment effect of corporate activities. Also, there is no legal provisions in Sri Lanka for businesses to carry out operations with the socially responsible manner. Therefore, they practice health and safety, fair dealing with the stakeholders and compliance with regulations for avoiding penalties when violation arise with the labour laws, contract law, environment and factory ordinance regulation. Experts in CSR stated that corporates should engage with effective CSR initiatives with the all professional participants in the organisation to overcome those issues. In that respect, this research was conducted to identify the FM value addition in CSR. Accordingly, FM experts accepted with FM value addition on following areas of CSR, Employee health and safety, Environment protection and avoidance of nuisance, Ethical responsibility, Legal compliance and Economic responsibility by the following activities of FM, such as health and safety, environmental management, eco-friendly purchasing and housekeeping, creating supportive corporate culture, energy saving, emergency preparedness, waste management, resource management and risk management practices, which are adding value to core business in terms of profitability and functionality. As well as, it is adding value to the wellbeing of society. Therefore, FM has a major role in the CSR.

6. REFERENCES

Alexander , K. and Brown, M., 2006. Community-based facilities management. *Facilities,* 24(7/8), pp.250-268.

Anker Jensen, P., van der Voordt, T., Coenen, C., von Felten, D., Lindholm, A.L., Balslev Nielsen, S., Riratanaphong, C. and Pfenninger, M., 2012. In search for the added value of FM: what we know and what we need to learn. *Facilities*, *30*(5/6), pp.199-217.

Annik , M. F., 2006. Environmental management and corporate social responsibility. *Clean Technologies and Environmental Policy,* 8(4), pp.217-220.

Asemah , E., Okpanachi, R. and Edegoh , L., 2013. Business Advantages of Corporate Social Responsibility Practice: A Critical Review. *Journal of Business Management,* 18, pp.114-125.

Bowen, H., 1953. *Social Responsibilities of the Businessman.* New York: Harper.

Carroll, A. B., 1979. A three-dimensional conceptual model of corporate social performance. *Academy of Management Review,* 4(4), pp.497-505.

Central Bank of Sri Lanka [CBSL], 2015. *Annual Report 2015,* Sri Lanka.

Chen, C., 2011. The major components of corporate social responsibility. *Journal of Global Responsibility,* 2(1), pp.85-99.

Chotipanich, S., 2004. Positioning facility management. *Facilities,* 22(13/14), pp.364-372.

Conely, B., 2017. Investing in the Future with CSR. *Facility Management Journal,* pp.45-109.

Creswell, J. W., 2008. Editorial: Mapping the Field of Mixed Methods Research. *Journal of Mixed Methods Research,* 3(2), pp.95-108.

Elyna, M. N., 2014. Facilities management: the business enabler. *Journal of Facilities Management,* 12(4), pp.11-16.

Feijoo, B. F., Romero, S. and Ruiz, S., 2014. Effect of Stakeholders' Pressure on Transparency of Sustainability Reports within the GRI Framework. *Journal of Business Ethics,* 122(1), pp.53-63.

Frederick, W. C., 1960. The Growing Concern Over Business Responsibility. *California Management Review,* pp.54–61.

Fred, R., 2008. Why corporate social responsibility should be popularised but not imposed. *Corporate Governance,* 8(3), pp.330-341.

Gadenne, D. L., Kennedy, J. and McKeiver, C., 2009. An Empirical Study of Environmental Awareness and Practices in SMEs. *Journal of Business Ethics,* 84(1), pp.45-63.

Garriga, E. and Melé, D., 2004. Corporate Social Responsibility Theories: Mapping the Territory. *Journal of Business Ethics,* 53(1-2), pp.51-74.

Guay, T., Doh, J. P. and Sinclair, G., 2004. Special Issue on Ethical Investment and Corporate Social Responsibility. *Journal of Business Ethics,* 52(1), pp.125-139.

Hamza, A., 2014. Interviewing as a Data Collection Method: A Critical Review. *English Linguistics Research,* 3(1), pp.53-60.

Harris, R., 2016. New organisations and new workplaces: Implications for workplace design and management. *Journal of Corporate Real Estate,* 18(1), pp.4-16.

International Facilities Management Assosiation(IFMA), 2017. [Online] Available at: http://www.ifma.org/about/what-is-facility-management [Accessed 24 march 2017].

Jamali, D. and Mirshak, R., 2007. Corporate social responsibility (CSR): theory and practice in a developing country context. *Journal of Business Ethics,* 72(3), pp.243-262.

Jensen, P., 2010. The Facilities Management Value Map: a conceptual framework. *Facilities,* 28(3/4), pp.175-188.

Jensen, P., Voordt , T., Coenen, C. and Sarasoja, A., 2014. Reflecting on future research concerning the added value of FM. *Facilities,* 32(13/14), pp.856-870.

Junghans, A. and Olsson, N., 2014. Discussion of facilities management as an academic discipline. 32(1/2), pp.67-79.

Kamaruzzaman , S. N. and Zawawi , E. A., 2010. Development of facilities management in Malaysia. *Journal of Facilities Management ,* 8(1), pp.75-81 .

Lambooy, T., 2014. Legal Aspects of Corporate Social Responsibility. *Utrecht Journal of International and European Law,* 30(78), pp.1-6.

Lantos, G. P., 2001. The boundaries of strategic corporate social responsibility. *Journal of Consumer Marketing,* 18(7), pp.595-632.

Lichtenstein, D. R., Drumwright, M. E. and Braig, B. M., 2004. The Effect of Corporate Social Responsibility on Customer Donations to Corporate-Supported Nonprofits. *Journal of Marketing,* Volume 68, pp.16–32.

Lindgreen , A. and Swaen, V., 2010. Corporate Social Responsibility. *International Journal of Management Reviews,* 12(1), pp.1-7.

Lyon, T. P. and Maxwell, J. W., 2008. Corporate Social Responsibility and the Environment: A Theoretical Perspective. *Review of Environmental Economics and Policy,* 1(0), pp.1-22.

Maignan, I., 2001. Consumers' perceptions of corporate social responsibilities. *A cross- cultural comparison. Journal of Business Ethics,* 30(1), pp.57-72.

Marrewijk, M., 2003. Concepts and Definitions of CSR and Corporate Sustainability: Between Agency and Communion. *Journal of Business Ethics,* 44(2-3), pp.95-105.

Martinez, J. B., 2012. *International Corporate Social Responsibility: The Role of Corpo rations in the Economic Order of the 21st Century.* Alphen aan den Rijn: Kluwer Law international.

Montero, M. J., Araque, R. A. and Rey, J. M., 2009. Occupational health and safety in the framework of corporate social responsibility. *Safety Science,* 47(10), pp.1440-1445.

Musa, Z. and Pitt , M., 2009. Defining facilities management service delivery in UK shopping centres. *Journal of Retail and Leisure Property,* 8(3), pp.193-205.

Nurn, C. W. and Tan, G., 2010. Obtaining intangible and tangible benefits from corporate social responsibility. *International Review of Business Research Papers,* 6(4), pp.360-371.

Peloza, J. and Shang, J., 2011. How can corporate social responsibility activities create value for stakeholders? A systematic review. *Journal of the Academy of Marketing Science,* 39(1), pp.117-135.

Rajmanthri, S., 2005. Effects of Corporate Social Responsibility (CSR) on organizational sustainability: A case study of the Sri Lankan Corporate Sector. *Social Responsibility Journal,* 1(3/4), pp.149-152.

Rathnasiri, H., 2003. Corporate social responsibility practices of Sri Lankan private sector: an exploratory study. *Sri Lanka Journal of Management,* 8(3/4), pp.195-228.

Redlein, A., Loesch, J. and Fuke, F., 2015. Corporate Social Responsibility (CSR) and Facility Management (FM) in Europe. *International Journal of Facilities Management,* 6(1), pp.15-25.

Reese, C. D., 2003. *Occupational Health and Safety Management.* New York: Lewis Publishers.

Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students.* Harlow: Pearson Education.

Sharma, S.K. and Mehta, S., 2012. Where Do We Go from Here? Viewing Corporate Social Responsibility through a Sustainability Lens. *Journal of Contemporary Management Research*, *6*(2), pp.69-76.

Strachan, P., Sinclair, I. and Lal, D., 2003. Managing ISO 14001 implementation in the United Kingdom Continental Shelf (UKCS). *Corporate Social Responsibility and Environmental Management,* 10, pp.50-63.

Supanti, D., Butcher, K. and Fredline, L., 2015. Enhancing the employer-employee relationship through corporate social responsibility (CSR) engagement. *International Journal of Contemporary Hospitality Management,* 27(7), pp.1479-1498.

Turker, D., 2009. How corporate social responsibility influences organizational commitment. *Journal of Business Ethics,* 89, pp.189-204.

Perera, G.P.P.S., Tennakoon, T.M.M.P., Kulatunga, U., Jayasena, H.S. and Wijewickrama, M.K.C.S., 2019. Factors affecting the selection of a procurement method for steel building construction. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 340-349. DOI: doi.org/10.31705/WCS.2019.34. Available at: https://2019.ciobwcs.com/papers

FACTORS AFFECTING THE SELECTION OF A PROCUREMENT METHOD FOR STEEL BUILDING CONSTRUCTION

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ABSTRACT

Construction procurement involves organizing processes of acquiring services and products for activities starting from project investigation to completion of a project. Along with the development of new concepts and technologies, construction procurement arrangements were also developed to draw the best value for construction organizations. Selecting the best procurement method for a specific project is a challenge since the availability of diverse procurement options and subjective factors affecting the selection of procurement methods. An inappropriate selection of a procurement method leads to project failure while adversely affecting the expectation of stakeholders and the economy. Since the number of steel building constructions are increasing in the Sri Lankan context this study aims to identify factors which highly influence the selection of a procurement method for steel building construction in Sri Lanka. In order to achieve the aim, initially, a comprehensive literature survey was carried out to identify factors which influence the procurement selection for building construction. Accordingly, 42 factors were identified. Subsequently, a quantitative research approach was followed to list down the factors on their significance in selecting procurement method for steel building construction in Sri Lanka. Consequently, 26 factors were concluded as the most significant factors, which influence the procurement selection of steel building construction through Relative Importance Index (RII). Procurement Path Decision Chart was used to analyses the procurement selection factor and construction management was identified as the most suitable procurement method for steel building construction in Sri Lanka.

Keywords: *Procurement Methods; Selection Criteria; Steel Building Construction.*

1. INTRODUCTION

Construction industry consist of a vast scope of activities that display unique and complex characteristics and establishes a major part in the economy (Behm, 2008). The quality of a construction project affects the success of the construction sector. Thus, the management of project standards in terms of the construction technologies utilized becomes a major a concern (Ali and Kamaruzzaman, 2010).

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Likewise, as underlined by Ali and Kamaruzzaman (2010), scope, cost, time and quality were among the factors of project success which significantly dependent upon the construction technology used. Hence, steel framed building construction had gained popularity as a widely used construction technology considering the advantages in terms of project success factors (Patel and Jani, 2013).

Conversely, steel structural construction projects encounter issues during the construction, transportation, installation and operational stages (Rashid *et al.,* 2016). The procurement of steel is a commercial process that involve the experience and interest of client, detailers, fabricators, architects, and qualified engineers (Farrow, 2007). Selection of a procurement method is a major concern since it defines the role of contracting parties and the extent of innovation in the project (Valence, 2010).

Therefore, steel building procurement is indicative of the overall framework of responsibilities and authorities for participants of the construction process. Selecting a suitable procurement method is a critical point that govern the success of the project (Cheung *et al.,* 2001). Henceforth, the scope of this research paper was delimited to identify and evaluate the selection criteria for procurement methods for steel buildings.

2. STEEL BUILDING CONSTRUCTION

The popularity of steel building construction over the traditional construction technology is observed due to several reasons. Structural steel is a cost effective material for building construction (Glidden, 2000). Recently, new technologies have become available to fabricate and erect steel members by reducing the cost of construction to make quick profits (Besgul, 2006). Unlike the reinforced concrete structures, steel structures have the advantage of a lower structured self-weight, lower cost and cover a larger occupying area (Guangyu *et al.,* 2008). Further, they are durable and easy to assemble (Spacone and Tawil, 2004). Steel structures are very suitable for buildings that require long spans, such as sports facilities, atriums, assembly places and convention centres, since it allows longer spans without requiring columns in between (Mehta, Scarborough and Armpriest, 2012). Despite the availability of researches to enhance the activities related to steel building construction, performance control, steel building cost control and cost optimization, less concern had been given to steel building construction procurement.

3. PROCUREMENT METHODS

Procurement is the process of management and fulfilment of construction projects. Further, it has been described as success of a logical action occurred or performed for the completion of a project (Mathonsi and Thwala, 2012; Ratnasabapathy, Rameezdeen and Gamage, 2006). The most commonly used procurement methods can be identified as traditional method, integrated procurement method and management procurement method (Davis, Love, and Baccarini, 2006). Still, there is no specific procurement method that is applicable to all types of construction projects (Sawalhi and Agha, 2017). Yet, the appropriate selection of a procurement system can be of assistance to minimize problems during the construction (Sawalhi and Agha, 2017). Examining the factors under client requirements, project characteristics and external environment can be beneficial in selecting a procurement method (Gbadebo and Ojo, 2012).

4. CONSTRUCTION PROCUREMENT SELECTION

Based on the literature findings, 42 selection factors are listed in Table 1. Conferring to Table 1, the factors that influence the selection of procurement methods are classified as internal and external factors. The internal factors are again segmented in to client-based selection factors and project-based selection factors.

Table 1: Construction procurement selection factors

Construction Procurement Selection factors		
Internal		**External**
Client	**Project**	
Project completion within budget	Technical complexity of the project	Natural disasters
Short construction period	Design reliability	Material availability
Good quality of construction project	shop drawings process	Industrial actions
Experienced clients	Prefabrication process	Regulatory environment regulating feasibility
Inexperienced clients	Material transportation process	Globalization
Client's specific requirements and objectives can implement.	Erection process	Government policies
flexibility to change design during both design and construction periods	Project funding method	Market forces
Quick response to clients' new requirements	Constructability of design-high	Political considerations
According to client financial capabilities minimum risk	Site risk factors	Environmental issues (Earthquakes)
Allocation of responsibility	Available resources of project	Incensement weather
Qualified professional involvement	Construction method- new construction	Market Competitiveness
Client willingness to take risk	Qualified knowledgeable and experienced contractor	
Payment modality	Minimizes Construction Aggravation	
	Material distribution	
	Project size-high	
	Project site location	
	Skilled / unskilled labour availability-lower	
	Project type residency/commercial	

Source: Adapted from Ratnasabapathy, *et al.* (2008) and Mathonsi and Thwala (2012)

Based on Table 1, it can be identified that most of the selection factors are influenced by various complications during design, construction, transportation, installation and operation (Rashid *et al.*, 2016). Hence the gravity of the importance of each of the listed factors required to be identified as the initial step of the selection of a most suitable procurement method for steel building construction.

5. RESEARCH METHOD

The literature review clearly outlined construction procurement method selection factors. Hence, a deductive research approach was followed to prioritize the selection factors. A survey research strategy was initialized since it encourages significant number of observations prior to driving conclusions. A quantitative method was determined as the most suitable research choice since there has been a lack of quantitative research related to procurement method selection. The survey was carried out among various construction industry professionals. According to Burns (1994), it is important to select a larger sample size (>= 30) in order to have less errors in the findings. As the data collection technique, a questionnaire was distributed among 70 participants selected through convenient sampling. Subsequently, 45 questionnaires were received denoting a response rate of 64.29%. The questionnaire consisted questions designed with a 5-point Likert scale to mark the importance of each selection factor.

Table 2 elucidates the years of experience, proficient fields and the organisations they are representing.

Table 2: Respondents' profile

Respondents' characteristic	Categories	Count
Years of experience	0-5 years	2
	5-10 years	3
	10-15 years	7
	15-20 years	15
	More than 20 years	18
Proficient Fields	Construction projects administration	18
	Project procurement	45
	Dispute resolution	15
Organisation	Client	9
	Contractor	18
	Consultant	11
	Construction management	7

The collected data via questionnaires was analysed based on the Weighted Mean Rating (WMR) given in formula (01), which reflected the importance given to each of the selection factor by the respondents.

$$WMR = \frac{\sum_{i=1}^{5}(x_i \times f_i)}{R\%} \quad (01)$$

Where: WMR= Mean Rating for an attribute; f_i = Frequency of responses for an attribute (ranging from 1-5); R%= Percentage response to rating point of an attribute.

Successively, the Standard Deviation (SD) was calculated which quantified the discrepancy of the data set around the mean value. Higher the value of SD, so as the deviation of the data around the mean value and vice versa. The standard deviation for each variable was derived using formula (02).

$$SD = \sqrt{\frac{\sum(Ri - Mi)^2}{n}} \qquad (02)$$

Where: SD = Standard deviation value, Mi. = Mean value of particular variable, Ri = Weightage given to each variable based on the respondents' level of agreement, n = Total number of respondents

The T value was obtained for each of the procurement method selection factor to identify the relative importance of each factor particularly for steel building construction procurement. The IBM SPSS Statistics software was used to test the null hypothesis; "important" (H_o): $\mu <= \mu_o$ against the alternative hypothesis; "not important" (H_1): $\mu > \mu_o$, where μ_o was the population mean. μ_o was given a fixed value of 3, since according to the Likert scale, point 3 was neutral. The decision rule was applied to determine whether the null hypothesis could be rejected or accepted. Where the degree of freedom is 26, the critical t-value was taken as 2.0325 as derived from the table of t-values 30-2.042 and 40-2.021 in confident level 95%.

Therefore, when the observed t-value is greater than critical t-value, the null hypothesis is rejected. Therefore, in the analysis, when t observed value is greater than the t-critical value, was considered as a very significant factor while the null hypothesis is rejected and the alternate hypothesis is accepted. However, if the t observed value for one factor had been less than the t-critical value, the null hypothesis would have been retained.

Subsequently, the Relative Important Index was used as an analysis technique for questionnaire responses, which had been used by many researchers to determine the relative significance of the attributes. Hence, RII was used to rank the important and very important factors derived through the t-value and verified through the SD. RII equation which has been used in this research study is given in equation (03).

$$RII = \frac{\Sigma W}{A \times N} \qquad (03)$$

Where, W= Constant expressing the weighting given to each response, A= the highest weighting, n = the frequency of responses and N= Total Number in the Responses.

Once the ranking of the procurement method selection factors was completed scope of this paper is realized.

6. RESEARCH FINDINGS AND DISCUSSION

6.1 LEVEL OF SIGNIFICANCE OF THE PROCUREMENT METHOD SELECTION FACTORS

Considering the WMR, SD and t-value, the factors considered when selecting a suitable procurement method for steel building projects were categorized as Very Important (VI), Important (I), and Not Important (NI) as illustrated in Table 3.

Table 3: SD, TV, WMR and the level of significance of considered factors

Ref. No.	Considered Factor	SD	TV	MW	VI/ I/ NI
A	**Client characteristic related procurement selection factors**				
1	Complete project within the established budget	0.7506	12.428	4.475	VI
2	Short construction period	0.3848	29.995	4.825	VI
3	Good quality of construction project	0.7696	5.342	3.650	I
4	Experienced clients	1.2800	0.247	3.050	NI
5	Inexperienced clients	1.0561	-1.497	2.750	NI
6	Client's specific requirements and objectives can implement.	0.5943	12.504	4.175	VI
7	flexibility to change design during both design and construction periods	0.7442	7.6490	3.900	I
8	Quick response to clients' new requirements	0.7579	6.676	3.800	I
9	According to client financial capabilities minimum risk	1.0561	4.491	3.750	I
10	Allocation of responsibility	0.6718	0.941	3.100	NI
11	Qualified professional involvement	0.9443	4.521	3.675	I
12	Client willingness to take risk	0.8738	3.076	3.425	I
13	Payment modality	0.9388	5.895	3.875	I
B	**Project characteristic related procurement selection factors**				
1	Technical complexity of the project	0.6751	11.008	4.175	VI
2	Design reliability	0.6718	10.356	4.100	VI
3	shop drawings process	0.6405	9.874	4.000	VI
4	Prefabrication process	0.6597	9.347	3.975	I
5	Material transportation process	0.9195	-0.172	2.975	NI
6	Erection process	0.4634	15.354	4.125	VI
7	Project funding method	1.0099	5.167	3.825	I
8	Constructability of design-high	0.7161	13.248	4.500	VI
9	Site risk factors	0.8317	5.894	3.775	I
10	Available resources of project	0.7845	4.031	3.500	I
11	Construction method- new construction	0.6718	8.473	3.900	I
12	Qualified knowledgeable and experienced contractor	1.0350	7.180	4.175	VI
13	Minimizes Construction Aggravation	1.5357	-1.956	2.525	NI
14	Material distribution	1.2707	-3.857	2.225	NI
15	Project size-high	1.1206	-0.141	2.975	NI
16	Project site location	1.3085	-4.471	2.075	NI
17	Skilled / unskilled labour availability-lower	0.8022	6.701	3.850	I
18	Project type residency/commercial	1.4106	-0.448	2.900	NI

Ref. No.	Considered Factor	SD	TV	MW	VI/ I/ NI
C	**External characteristic related procurement selection factors**				
1	Natural disasters	0.9594	3.626	3.550	I
2	Material availability	0.6385	5.448	3.550	I
3	Industrial actions	1.0622	0.000	3.000	NI
4	Regulatory feasibility	0.6597	0.240	3.025	NI
5	Globalization	0.7299	0.650	3.075	NI
6	Government policies	1.0013	4.106	3.650	I
7	Market forces	1.0175	0.777	3.125	NI
8	Political considerations	1.0834	-4.816	2.175	NI
9	Environmental issues (Earthquakes)	1.0266	4.005	3.650	I
10	Incensement weather	1.0908	-4.639	2.200	NI
11	Market Competitiveness	0.9997	1.423	3.225	NI

Consequently, different respondents propounded different criteria weights. According to the result of the MWR analysis of the gathered data, very important factors were construction period, ability to complete the project within the set budget and the ability to implement the client's specific requirements. This result was backed by a mean value exceeding 4.00. Moreover, the critical t value was 2.0325 and all the three factors gain values of 12.428, 29.995 and 12.504, which showcased the significance level of the factors.

Similarly, technical complexity of the project, design reliability, shop drawings process, erection process, constructability of design-high and qualified knowledgeable and experienced contractor were the very important procurement method selection factors. The significance level (t- value) of the factors were identified as 11.008, 10.356, 9.874, 15.354, 13.248 and 7.180.

The external factors of procurement selection with significance value more than the critical t- value were natural disasters, material availability, Government policies and Environmental issues. The t-value of the factors were identified as 3.626, 5.488, 4.166 and 4.005. Alternatively, industrial actions, regulating feasibility, globalization, market forces, political considerations, incensement weather and market competitiveness factors were disregarded due to their respective t-values 0.000, 0.240, 0.650, 0.777, -4.816, -4.639 of and 1.423 which were lower than the critical t-value of 2.0325. These results demonstrated the very important factors and the factors to be disregarded in procurement selection process of steel buildings construction.

6.2 RANKING THE PROCUREMENT SELECTION PARAMETERS FOR STEEL BUILDING CONSTRUCTION

Subsequently, there were 26 factors which were very important and important to steel building construction procurement methods. RII value was used to calculate a unique value for each factor and known as, "utility factor". Utility factor represents how much each procurement selection factor successfully achieve the respective procurement method.

Out of the 42 procurement parameters considered for the ranking process, the top 26 procurement selection parameters for steel building are ranked in Table 4 based on the utility factor.

Table 4: Top ranked procurement selection factors

Procurement selection parameters for steel building construction	RII	Rank
Short construction period	0.9650	1
Higher constructability of design	0.9000	2
Complete project within the established budget	0.8950	3
Client's specific requirements and objectives implementation	0.8350	4
Technical complexity of the project	0.8350	5
Qualified knowledgeable and experienced contractor	0.8350	5
Erection process	0.8250	7
Design reliability	0.8200	8
Shop drawings process	0.8000	9
Prefabrication process	0.7950	10
Flexibility to change design during both design and construction periods	0.7800	11
Construction method- new construction	0.7800	11
Payment modality	0.7750	13
Skilled / unskilled labour availability-lower	0.7700	14
Project funding method	0.7650	15
Quick response to client's new requirements	0.7600	16
Site risk factors	0.7550	17
According to client financial capabilities minimum risk	0.7500	18
Qualified professional involvement	0.7350	19
Good quality of construction project	0.7300	20
Government policies	0.7300	20
Environmental issues	0.7300	22
Natural disasters (Earthquakes)	0.7100	23
Material availability	0.7100	23
Available resources for the project	0.7000	25
Client's willingness to take risk	0.6850	26

According to the findings of the survey, short construction period was considered as the most significant factor which affects when selecting a procurement method for steel building construction projects. Gbadebo and Ojo (2012) had emphasised a similar notion in their study, where the time duration consumed by the pre-contract stage for the procurement process was a disadvantage to projects with shorter duration.

Moreover, the factor ranked at the second place; higher constructability of the design, had also fortified, to select a procurement method with limited or no changes to the design, thus also fulfilling the third top rank factor, complete project within the established budget (Luu and Chen 2003). The lowest ranking for client's willingness to take risk can be explained via the same literature mentioned above because, the inflexibility to change in terms of duration, design and budget through an appropriate procurement method, reduce the risk to the client.

7. CONCLUSIONS

The scope of this paper had been limited to identifying and ranking the selection factors of procurement methods for steel building construction which was a section of a study for selecting a suitable procurement method for steel building construction. The study could be extended to select a procurement method in a qualitative or quantitative way.

As a conclusion the key findings were categorised under two streams. Firstly, the selection factors of a procurement method for steel building construction were identified for their level of importance. Only 9 factors out of 46 factors were recognized as very important since they had a significantly higher t-values than the established critical t-value of 2.0325. The important factors had a t-value which was closer to the critical t-value. Hence, 17 important factors were also selected for the ranking purpose. 20 factors including experience of the client, material distribution, project size, project location, globalization and market forces were disregarded since their t-values were less than the critical t-value. Hence, it was concluded that only 26 factors out of the 46 factors identified in the literature, were important when selecting a procurement method for steel building construction.

Secondly, the ranking process was conducted through RII method, which concluded, a procurement method conforming to the short construction period, higher constructability of design and project completion within the established budget should be given priority in the selection process of an appropriate procurement method for steel building construction. The result of the ranking confirmed the previous literature, which had only discovered qualitatively, the significance of the short construction period and higher constructability of the design of the steel building construction when selecting a suitable procurement method.

8. REFERENCES

Ali, A., and Kamaruzzaman, S., 2010. Cost performance for building construction projects in Klang Valley. *Journal of Building Performance, 1*(1), pp.110-118.

Behm, M., 2008. Construction Sector. *Safety Research, 39*(2), pp.175-178.

Besgul, O., 2006. Design and production of steel buildings: a case study in Ankara (Doctoral dissertation, Middle East Technical University).

Cheung, S., Lam, T., Leung, M.Y. and Wan, Y., 2001. An analytical hierarchy process based procurement selection method. *Construction Management and Economics* (19), pp.427-437.

Davis, P., Love, P., and Baccarini, D., 2006. *Building procurement methods.* Brisbane: Australian Government's Cooperative Research Centres.

Farrow, C.B., 2007. Integrated Steel Design: Applying Lean Concepts. In *Proceedings of 15th Conference of the International Group for Lean Construction, East Lansing, Michigan.*

Gbadebo, M. A. and Ojo, A. E., 2012. Critical selection criteria for appropriate procurement strategy for project delivery in Nigeria. *Emerging Trends in Economics and Management Sciences (JETEMS), 3*(5), pp.422-428.

Glidden, B., 2000. *Building design and construction handbook*. 6th ed, F. S. Merritt and J. T. Ricketts (eds). New York: McGraw-Hill Companies.

Guangyu, H., Binlei, C., Qisong, M., Xiangyang, L. and Jia, H., 2008. Design and research on composite steel and concrete frame core wall structure. *The 14th World Conference on Earthquake Engineering. Beijing, China.*

Rashid, I.A., Aboul Haggag, S.Y., Mahdi, I. and Elhegazy, H.M., 2016. Construction Performance Control in Steel Structures Projects. *Industrial Engineering and Management*, *5*(201), pp.2169-0316.

Luu, D. T., Ng, T. S., and Chen, S. E., 2003. Parameters governing the selection of procurement system an empirical survey. *Engineering, Construction and Architectural Management, 10*(3), pp.209-218.

Mathonsi, D. W. and Thwala, W. D., 2012. Selection of procurement systems in the South African construction industry: An exploratory study. *Acta Commercii, 12*(1), pp.13-26.

Mehta, M. L., Scarborough, W. and Armpriest, D., 2012. *Building construction: principles, materials, and systems*. 2nd ed, Pearson.

Patel, P. V., and Jani, K., 2013. Analysis and design of diagrid structural system for high rise steel buildings. *Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference on Engineering (NUiCONE-2012). 51*, pp.92-100. Ahmedabad: Elsevier Ltd.

Ratnasabapathy, S., Rameezdeen, R., and Gamage, I., 2006. Macro level factors affecting the construction procurement selection: a multi criteria model. *In The Joint International Conference on Construction Culture, Innovation and Management (CCIM).* (pp.581-591). Moratuwa: Department of Building Economics, University of Moratuwa, Sri Lanka.

Ratnasabapathy, S., Rameezdeen, R. and Lebbe, N. A., 2008. Exploratory study of external environmental factors influencing the procurement selection in construction. In *Proceedings of the CIB International Conference on Building Education and Research*, *10-15 February 2008, Kandalama, Sri Lanka*.

Sawalhi, N. I., and Agha, O. E., 2017. Multi-attribute utility theory for selecting an appropriate procurement method in the construction projects. *Construction in Developing Countries, 22*(1), pp.75-96.

Spacone, E., and Tawil, S. E., 2004. Nonlinear analysis of steel-concrete composite structures: state of the art. *Structural Engineering, 130*(2), pp.159–168.

Valence, D. G., 2010. Innovation, procurement and construction industry development. *Australasian Journal of Construction Economics and Building, 10*(4), pp.50-59.

Withanage, I.M., Zainudeen, N. and Nadeeshani, M., 2019. Financial viability of using green roofing in residential buildings. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 350-359. DOI: doi.org/10.31705/WCS.2019.35. Available at: https://2019.ciobwcs.com/papers

FINANCIAL VIABILITY OF USING GREEN ROOFING IN RESIDENTIAL BUILDINGS

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ABSTRACT

As a result of increased attention towards sustainability worldwide, green concepts have become popular in the construction industry. Green roof is one of the essential elements in a green building that provide many advantages while creating a pleasant appearance for the total building. Green roofs play a major role in energy saving of a building. However, compared to a conventional roof, the initial and maintenance costs of a green roof is quite high due to the additional construction and high maintenance requirements. Thus, this paper compares the Life Cycle Cost (LCC) of a green roof with that of a conventional ceramic tile roof in order to determine the financial viability of green roofing. Findings were gathered from several cases and past researches under initial cost, maintenance cost and energy saving of green roofs and adopted to the selected case for the analysis. Findings of the study indicate that initial cost of the green roof was higher than conventional and represented 8.39:(-6.55) proportion of the total life cycle cost of the building. Similarly, maintenance, operational and replacement costs were also higher than the conventional representing 12.08:(-6.55) proportion of the total life cycle cost of the building. Green roof also had higher energy cost than the conventional, representing (-23.64):(-6.55) proportion of total life cycle cost of the building. As a result, it was found that (-Rs. 11,654.70)/m² net saving by a green roof is considerable despite of the high initial and the maintenance cost. According to the study, green roofing concept is financially and environmentally beneficial concept even though there are some barriers, like lack of knowledge, lack of techniques, lack of standards in implementing this concept in the Sri Lankan context. Hence, it is recommended to use green roofing in residential buildings.

Keywords: *Energy Saving; Green Roof; Green Roof Cost; Life Cycle Cost.*

1. INTRODUCTION

Since climate change is a vast environmental issue in 21st century, it has been stated that the climatic change can be named as a deviation of the global climate due to the growing average global temperature (Intergovernmental Panel on Climate Change, 2013; Cook, 2017). Further, it has predicted that the net annual cost on damage expenses of climate changes will rise due to this increment of the global temperature (The Earth Science Communications Team at Nasa' Jet Populsion Labority, 2017). Hence, scientists and engineers have been searching a better explanation to overcome the effects of global warming in the modern world over last few decades (Dareeju *et al.*, 2011). However, Sustainable development has overtaken the need of seeking the solutions, through a

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mechanism of meeting the human development goals in natural ways (Kazi and Kazi, 2016). Subsequently, green building concept gives a greater level of environmental, economic and engineering performance within the construction sector (Samer, 2013).

As per the Green Building Council of Sri Lanka (2015), the green building is a building which uses low energy and water as well as increasing the indoor air quality. Respectively, green roofing is a one of effective technique to be followed in the term of green building concept. The origin of green roofs may drive back to the 79 AD and it has initiated as a roof garden (Ahmed and Alibaba, 2016). Further, The Hanging Gardens of Babylon is one of the most famous green roofs in the world which was constructed in 500 BC (Lawrence Technological University, 2006). However, the modern roofing concept was started in Germany in 1960s, where vegetation was grown on the roofs to mitigate effect of solar radiation (Oberndorfer *et al*., 2007; Fellows, 2012).

Even though vegetated roofs can be identified as one of the substitutes for land covering method which can give various economic benefits in urban city area, Blackhurst *et al*. (2010) have pointed out that the cost of green roofing is not economical (Carter and Butler, 2008). However, the challenges like initial high construction cost and high maintenance cost are deemed to associate with the green roofs. Blackhurst *et al*. (2010) have further explained that the cost will be reasonable when the social benefits are included. Also, it is an obligation of occupants to maintain the roof garden well, despite the fact that it incurs high maintenance cost (Klinkenborn, 2009). Thus, this paper aims to appraise the financial costs and benefits of green roofing during its life cycle including the analysis of the energy saving that could accrue by green roofs.

2. LITERATURE REVIEW

2.1 COMPONENTS AND TYPES OF GREEN ROOFING

A green roof consists of several layers namely plant/ vegetation layer, growing medium, filter layer, Drainage layer, protection layer and waterproofing layer. These components can further divide into two main categories as living component and structural component, where the vegetation layer and growing medium considers as living component. Even though, Sedum plants were used as main vegetation layer in most of the green roof gardens, use of various plantations is helpful to increase the effectiveness of the green roof (Wolf and Lundholm, 2008; Fellows, 2012). Generally, growing medium includes 80% of a lightweight inorganic material and the remaining is an organic material (Beattie and Bergharge, 2004).

Various types of green roofs have been used in different countries under different weather conditions. (Williams *et al*., 2010). While, extensive and intensive are the two major types, generally 3 types of green roofs can be identified as intensive, extensive and semi intensive according to the Department of Energy-USA (2004). Extensive roofing is a lightweight system where the build-up height of the layers is less than 100mm and the maintenance requirement is low (The Green Roof Center in UK, 2011). Intensive green roofs are like a garden or park with plants, trees and bushes, where the depth of the substrate is greater than 200mm (The Climate Protection Partnership Division in the U.S. Environmental Protection Agency's Office of Atmospheric Programs, n.d.). Respectively, semi intensive green roof; a combination of the both types, carries 100mm to 200mm substrate depth (Department of Planning and Local Government, 2010).

2.2 BENEFITS OF GREEN ROOFING

According to Sadeghian (2017), green roof gives ecological, aesthetic and financial benefits. Further, there were policies used to promote green roofing as a part of sustainable concept mainly due to these benefits of the green roofing concept (Sutton, 2015). Some of benefits of green roofing are as follows.

- Urban heat island mitigation
- Thermal insulation with reduced building energy costs
- Expanding the urban storm water management
- Enhancing the aesthetic of cityscapes
- Increasing the wildlife habitat

2.3 BARRIERS TO GREEN ROOFING

The barriers will drive any concept away if those barriers were not identified and treated properly. The review of literature summarises the barriers in adopting green roofing as follows (Townshend, 2007; Ngan, 2004).

- Lack of knowledge and awareness
- Technical difficulty during the design and construction
- Lack of standards
- Difficulties in repairs
- Cost of the green roofing
- Absence of government regulation

2.4 LIFE CYCLE COSTING

Life Cycle Costing (LCC) is an economic analysis which is used in selecting cost effective alternatives (U.S.General Service Administration, 2017). The elements of LCC are initial capital costs, life of the asset, the discount rate, operating and maintenance costs, disposal cost, information and feedback, uncertainty and sensitivity analysis (Woodward, 1997). In LCC technique, all their future costs and benefits are identified and bring them to their present values (Peri *et al*., 2012).

3. RESEARCH METHODOLOGY

This study was conducted under three main phases. Firstly, a comprehensive literature synthesis was carried out to review the concept of green roofing, types of green roofs, benefits and barriers of green roof. Secondly, preliminary interviews and site visits were conducted to obtain a better understanding on green roofs in Sri Lanka as it is relatively a new concept. Under the preliminary interviews, an expert who involved in one of famous roof gardens was interviewed. In the site visit and the preliminary interview, information related to construction methodologies and materials details were collected.

The type of intensive green roofs was the target green roofing concept of this research study. Therefore, as the third step, a case study was undertaken to perform the comparative LCC analysis between traditional and intensive green roofing systems. The Table 1 presents the steps followed in performing the comparative LCC analysis.

Table 1: Steps followed in data collection

Step	Related Action
Identify and analyse the initial costs, maintenance and replacement costs	From selected cases To calculate the initial cost, the proposed green roof was used. This green roof has 5 cost proposals and by using these cost proposals initial cost was calculated. To calculate, maintenance and replacement cost, separate projects were used. By using 2 separate projects in Galle and Colombo average maintenance and replacement cost were calculated.
Analyse the energy saving that could accrue due to green roofs.	By comparing the electricity consumption of air conditioning of non-green roof building (ceramic tile roof) and green roof, the energy saving was calculated. To calculate above details, top floor of the apartment complex was used. There was 5 condominiums and one was not in a regular use. So, remaining four apartments were used. Out of those 4, two were A/C apartments and remaining two were non A/C apartments. So, by considering electrical consumption of each condominium for one year, additional cost for the A/C was calculated. That will be the energy saving if the A/C requirement was avoided. Theoretical calculation used to get the green roof energy saving.
Appraise the all the financial costs and benefits of green roofing during the life cycle	The analysis was carried out for 30 years life span for the roof floor of the condominium of building which was in centre of the Colombo city. Initial cost, maintenance and replacement cost and energy saving were calculated based on similar kind of buildings and those details were used for the analysis. To calculate the discounting factor, average annual interest rate and average annual inflation rate were considered. Average annual interest rate depends on average lending rate and average saving rate. So, by considering last 20 years, average inflation rate, average saving interest rate and average lending interest rate were calculated. Base on those average rates, discounting factor was calculated.
LCC analysis	A comparative analysis of LCC was performed between ceramic tile roofing and green roofing to determine the financial viability of green roofing against conventional roofing.

4. RESEARCH FINDINGS AND DISCUSSION

In the research findings, green roof was proposed to roof top of the condominium building. The area of the roof was 791.05 m^2. The green roof has been applied to an area of 562.43 m^2. The rest of the area was covered with staircase.

4.1 COMPARISON OF INITIAL COST

Since initial cost represents one of the core elements of LCC, the initial cost was identified based on the cost of similar kind of green roofs which were located in the same area. There were five cost estimates for green roofs which were used for calculating initial cost. The average rate per unit of each material of green roofs were considered, while excluding the considerable rate deviations of materials. After measuring the unit quantities of each material with the help of drawings and specifications, initial cost of each type of roofs were quantified. By using those details, the initial unit cost was calculated. Based on the calculated initial unit cost of green roof, the cost of the proposed green roof was estimated.

In the selected roof, there was ceramic tiles finishing. Most of the high-rise condominiums have ceramic tile finish. Thus, research was continued with the ceramic tile roof. Based on actual construction details, the cost of the ceramic tiles was identified.

The initial cost of the green roof and ceramic tile finished roof for the selected roof are as follows.

- Initial cost of Green roof Rs. 5,011,408.78
- Initial cost of Ceramic tile roof Rs. 2,469,067.70

This confirms the fact that green roof incurs more initial investment than conventional roofs.

4.2 COMPARISON OF MAINTENANCE AND REPLACEMENT COST

Maintenance and replacement cost of green roofs have been calculated using two projects which are currently being maintained and cost data was collected based on the maintenance budget records.

- Further, it has been considered that the top most vegetation layer will be removed and replaced once in every 5 years.
- Simultaneously, maintenance cost of ceramic tile cover roofing was also calculated irrespective of the replacement cost because it can be used for 30 years without any replacement.
- According to collected data, Table 2 was developed. Table 2 clearly shows that green roof has high maintenance and replacement cost than ceramic tile roofing

Table 2: Maintenance and operational cost comparison of green roof and ceramic tile finishing

Type	Maintenance Cost	Replacement Cost
Green roof	8,385,216.48	3,687,404.91
Ceramic Tile Roof	3,953,380.00	0.00

4.3 COMPARISON OF ENERGY COST SAVING

Few steps were undertaken to calculate the energy saving of the green roof. Based on the literature synthetises, modern cities used A/C and fan systems to reduce temperature of buildings. However, green roofs can reduce temperature of the building by a considerable amount. So, the energy cost saving was calculated based on the electrical (energy) cost of the A/C and the fan cost of the ceramic tile building and the temperature reduction of green building.

While calculating additional energy cost of the conventional roofing building, the number of occupancies need to consider because the electrical consumption was depending on the number of occupancies. Both A/C and Non-A/C rooms, there was same number of occupancies in the apartments. So, occupancy number did not affect the calculation. Base on the analysis, additional cost of A/C was identified based on current tariff rates. That is the energy saving if A/C was not used.

The average electrical consumption of non-A/C apartments per month = 210.00 kWh. So, the average electrical tariff of non - A/C apartments of the selected project were calculated according to the electricity board norms and it was Rs. 5413.50.

The average electrical consumption of the A/C apartments per month = 690.83 kWh. The average electrical tariff of A/C apartments of the selected project was calculated according to the electricity board norms and it was Rs. 27,050.85.

Additional cost for Air Conditioning apartment = Rs. 27,050.85 – Rs. 5,413.50

= Rs. 21,637.35

Based on previous researches, the temperature reduction was identified (as the current study did not collect those data due to time constraint). Based on thermal conductivity of the materials, and the temperature reduction in ceramic tile roof and the green roof, the A/C cost of the green roof was calculated as Rs. 46,779.38. The calculation was done based on equations (01) and (02) given below.

$$Q = KA(T2\text{-}T1)/L \tag{01}$$

$$Q = A(T2\text{-}T1)/((L1/K1) + (L2/K2) + (L3/K3)) \tag{02}$$

Where;

Q = Heat Transfer
K/K1, K2, K3 = Thermal Conductivity
A = Considered Area
L/ L1, L2, L3 = Thickness of the material
T 2 =Temperature of Outer face
T1 = Temperature of Inner face

A/C Energy Saving in the green building = Rs. 259,648.20 - Rs. 46,779.38

= Rs. 212, 868.82

This amount is comparative amount with ceramic tile roof. So, Energy saving of the ceramic tile cover roof was considered as Zero. There was some energy saving with ceramic tile cover roof when it was compared with slab.

4.4 LCC COMPARISON BETWEEN GREEN AND CONVENTIONAL ROOFS

When calculating LCC, initial cost, repair and maintenance cost and the energy saving were already calculated. The next step involved, discounting where discounting factor was calculated considering average interest rate and the inflation rate. To calculate average inflation rate, past 20 years was considered, and abnormal deviated years was removed from the calculation. So, average inflation rate calculated was 6.54%.

When calculating interest rate, savings interest rate and lending interest rate was considered. According to bank details, the lending percentage for housing projects is 75%. So, remaining 25% must invest by the customer.

Base on above factor and 20 years lending and savings ratios, the average interest rate was calculated.

- Average savings interest rate = 8.17%
- Average lending interest rate = 14.54 %

According to bank data, the proportion between lending rate and savings rate is 75%: 25%. So average interest rate is 12.95%.

Based on the calculated average inflation rate(g) and average interest rate (r), discounting rate (I) was calculated using equation (03).

$$I = ((1+r)/(1+g) + 1) \times 100\% \quad (03)$$

$$= (1+12.95\%)/(1+6.54\%) + 1)100\%$$

$$= 2.06\%$$

Then the LCC was carried out and identified the most economical roofing type. The calculation was done for 30 years and the life spam of ceramic tile finishing roof was considered 30 years and green roof has 5-year major repairs and finally life span ends in 30 years. That means after 30 years, there was no value of both roofing systems. In the LCC calculation, the base year was considered 2018.

In the LCC calculation, cost values were considered positive and benefits were considered negative.

Table 3: Comparison of LCC between green roof and ceramic tile roof

Stage	Discounting Factor (2.06%)	Green Roof (Net Present Value) Rs.	Discounting Factor (2.06%)	Ceramic Tile Roof (Net Present Value) Rs.
Initial Cost	1	5,011,408.78	1	2,469,067.70
Operational & Maintenance cost	22.21	8,385,216.48	22.21	3,953,380.00
Replacement cost	3.72	3,687,404.91	0	0.00
Energy Cost	22.21	(23,639,082.46)	0	0.00
LCC		**(6,555,052.29)**		**6,422,447.70**

Figure 1 shows the graphical representation of the LCC differences between green roof and ceramic tile finishing.

The limitations and assumptions used in the analysis include:

- The accuracy of the calculation is subjected to available data. There were only few numbers of green usage and the data were collected from those few projects.
- Lack of historical data available as the use of green roofing is relatively new to the country.
- In the calculation of some factors, only a few number of projects were considered.

- The economic life of the building was assumed as 30 years. This might vary according to physical factors.
- The accuracy of electrical consumption of A/C is little questionable as there was no any standard method to calculate the exact electrical consumption by A/C.

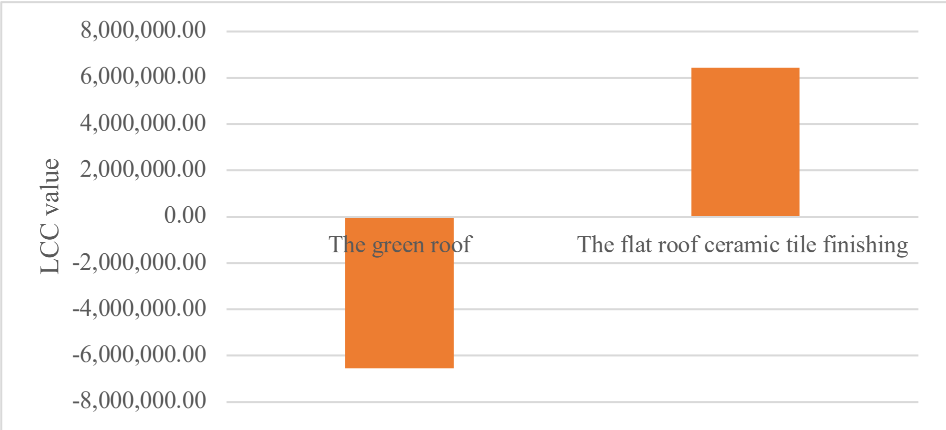

Figure 1: LCC comparison between green roof and ceramic tile roofing

5. CONCLUSIONS AND RECOMMENDATIONS

The urbanization process and the growth of urban areas have increased in recent years. As a result, many natural landscapes have been destructed and many adverse effects have arisen. Among all the adverse effects, less greenery areas, air pollution, drainage problems, urban heat island effect and decrement of natural wildlife habitats have majorly effected to urban areas, citizens and wildlife. Several new concepts have proposed in mitigating these adverse effects where the green roof becomes one alternative to address these issues.

When consider the green roofing, it can be applied for roof slab covering in buildings. Green roof has higher initial cost and replacement cost than other slab covering methods. However, there will be a huge energy saving because of the reduction of cooling cost of the building. The requirement of cooling method is minimized in buildings having green roofs.

This energy saving was calculated by using LCC method. When calculating LCC, to get more fair result, average rates were considered to determine the discounting factor.

According to the outcome of the study, the LCC of ceramic tile cover was **Rs. 6,422,447.70** for **562.43 m^2.** That means the LCC per m^2 is Rs. 11,419.1 /m^2. The LCC of the green roof was **(-Rs. 6,555,052.29)** for selected area, which gives LCC per m^2 **(-Rs. 11,654.70)** /m^2. Accordingly, it can be seen that there was Rs. 23,073.80/= cost benefit when the green roof is installed as the roof cover.

Based on the results of the study, green roofing concept can be recommended as an appropriate roofing method which provides various benefits to the economic (when consider the whole life) cost, social and environmental aspects which the public community needs to be aware of. Thus, necessary actions and measures should be developed to overcome the barriers in adopting a green roof. Finally, it is expected that this study would motivate increasing investments on green roofs to create sustainable cities.

6. REFERENCES

Ahmed, R.M. and Alibaba, H.Z., 2016. An Evaluation of Green roofing in Buildings. *International Journal of Scientific and Research Publications*, 6(1), pp.366-373.

Beattie, D. and Bergharge, R., 2004. *Green roof media characteristics: The basics.* Oregon: In Greening Rooftops for Sustainable Communities.

Blackhurst, M., Hendrickson, C. and Matthews, H.S., 2010. Cost-effectiveness of green roofs. *Journal of Architectural Engineering*, 16(4), pp.136-143.

Carter, T. and Butler, a. C., 2008. Ecological impacts of replacing traditional roofs with green roofs in two urban areas. *Cities and the Environment,* 1(2), p.17.

Cook, J., 2017. *Global warming vs Climate Change. Retrieved from Skeptical Science.* [Online] Available at: https://www.skepticalscience.com/climate-change-globalwarming.htm

Dareeju, B., Meegahage, J. and Halwatura, R., 2011. Performance of Green Roof against the Global warming. *Annual Transactions of IESL,* pp. 297-302.

Department of Energy-USA, 2004. *Federal Technology Alert: Green Roofs..* Washington, D.C.: Department of Energy.

Department of Planning and Local Government, 2010. *Rain gardens,Green roofs and infiltration systems water sensitive urban design technical manual,* Adilaide: Department of Planning and Local Government.

Fellows, M., 2012. *NASA & Green Roof Research.* Washington: National Aeronautics and Space Administration.

Green Building Council Sri Lanka , 2015. *The GREENSL®Rating System for built environment.* Colombo: Green Building Council of Sri Lanka.

Intergovernmental Panel on Climate Change, 2013. *Climate changes-2013,* New York: Cambridge University Press.

Kazi, S. M. and Kazi, M. S. M., 2016. *Understanding sustainable development.* [Online] Available at: http://www.The energy and resource institute.com/Understanding sustainable development

Klinkenborg, V., 2009. Green roofs [Online]. In: *National Geographic Magazine*. Available from: http://ngm.nationalgeographic.com/2009/05/green-roofs/klinkenborg-text.

Lawrence Technological University, 2006. *Stormwater Institute History of Greenroofs.* [Online] Available at: https://www.ltu.edu/water/greenroofs_history.asp

Ngan, G., 2004. Green Roof Policies: Tools for Encouraging Sustainable Design. *Landscape Architecture Canada Foundation,* pp. 6-12.

Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R.R., Doshi, H., Dunnett, N., Gaffin, S., Köhler, M., Liu, K.K. and Rowe, B., 2007. Green roofs as urban ecosystems: ecological structures, functions, and services. *BioScience*, *57*(10), pp.823-833.

Peri, G., Traverso, M., Finkbeiner, M. and Rizzo, G., 2012. The cost of green roofs disposal in a life cycle perspective: Covering the gap. *Energy*, 48(1), pp.406-414.

Sadeghian, M. M., 2017. Green roof, A review of history and benefits. *Science and Technology,* pp.510-515.

Samer, M., 2013. Towards the implementation of the Green Building concept in agricultural buildings: a literature review. *Agricultural Engineering International: CIGR Journal*, 15(2), pp.25-46.

Sutton, R. K., 2015. *Introduction to green roof ecosystems,* Lincoln: Springer International Publishing Switzerland.

The Climate Protection Partnership Division in the U.S. Environmental Protection Agency's Office of Atmospheric Programs, n.d.. Reducing urban heat islands: Compendium of compendium of strategies. *Green Roofs,* pp.1-26.

The Earth Science Communications Team at Nasa' Jet Populsion Labority, 2017. *Global Climate Changes.* [Online] Available at: https://climate.nasa.gov/effects/ [Accessed 07 11 2017].

The Green Roof Center in UK, 2011. *Green Roofing Hand BooK.* The green roof center.

Townshend, D., 2007. *Study on green roof application in Hong Kong*. Urbis Limited: Hong Kong.

U.S.General Service Administration, 2017. *GSA.gov.* [Online] Available at: https://www.gsa.gov

Williams, N.S., Rayner, J.P. and Raynor, K.J., 2010. Green roofs for a wide brown land: Opportunities and barriers for rooftop greening in Australia. *Urban Forestry and Urban Greening*, 9(3), pp.245-251.

Wolf, D. and Lundholm, J.T., 2008. Water uptake in green roof microcosms: Effects of plant species and water availability. *Ecological Engineering,* 33(2), pp.179-186.

Woodward, D.G., 1997. Life cycle costing-theory, information acquisition and application. *International Journal of Project Management,* 15(6), pp.335-344.

Peiris, M.P.S.N. and De Silva, N., 2019. Fuzzy logic model to benchmark maintenance strategies for concrete structures. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 360-367. DOI: doi.org/10.31705/WCS.2019.36. Available at: https://2019.ciobwcs.com/papers

FUZZY LOGIC MODEL TO BENCHMARK MAINTENANCE STRATEGIES FOR CONCRETE STRUCTURES

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ABSTRACT

Maintenance of a building, which is of utmost importance, has become a burden to organisations worldwide, due to the unplanned approach towards it. Recently, views on building maintenance had undergone fundamental changes and are currently thought of as a crucial function in any organisation. Regrettably, around one-third of the allocated maintenance costs are wasted due to the ineffectiveness of maintenance planning. As a remedy to this loss, many organisations are currently shifting towards the incorporation of maintenance strategies such as corrective maintenance, preventive maintenance, and predictive maintenance. However, the implementation of these strategies itself will not solve the problem. Significant planning should be undergone in order to obtain the maximum benefit of executing these strategies. Introducing a tool to support planning and decision-making regarding maintenance strategy implementation will hence simplify this process. Therefore, the aim of this paper is to review existing literature on maintenance strategies and develop a fuzzy logic model to find the best combination of such maintenance strategies for concrete structures. Hence this paper portrays a conceptual model that can be adopted to benchmark maintenance strategies for concrete structures, by adapting the existing models which are commonly developed for maintenance of machinery and equipment.

Keywords: *Benchmarking of Maintenance; Building Defects; Concrete Structures; Fuzzy Logic; Maintenance Strategies.*

1. INTRODUCTION

Buildings are man-made structures used for providing shelter, protection and a platform for human activities (Hussain, 2016). Concrete structures, in specific, are the most common type of high-rise buildings, which is proven for its high durability and strength (Ali, 2001). However, its performance depends on the way it is designed, constructed and maintained (Dias, 2013). At present, many initiatives are researched to optimize design and construction practices of concrete structures aiming at obtaining highly durable and strong buildings (Ali, 2001). However, maintenance of concrete structures is undergone very poor maintenance practices, hence, contributing towards the faster deterioration of buildings (Dias, 2013).

Deterioration of concrete structures comes in the form of concrete defects such as dampness, cracks, water penetration, corrosion, etc. (Bakri and Mydin, 2012). According to the author, these defects undergo a severe process of internal deterioration before

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appearing on the surface or any location visible. Therefore, it is vital to carry out maintenance at the early stage of the deterioration or even before starting the deterioration, in order to maintain its expected performance such as durability, integrity, strength, etc., of the structure.

Recent building maintenance records depict the sole usage of Corrective Maintenance (CM) strategy for concrete structures (Suffian, 2013). Maintenance activities in CM are done after the defect occurs, and thus is considered as unplanned maintenance. Therefore, it can be regarded as treating a wound to stop it from becoming worse (Deighton, 2016).

As a result, Preventive Maintenance (PM) and Predictive Maintenance (PdM) are introduced as planned strategies (Swanson, 2001). They can be applied to treat the root cause of the defects, thereby minimizing the damage to the structure. However, these are not commonly practiced in high rise concrete structures due to the extensive planning required and complexity (Olanrewaju *et al*., 2010). Therefore, researchers have suggested the use of unplanned (such as CM) and planned strategies in combination (Arruda, 2006; Pintelon *et al*., 2006; Ahuja and Khamba, 2008; Albarkoly and Park, 2015).

Therefore, it is vital to find the best combination of suitable maintenance strategies for the maintenance of concrete structures. Previous researchers have developed a Fuzzy Logic (FL) models mainly for maintenance planning of machinery (Al-Najjar and Alsyouf, 2003; Sharma *et al*., 2005). However, no such models have been developed for concrete structures. Hence, it is high time to develop a theoretical model to facilitate this purpose (Olanrewaju *et al*., 2010).

This research aims to develop a failure-cause based FL model for concrete structures enabling building managers to select the best combination of maintenance strategies for their buildings. This may contribute towards minimizing the negative impact of poor maintenance by utilizing the best combination of maintenance strategies at the initial stages itself.

2. LITERATURE REVIEW

2.1 MAINTENANCE IN CONCRETE STRUCTURES

Maintenance in concrete structures mainly comes in the form of defects. The summary of various defects which are to be seen in these structures, as highlighted by several authors including Chong and Low (2006), Chew *et al*., (2004), Bakri and Mydin (2012), are shown in Table 1.

Table 1: Building elements and related defects

Building Element	Defects
Columns and beams	Concrete crack, Plaster crack, stain, paint peeling, and blister
Internal Walls	Plaster crack, stain, water seepage, paint peeling and blister, paint and plaster patchy, chipped, concrete and tiles crack, other types of cracks, tiles falling/ popping
External Walls	Cracks, wall dampness, plaster crack, crazing, biological growth, staining, paint peeling, paint crack, blistering, discoloration, chalking, efflorescence

Building Element	Defects
Roof	Leakage, cracks, waterproofing delaminating, stain
Floor	Cracks, water seepage, tile delamination, unevenness, stains, hollowness, discoloured tiles, efflorescence, chipped tiles

The objective of maintenance management is avoiding, diminishing and restoring building defects by improved preparation and execution using suitable resources at the correct time and lowest whole life-cycle cost (Tucker, 2007). With the aim of pursuing this objective, maintenance managers are currently considering cost-effective and reliable maintenance strategies to be implemented in organisations (Lee and Scott, 2009).

2.2 MAINTENANCE STRATEGIES FOR CONCRETE STRUCTURES

In maintaining a building/concrete structure there are typically numerous strategic options and different decisions to be considered by the management. Different authors have interpreted the options in different ways. However, out of the maintenance strategies available, the following three are commonly used (Horner *et al*., 1997; Begley, 2001; Lee and Scott, 2009; Lind and Muyingo, 2012; Bakri and Mydin, 2014).

2.2.1 Corrective Maintenance

Mostafa (2004) explains CM as unexpected activities carried out to bring the building back to its operating condition, or a building element to a condition that is fit for the intended purpose. According to the author, the main characteristic of CM is that actions are only completed after a failure. Hence, it causes several disadvantages such as higher downtime and overall maintenance costs (Sharma *et al*., 2005).

2.2.2 Preventive Maintenance

The aim of conducting PM is to minimise the recurrent and unexpected failures by performing maintenance activities such as repairs, testing, and inspection at a precise prearranged interval of time without considering the condition of the building (Garg and Deshmukh, 2006). Author further claims that the successful execution of PM and determination of time interval requires a decision support system.

2.2.3 Predictive Maintenance

The main outcome of PdM is deciding whether to maintain a building or not, according to its condition (Garg and Deshmukh, 2006). According to the author, this strategy lessens the chance of sudden failures with the help of diagnostics and timely interference. For example, diagnostic equipment is incorporated to measure the physical conditions such as crack propagation, corrosion, etc. to find out the root cause(s) and failure mechanisms (Chen and Trivedi, 2002).

However, among those, the most common type of maintenance strategy used in buildings/concrete structures is CM because it is the traditional method which is also simple in use (Lind and Muyingo, 2012). Planned PM is also used according to the authors. PdM is slightly used due to the complexity and the knowledge and experience required.

While many literature articles have been published on building maintenance and strategies to be adopted in implementing maintenance, effective use of these concepts cannot be achieved without suitable decision support systems or tools. Hence certain studies have considered maintenance strategy benchmarks to obtain better results.

2.3 USE OF FUZZY LOGIC FOR BENCHMARKING OF MAINTENANCE STRATEGIES

Literature found various studies that used FL in maintenance decision making. FL is identified as a strong methodology in transforming statements in natural language- verbal formation of the problem (such as level of maintenance required, optimised use of maintenance strategies) into a mathematical logic function called 'fuzzy numbers' (Sharma *et al*., 2005).

The studies discussed below have used FL to make maintenance-related decisions of machinery parts (See Table 2).

Table 2: Previous studies on FL based maintenance strategy selection

Source	Year
Sharma *et al*.	2005
Al-Najjar and Alsyouf	2003
Mechefske and Wang	2001

Mechefske and Wang (2001) have used FL to attain biased assessments of maintenance strategies to obtain unbiased maintenance decisions for defects of centrifugal and reciprocal compressors. Al-Najjar and Alsyouf (2003) have used FL to develop a model to select the most effective maintenance strategy for machinery and equipment. This model was established using fuzzy logic functions derived based on a number of machine defects associated with rolling element bearings. Later in 2015, Sankpal *et al*. (2015) have developed a similar model for maintenance strategy selection of machine parts using a risk-based approach. Thus, this defect-oriented maintenance strategy model (refer Figure 1) could be used as an effective tool to analyse the importance of different failure causes in machines and the best combination of maintenance strategies to overcome them.

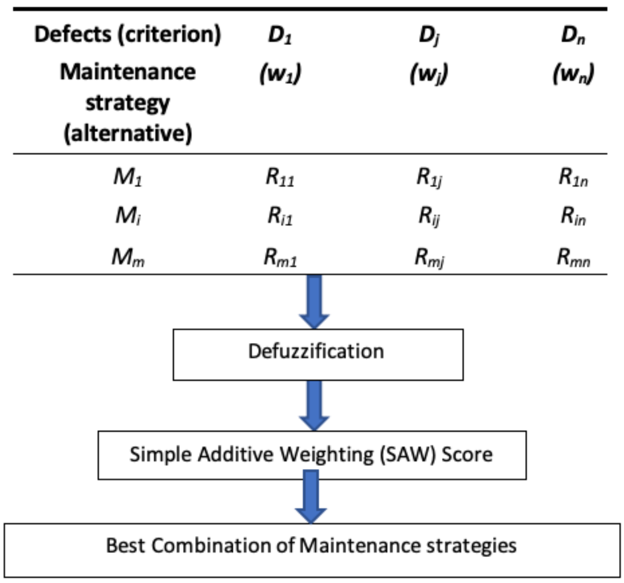

Figure 1: Defect-oriented maintenance strategy model

D_j = j^{th} Defect
M_i = i^{th} Maintenance Strategy
'm' = Number of maintenance strategies
'n' = Number of defects (criteria) in the plant
w = $\{w_j$, for $j = 1, 2, \ldots, n\}$ → fuzzy numbers indicating weights/importance of the criteria
R = $\{R_{ij}$, for $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n\}$ → fuzzy numbers rating capability of the maintenance strategy (M) on identifying changes in the criterion

The model in Figure 1 uses defects of a particular machine (e.g. temperature, vibration) indicated by 'D_j' as the criteria for benchmarking maintenance strategies for this machine. Each defect is given a weight 'w_j' in fuzzy numbers to indicate its impact on machine deterioration (e.g. impact of high temperature (criterion) on machine deterioration). Each maintenance strategy (M_i) is ranked against each defect using a fuzzy number 'R_{ij}' indicating the capability of M_i on identifying changes in D_j (e.g. how well can CM detect high temperature variations inside a machine?) The fuzzy 'R' values and fuzzy 'w' values are then defuzzified to obtain meaningful numbers. These defuzzified numbers are then ranked using Simple Additive Weighting (SAW) and a score (S_i) is established for each maintenance strategy as given in equation (01).

$$S_i = \sum W_j R_{ij} \qquad (01)$$

where, S_i = scores; W_j = weight of j^{th} defect; and R_{ij} = effectiveness of i^{th} maintenance strategy in rectifying the j^{th} defect

These scores are finally normalised to obtain percentages of each maintenance strategy which can be used as a benchmark

3. RESEARCH METHOD

As discussed above, a defect-oriented maintenance strategy model developed using FL is identified as an effective tool for maintenance decision making in machinery. Thus, in this research, the defect-oriented maintenance strategy model developed originally by Al-Najjar and Alsyouf (2003) is modified to develop a '*concrete defect-oriented maintenance strategy (CDMS)*' model to benchmark maintenance strategies established for concrete structures.

Since the concrete structures are formed using a number of elements, separate CDMS models were developed to analyse maintenance needs and the best combination of maintenance strategies for each element. Figure 2 illustrates the CDMS model developed for the structural element 'roof' of a building.

Four types of defects including leakages, cracks, waterproofing delamination and stains are selected as defects (n=4) in roofs. The weightages (w) for those defects are derived based on the impact of those defects to the deterioration of the concrete structure. In this regard, six factors such as (1) impact on safety and health of building occupants, (2) frequency of occurrence, (3) cost of rectification, (4) impact on building performance, (5) ease of rectification of the defects, and (6) tendency to form another defect' are used to assess the impact (Das and Chew, 2011; Chew and De Silva, 2004). The ratings obtained for these factors (in terms of high, medium, low) are fed into the model using FL membership functions to obtain weightages (w) in fuzzy numbers.

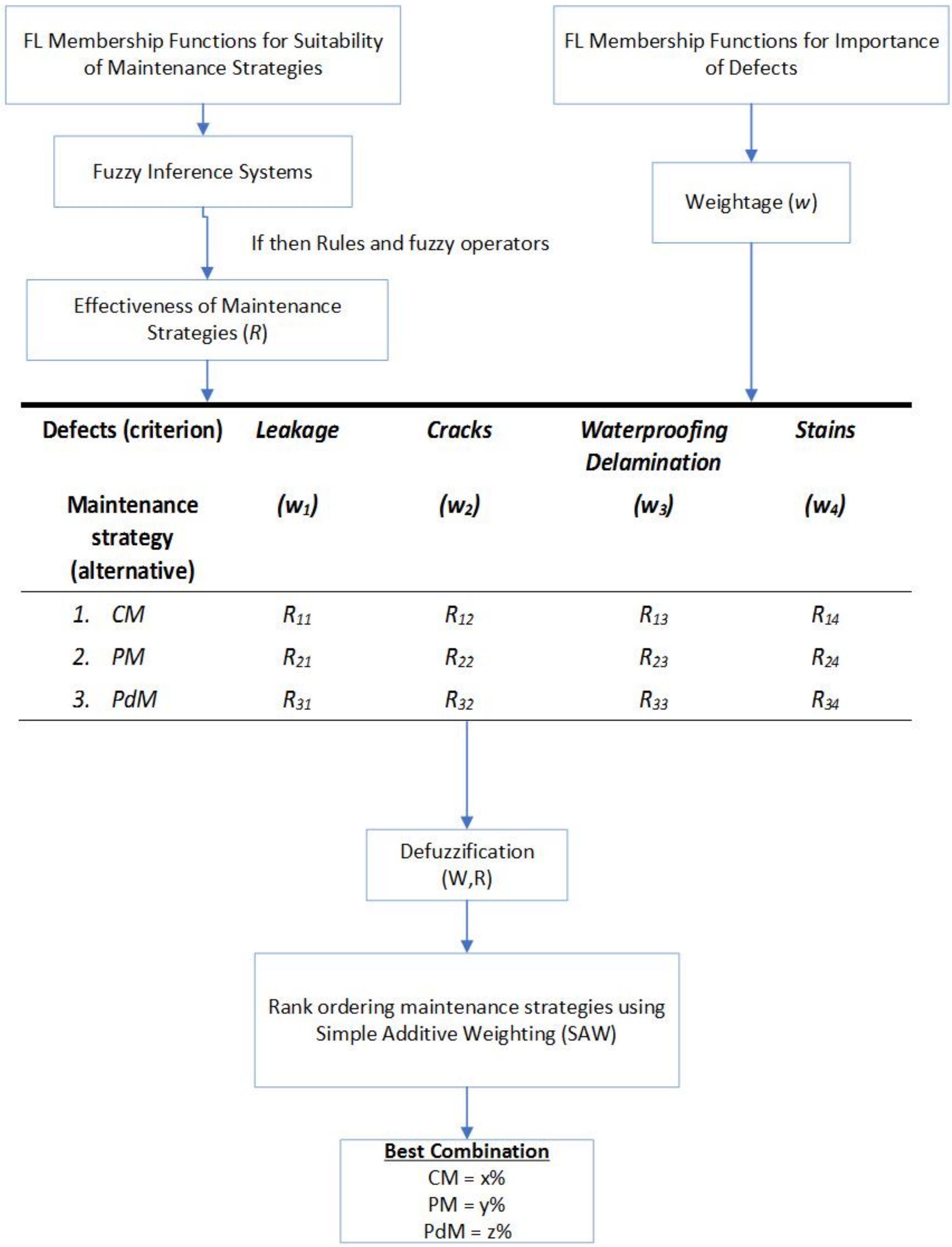

Figure 2: Concrete Defect-oriented Maintenance Strategy (CDMS) model for roof element

Three maintenance strategies (most commonly used) such as CM, PM and PdM are selected to benchmark the maintenance strategies (i.e. best combination of maintenance strategies). Their suitability to rectify each defect is assessed based on four factors; (1) value-added to element, (2) maintenance cost, (3) execution capability, and (4) impact on safety and health of occupants (Bevilacqua and Braglia, 2000; Wang *et al*., 2006; Azizi and Fathi, 2014). Assessment ratings obtained (in terms of high, medium, low) are then fed into the model using FL membership functions. Using if-then rules and fuzzy operators, a fuzzy inference system converts the assessment results to obtain 'R' values in fuzzy numbers. The interpretation of 'R' by Al-Najjar and Alsyouf (2003) for machines has been modified in the CDMS to suit the context of buildings. Therefore in the proposed

CDMS 'R' value indicates the effectiveness of each maintenance strategy in rectifying each defect. For example, R_{11} in Figure 2 is a fuzzy number that indicates how effective CM is in rectifying leakages.

In the next step, all fuzzy numbers are defuzzified in order to convert fuzzy numbers into real numbers that can be understood by humans. Since all 'w' values and 'R' values are in fuzzy numbers, they are defuzzified for meaningful information.

Next, the scores S_i are calculated using equation (01) and normalised to obtain the best combination of maintenance strategies for the structural element roof as illustrated in Figure 2. The percentages x, y, and z indicate the proportions of CM, PM, and PdM respectively required to obtain the best combination of maintenance strategies for roof maintenance.

4. CONCLUSIONS

The aim of this paper is to benchmark the maintenance strategies for concrete structures. Literature was collected and is presented on maintenance requirements and maintenance strategies used for concrete structures, an introduction to FL and its applications in maintenance strategy benchmarking. A conceptual model is presented in the methodology as a tool for building managers.

The model presents a methodology that can be used to convert expert knowledge and judgements regarding concrete structure maintenance into solid, quantitative benchmarks. The model uses qualitative information such as the impact of building defects, level of maintenance required and effectiveness of maintenance strategies. The fuzzy operators are used to covert these qualitative data into fuzzy numbers to map the defects and the strategies based on suitability. These fuzzy numbers are then defuzzified and rank-ordered to establish the best proportion of maintenance strategies to be carried out on an element. The model in this paper is presented for the element 'roof'.

This model can be used by building managers to take the correct decision in the selection of maintenance strategies. This can be considered as a novel concept that can be used as a maintenance planning tool by the building managers while enhancing the attention towards maintenance of concrete structures. It is also suggested that this model is tested for validity in further research.

5. REFERENCES

Ahuja, I. and Khamba, J., 2008. Total productive maintenance literature review and directions. *International Journal of Quality & Reliability Management,* 25(7), pp.709-756.

Albarkoly, K. M. and Park, K. S., 2015. Implementing a strategy of reliability centered maintenance (RCM) in the Libyan cement industry. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering,* 9(6), pp.1903-1912.

Ali, M. M., 2001. Evolution of Concrete Skyscrapers: from Ingalls to Jin mao. *Electronic Journal of Structural Engineering,* 1(1), pp.2-14.

Al-Najjar, B. and Alsyouf, I., 2003. Selecting the most efficient maintenance approach using fuzzy multiple criteria decision making. *International Journal of Production Economics,* 84(1), pp.85-100.

Arruda, C. H., 2006. *Maintenance Evaluation and Benchmarking,* Chile: MAPLA.

Azizi, A. and Fathi, K., 2014. Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process. *Management Science Letters,* 4(5), pp.893-898.

Bakri, N. and Mydin, M., 2014. General building defects: causes, symptoms and remedial work. *European Journal of Technology and Design,* 3(1), pp.4-17.

Begley, M., 2001. *EPM FM1 – Maintenance Strategy*.

Bevilacqua, M. and Braglia, M., 2000. The analytic hierarchy process applied to maintenance strategy selection. *Reliability Engineering and System Safety,*70(1), pp.71-83.

Chen, D. and Trivedi, K., 2002. Closed-form analytical results for condition-based maintenance. *Reliability Engineering & System Safety,* 76(1), pp.43-51.

Chew, M., and De Silva, N., 2004. Factorial method for performance assessment of building facades. *Journal of Construction Engineering and Management,* 130(4), pp.525-533.

Chew, M. Y., De Silva, N. and Tan, S. S., 2004. A neural network approach to assessing building façade maintainability in the tropics. *Construction Management and Economics,* 22(6), pp.581-594.

Chong, W.-K. and Low, S.P., 2006. Latent building defects: causes and design strategies to prevent them. *Journal of Performance of Constructed Facilities,* 20(3), pp.213-221.

Das, S. and Chew, M., 2011. Generic method of grading building defects using FMECA to improve maintainability decisions. *Journal of Performance of Constructed Facilities, 25*(6), pp.522-533.

Deighton, M. G., 2016. Chapter 5 - Maintenance Management. In: *Facility Integrity Management,* pp.87-139.

Dias, W.P.S., 2013. Factors influencing the service life of buildings. *Engineer: Journal of the Institution of Engineers, Sri Lanka*, 46(4), pp.1-7.

Garg, A. and Deshmukh, S. G., 2006. Maintenance management: literature review and directions. *Journal of Quality in Maintenance Engineering,* 12(3), pp.205-238.

Horner, R. M., El-Haram, M. A. and Munns, A. K., 1997. Building maintenance strategy: a new management approach. *Journal of Quality in Maintenance Engineering,* 3(4), pp.273-280.

Hussain, M., 2016. Built Environment and Health. *IOSR Journal of Humanities and Social Science,* pp.1-6.

Olanrewaju, A.L., Khamidi, M.F. and Idrus, A., 2010. Building maintenance management in a Malaysian university campuses: a case study. *Australasian Journal of Construction Economics and Building*, 10(1/2), p.101.

Lee, H. H. Y. and Scott, D., 2009. Overview of maintenance strategy, acceptable maintenance standard and resources from a building maintenance operation perspective. *Journal of Building Appraisal,* 4(4), pp.269-278.

Lind, H. and Muyingo, H., 2012. Building maintenance strategies: planning under uncertainty. *Property Management,* 30(1), pp.14-28.

Mechefske, C. and Wang, Z., 2001. Using fuzzy linguistics to select optimum maintenance and condition monitoring strategies. *Mechanical Systems and Signal Processing,* 15(6), pp.1129-1140.

Mostafa, S. I., 2004. Implementation of proactive maintenance in the Egyptian Glass Company. *Journal of Quality in Maintenance Engineering,* 10(2), pp.107-122.

Mydin, M., 2015. Significance of building maintenance management system towards sustainable development: A review. *Journal of Engineering Studies and Research,* 21(1), pp.58-65.

Pintelon, L., Pinjala, S. K. and Vereecke, A., 2006. Evaluating the effectiveness of maintenance strategies. *Journal of Quality in Maintenance Engineering,* 12(1), pp.7-20.

Sankpal, P., Andrew, A. and Kumanan, S., 2015. Maintenance Strategies selection using Fuzzy FMEA and Integer Programming. In *Proceedings of the International Conference on Advances in Production and Industrial Engineering (p. 503).*

Sharma, R. K., Kumar, D. and Kumar, P., 2005. FLM to select suitable maintenance strategy in process industries using MISO model. *Journal of Quality in Maintenance Engineering,* 11(4), pp.359-374.

Suffian, A., 2013. Some common maintenance problems and building defects: Our experiences. *Procedia Engineering*, 54, pp.101-108.

Swanson, L., 2001. Linking maintenance strategies to performance. *International Journal of Production Economics,* 70(3), pp.237-244.

Tucker, M., 2007. *Building Maintenance Management,* Blackwell Publishing Ltd.

Wang, L., Chu, J. and Wu, J., 2006. Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process. *International Journal of Production Economics,* 107(1), pp.151-163.

Paino, J., Perera, S., Alashwal, A. and Rodrigo, M.N.N., 2019. Impact of fly-ash on carbon emissions in different concrete grades. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 368-377. DOI: doi.org/10.31705/WCS.2019.37. Available at: https://2019.ciobwcs.com/papers

IMPACT OF FLY-ASH ON CARBON EMISSIONS IN DIFFERENT CONCRETE GRADES

Jacob Paino[1], Srinath Perera[2], Ali Alashwal[3] and M.N.N. Rodrigo[4]

ABSTRACT

Concrete is one of the most used construction materials; however, it contributes to about 7% of all carbon emissions. Various supplementary cementitious materials such as fly-ash have been considered to enhance concrete performance. There is a limitation of studies that address the influence of fly-ash on carbon reduction in different grades of concrete. Hence, the aim of this study is to analyse the impacts of fly-ash in concrete on carbon emissions in construction projects. A comparison between carbon emissions of portland cement concrete projects and fly-ash concrete projects was conducted using data collected from 20 construction projects in New South Wales, Australia. The results showed that higher the grade of concrete used, higher the carbon dioxide emissions, due to the increase of portland cement needed to achieve the higher grades of concrete. Introducing fly-ash to the concrete mix showed a significant reduction in carbon emissions. However, from the financial perspective, it was found that the rate per cubic metre of fly-ash concrete is 2.1% more expensive than standard concrete mixes. Therefore, the idea of adopting fly-ash into the concrete mix may not deliver cost savings as expected. Overall, this study provided clear insight into the effects of concrete usage on the environment and ways to reduce carbon emission.

Keywords: *Building Construction; Carbon Emissions; Concrete; Fly-Ash.*

1. INTRODUCTION

The use of concrete on large-scale construction projects has become a critical environmental issue with concrete being one of the main building materials used in structural and non-structural elements of construction projects. Portland cement is being used within the concrete as the main hydraulic binder providing concrete its strength and structural properties (Mehta, 2002). The production of Portland cement is a high contributor of the Carbon Dioxide (CO_2) emissions released to the atmosphere. The rapid expansion of the construction work in Sydney was regarded as a contributor to CO_2 emissions in the past (Worrell *et al.*, 2001). Currently, the many ongoing construction

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projects in Western Sydney and in New South Wales are expected to have a similar impact.

Industrial waste products are not disposed as landfill and many materials can be developed into Supplementary Cementitious Materials (SCMs). Due to the massive usage of coal in power plants, there is a substantial amount of fly-ash being generated. The disposal or storing of fly-ash is very expensive, resulting in the need to find another usage for it (Siddique, 2011). Thus, fly-ash has been commonly added to the concrete mix. SCMs are recognised for the obvious benefits gained with regard to carbon emissions reduction because of the low amount of the calcium oxide in most SCMs. Some fly-ashes have a higher calcium oxide content, which could be used to replace limestone in clinker resulting in a 15% decrease in carbon emissions (Joseph and Tretsiakova-McNally, 2010). There is a limited number of studies that investigates how the addition of fly-ash contributes to reduce CO_2 emissions in different concrete grades. Hence, this study attempts to highlight the effect of fly-ash on carbon emissions while considering the amount of cost incurred. The objectives of this study are to review the use of fly-ash in concrete compared to other SCMs, evaluate the environmental effect of supplementing fly-ash into the concrete production process, and analyse the financial effect of supplementing fly-ash into the concrete production process in construction projects.

2. LITERATURE REVIEW

2.1 CONSTRUCTION CONCRETE

Concrete is formed by mixing a chemically inert aggregate, a binder, chemical additives and water. It is the most commonly used structural material in the construction industry and is proven to be used more than any other man-made material in the world (Sentowski, 2009). It is a versatile material that allows the usage of different aggregates and cementitious materials, which ultimately changes many of the properties allowing concrete to be used for multiple purposes on a wide range of projects (Juenger and Siddique, 2015). Carbon emissions from cement production on this scale is what contributes to most of the CO_2 released into the atmosphere (Aprianti, 2017).

According to Shi *et al*. (2008), there is roughly 10 billion tons of concrete produced each year in the modern construction industry. Aprianti (2017) and International Energy Agency (2019) has shown that cement production in concrete construction generates approximately 7% of all CO_2 released into the atmosphere around the world. When all aspects of concrete construction are considered like energy usage and demolition waste, it shows that concrete is not an ideal construction material in regard to sustainable development, which is what large construction companies are beginning to acknowledge (Aprianti, 2017). In Australia, cement production accounts for around 1.3% of greenhouse gas emissions that are released, which is still the biggest contributor in the construction industry but significantly lower compared to the rest of the world (McLellan *et al*., 2011). Therefore, the need of introducing sustainable methods to reduce these carbon emissions has aroused (Rodrigo *et al*., 2019). The most common form of sustainable methods being tested in current concrete construction is the introduction of SCMs, which could be one of the means to achieve a significant CO_2 reduction.

2.2 SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCM)

There are many different waste/by-product materials generated from different industries and in some cases these materials can be quite hazardous if not disposed correctly. However, the disposal of these materials is expensive and takes time, which leaves the waste in the environment for even longer. Therefore, many companies have started studying and implementing reuse of some of these products. There are a number of SCMs that are currently being investigated within the concrete production process such as Slag, Silica Fume and Fly-Ash (Aprianti, 2017). These recycled by-products have also shown possibilities of reducing the amounts of CO_2 emitted into the atmosphere during cement production. However, there is discussion on which SCM is more effective for concrete construction.

2.2.1 Slag

Slag is a waste by-product that is generated during the smelting and/or purifying of ore. One of the biggest recycling options for slag is in cement production, as it provides environmental and economic advantages (Shi *et al*., 2008). The analysis of the life cycle of cement and concrete in construction compared to cement with slag showed a 22% - 40% reduction in greenhouse gases released depending on the percentage of slag used (Crossin, 2015). Also, the price of slag compared to normal cement is seen to be the same according to studies conducted in both Australia and the US with the unit price per tonne increasing by US$20 from 2005 to 2011 (van Oss, 2011). However, recently market data has shown regular cement pricing drop with slag staying the same (Crossin, 2015).

However, slag may have a negative impact on concrete properties. For instance, the permeability of the concrete has shown to decrease as the volume of the slag cement increases (Sharif and Alvi, 2016). In addition, the replacement of general portland cement with slag cement has resulted in a decrease in shrinkage in the short term (Yuan *et al*., 2015). The use of slag has also proven to cause time delays in projects as the setting time with slag is reported to be much longer than standard concrete prepared using OPC. When implemented in large construction projects, this can be a real issue as it can cause long unwanted delays to project schedule (Shi *et al*., 2008).

2.2.2 Silica Fume

Silica fume is generated through the smelting process of silicon metal and ferrosilicon alloys and is viewed as a valuable by-product that can be reused in other industries (Telford, 1988). Silica fume, like slag, is seen as an environmental hazard when disposed of and dumped in landfills. Silica fume in concrete has proven to provide efficient and effective strength and bonding properties for concrete while also being beneficial for shotcrete application (Siddique, 2011). However, the cost of implementing silica fume is more expensive than regular portland cement in concrete. Siddique (2011) explores the effect silica fume has on concrete properties and highlights how the silica fume enhanced the strength properties of high performance concrete structures. The advantages of using silica fume are increased toughness of the concrete, increase in concrete durability, much higher compressive strength and extremely high resistance to chemical attacks like acids.

2.2.3 Fly-Ash

Fly-ash is a waste product produced from coal-fired power stations that operate to produce energy (Brown *et al*., 2018). Fly-ash in the cement mixture has shown to be cost effective, energy conserving and environmentally sustainable (Mehta and Gjorv, 1982).

Fly-ash accounts for approximately 75% of the total ash produced in the world and has been growing exponentially since the 1920s when coal operated power plants were first introduced (Joshi and Lothia, 1997). About 500 million tonnes, which is about 16% of the produced fly-ash globally, is used for alternate purposes like concrete production and the rest is being dumped into landfills (Ahmaruzzaman, 2010).

Fly-ash alters the properties of the concrete mix, making it stronger when more fly-ash is introduced. Different percentages of fly-ash in concrete present differing properties for the mixture and hence multiple purposes, however, the maximum amount that can be used currently without having any structural issues is 35% replacement (Jones *et al*., 2011). Islam and Islam (2013) found that the permeability and strength of the concrete increases with adding more fly-ash, but both will decrease once it goes beyond 30%. Fly-ash will be the focus of this study due to its increasing usage and advantages highlighted previously.

3. RESEARCH METHODOLOGY

A case study approach was used for data collection purposes of this study. Two case studies of two contractor companies were selected. Within each case study, two separate project data sets with a total of 20 projects were studied. For comparison purpose, the first case study comprised of 10 projects used standard concrete using Ordinary Portland Cement (OPC), while the second case study consisted of other 10 projects with fly-ash introduced in the concrete. Further, the data collection process included detailed documentary review of bills of quantities of all the projects. The collected data was used to compare the carbon emissions between OPC used concrete and fly-ash used concrete to achieve the second objective of this study as shown in Figure 1.

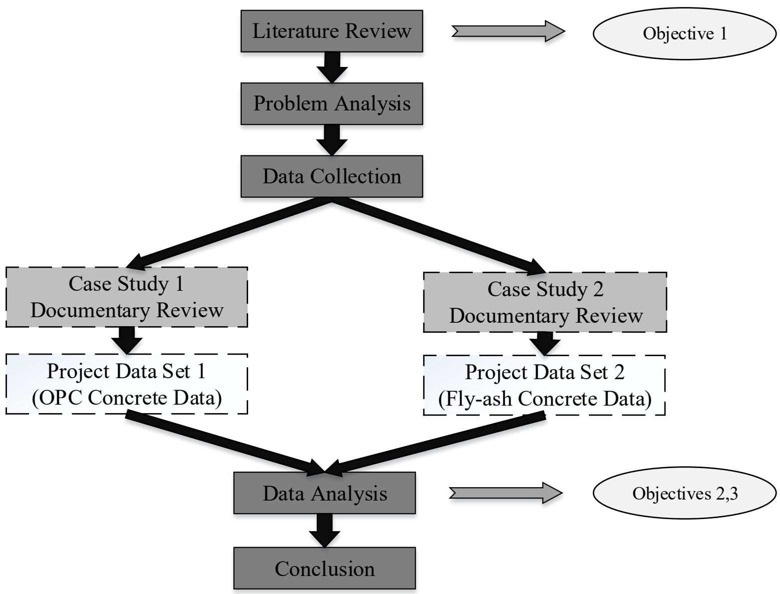


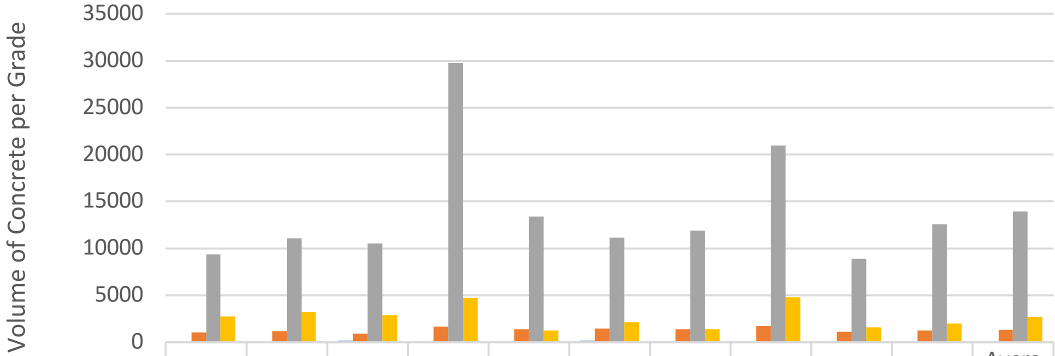
Figure 1: Research method framework of the study

To achieve the third objective, data was collected from concrete suppliers to carry out the financial analysis of fly-ash concrete and OPC concrete and investigate the cost effective type of concrete. The following section elaborately discusses the research findings of the study.

4. RESULTS AND DISCUSSION

4.1 CONCRETE USAGE IN DIFFERENT PROJECTS WITHOUT FLY-ASH

Figure 2 shows the data collected from 10 projects based in Sydney, which had used Portland cement (without fly-ash) in the concrete building elements. The figure shows the amounts of concrete used for each grade of concrete (25MPa, 32MPa, 40MPa and 80MPa) in each project (P1 to P10).



	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
25MPa (m3)	45	0	160	25	95	149	62	45	76	33	69
32MPa (m3)	1,028	1,157	912	1,646	1,362	1,458	1,377	1,745	1,095	1,267	1,304.
40MPa (m3)	9,338	11,081	10,500	29,750	13,420	11,165	11,892	20,965	8,860	12,550	13,952
80MPa (m3)	2,721	3,200	2,895	4,757	1,255	2,135	1,404	4,785	1,578	1,984	2,671.

Figure 2: Concrete volume per grade of concrete with Ordinary Portland Cement

Considering the average volume of concrete usage in each grade of concrete, it is emphasised that the mostly used grade in concrete elements is 40MPa followed by 80MPa. Besides when comparing the projects alone, this trend is noted except in the project P5, whereas 32MPa concrete has been used more than 80MPa concrete in P5.

4.2 CARBON EMISSIONS DUE TO USAGE OF PORTLAND CEMENT IN CONCRETE

Subsequent to the data collection carried out, it is required to estimate the CO_2 emissions according to the concrete strength and how much difference there is if any at all. Therefore, as the initial step, the average volumes calculated for each grade of concrete across all the projects have to be converted to metric tonnes in order to calculate how much CO_2 is emitted. It is calculated by multiplying the concrete volumes by 2.41 to convert cubic metres to tonne. On the other hand, the study carried out by National Ready Mixed Concrete Association (NRMCA) and Portland Cement Association (PCA) in the US stated that CO_2 emissions account for between 5% and 13% of concrete produced, varying according to concrete grade as follows; 25MPa-5%; 32MPa- 6%; 40MPa- 7%; and 80MPa-11% (NRMCA, 2008).

After incorporating the above factors, calculations were carried out to find out the CO_2 emissions accounted by each concrete grade as demonstrated in Table 1.

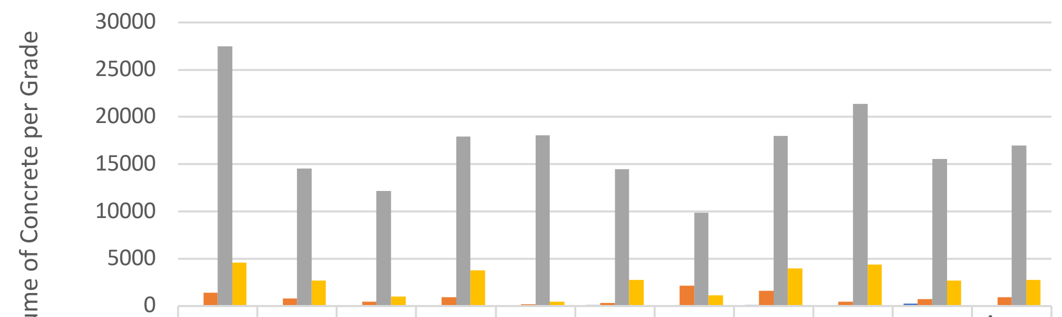
Table 1: Average CO_2 emissions per grade of concrete

	CO_2 Emissions per Concrete Grade			
	25MPa	**32MPa**	**40MPa**	**80MPa**
Volume (m^3)	69	1,304.7	13,952.1	2,671.4
Weight (t)	166.29	3,144.33	33,646.25	6,438.07
Percentage	5%	6%	7%	11%
CO_2 Emissions (t)	8.31	188.66	2,355.24	708.19

As identified in the literature review, the higher the grade of concrete, the more CO_2 that is released. This is because there is more Portland cement introduced in the higher the concrete grade. The sum in tonnage for each grade of concrete will later be compared with fly-ash concrete carbon emissions. The 40MPa concrete is a highly used concrete grade as it is very strong and is able to form many shapes easily. However, as shown on the graph, it releases a lot of CO_2 especially compared to the weaker concrete grades. 80MPa concrete is used predominantly for the high structural load bearing components of the buildings to ensure no failures occur. 25MPa and 32MPa are not as common as the stronger concrete grades for this type of construction, as they present no structural advantages, even though they present less environmental impact.

4.3 CONCRETE USAGE IN PROJECTS WITH FLY-ASH

Figure 3 displays the concrete volumes for the projects that contained fly-ash added into the concrete mixes. The results gathered from these concrete data will be used to compare against what was found previously with the OPC concrete mix to determine if fly-ash is beneficial environmentally.



	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Avera ge
25MPa (m3)	37	61	43	55	30	112	0	147	72	278	83.5
32MPa (m3)	1,397	805	443	952	172	357	2,144	1,614	465	745	909.4
40MPa (m3)	27,500	14,549	12,172	17,960	18,049	14,465	9,879	17,972	21,387	15,565	16,949
80MPa (m3)	4,569	2,699	1,032	3,780	490	2,755	1,165	3,949	4,386	2,686	2,751.

Figure 3: Concrete volume per grade of concrete with fly-ash

The total volumes of all the concrete grades for each project with fly-ash and the total average concrete is shown in Figure 3. These volumes are converted to tonnes so the CO_2 content can be calculated to determine the overall embodied carbon of the concrete production process. It is evident that there are greater volumes of high grade concrete

(40MPa and 80MPa), due to the high concrete strength that is required for these specific projects.

4.4 CARBON EMISSIONS REDUCTION DUE TO USAGE OF FLY-ASH IN CONCRETE

The concrete data from the previous section had to be converted to tonnes due to the fly-ash content and cement content being measured in tonnes. The required fly-ash data were obtained from the Green Star reports where the fly-ash data is given in kg per cube of concrete. The cement to fly-ash ratios in concrete grades along with the project specific data were used to carry out several calculations to determine the cement reduction due to usage of fly-ash. A summary of the calculations carried out is demonstrated in Table 2.

Table 2: Average CO_2 reductions per grade of concrete with fly-ash

	Carbon Reductions per Concrete Grade			
	25MPa	**32MPa**	**40MPa**	**80MPa**
Average Concrete Volume (m^3)	83.5	909.4	16,949.8	2,751.1
Fly-Ash Content (kg/cube)	80	90	90	140
Fly-Ash Content (t)	6.68	81.846	1,525.48	385.15
Average Cement Content (t)	6	369	7,360	1,784
Cement Reduction (t)	7.77	98.22	2,237.38	530.97
CO_2 Reduction (t)	7.2	91.05	2,074.05	492.21

The results revealed that the fly-ash content increases in kg per cube, the higher the concrete grade, due to the need for the higher strength properties. This also then reduces the total amount of portland cement used in the process. Furthermore, the results demonstrate the total amounts of cement reduced on average for the studied projects, where '*for every 1000kg of cement produced 927kg of CO_2 is released*', the amount of CO_2 that is reduced was calculated. From the table it is evident that the savings for the 40MPa concrete is substantial because of the amount of concrete used in this grade for these projects, where mostly it is used for elements in substructure and superstructure. In summary, the findings depict how much is being saved in carbon emissions with these large projects that have used fly-ash in concrete.

4.5 FINANCIAL ANALYSIS OF FLY-ASH IN CONCRETE

Implementing new design techniques that may appear beneficial in one category, may affect another area of business negatively. Fly-ash in concrete is environmentally beneficial; however, it may present to be costly, which is not ideal for project managers and construction companies. Multiple rates per cube of concrete were obtained from multiple concrete suppliers and subsequently, an average rate (in Australian Dollar) was formed for fly-ash and OPC used concrete as illustrated in Table 3. Together with this, a comparison was carried out to determine whether fly-ash is financially beneficial as well as environmentally. The pricing is tabulated under each concrete grade as the fly ash and cement content vary according to the grade of concrete.

Table 3: Rates per cube for different concrete grades

	Prices per Concrete Grade ($/cube)			
	25MPa	**32MPa**	**40MPa**	**80MPa**
OPC Concrete	224	232	236	248
Fly-Ash Concrete	229	237	241	253

The OPC concrete rates were provided by concrete suppliers and they are showing a gradual increase in price with the higher concrete grade. These rates were compared with multiple concrete suppliers and also construction estimating textbooks with current rates in Sydney. The concrete rates are subject to increase within the next 12 months, as they do every year, as indicated in the Consumer Price Index (CPI). The data collection process for the fly-ash rates were obtained from more specialist concrete suppliers as not all concrete suppliers have the option of providing fly-ash. Similar to the OPC used concrete mix, fly-ash concrete price increases as the concrete grade gets higher.

The concrete pricing for fly-ash concrete is about 2.1% more expensive than OPC concrete (refer to Table 3). This is due to the difficulty of obtaining fly-ash compared with Portland cement. Portland cement is readily available and stocked in many concrete plants, however, fly-ash is a special product that is generated at coal plants that need to be transported from specific locations. Therefore, although fly-ash is an environmentally friendly by-product for concrete production, it is not a cost effective option for Sydney based construction companies. Figure 4 shows the pricing comparison of the concrete rates in more detail.

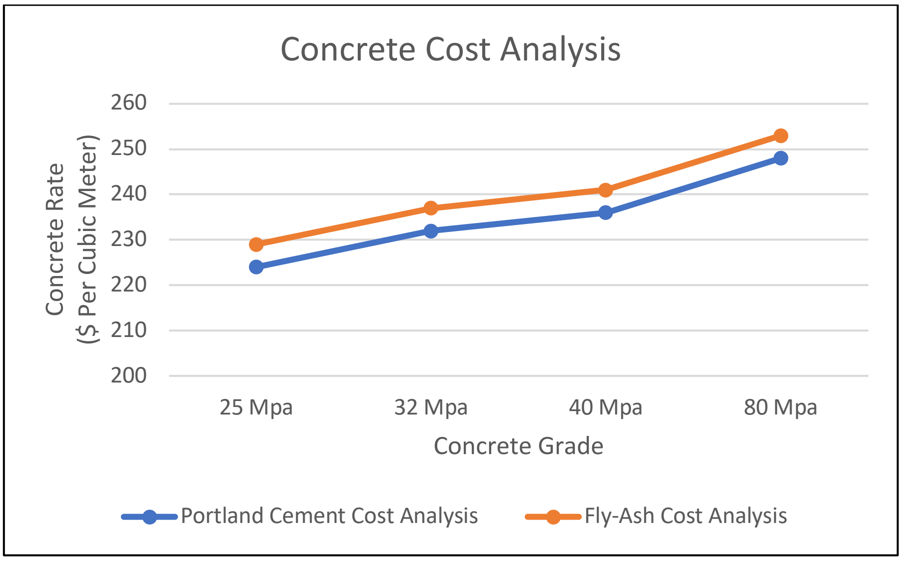


Figure 4: Sample graph of the costing analysis for fly-ash and Portland cement

According to Figure 4, the trend shows both lines increasing in price per grade of concrete at the exact same rate. In general, a standard percentage based on logistics and a margin is added to the OPC concrete rates when calculating the rate of fly-ash. In summary, though fly-ash concrete provided an environmentally friendly result by reducing the carbon emissions, it ultimately results in a higher cost compared to Portland cement concrete.

5. CONCLUSIONS

The principal aim of this research study was to analyse the impacts of fly-ash in concrete on carbon emissions. Initially, a literature review was conducted to compare the different SCMs such as fly-ash, silica fume and slag, to determine the most appropriate SCM for this research. The findings revealed that environmentally, fly-ash would be more ideal for concrete construction. Also, in regard to the properties of the concrete finish, it would provide the same or more strength than Portland cement.

The results of the environmental analysis through the usage of fly-ash in concrete were subject to large amounts of data collected through bills of quantities of various projects completed in Sydney and Western Sydney. Subsequently, the carbon emissions between 10 projects using OPC concrete and 10 projects using fly-ash were compared and carbon reduction was calculated to identify where the most carbon savings occur. The calculations of the study revealed that fly-ash provides environmental benefits and it can be recommended for construction companies to use it. Furthermore, savings for the 40MPa concrete is substantial due to the usage of large amounts of concrete in this grade for substructure and superstructure elements in these projects. Subsequently, the financial analysis of OPC concrete and fly-ash used concrete was carried out and the result was not favourable as fly-ash was proven to be a less cost effective method than OPC concrete. Similarly, implementing of fly-ash into Envisia and Geopolymer concrete to investigate the effect of fly-ash in these types of concrete would be an interesting area to be researched on in the future.

6. ACKNOWLEDGEMENT

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7. REFERENCES

Ahmaruzzaman, M. 2010. A review on the utilization of fly ash. *Progress in Energy and Combustion Science*, 36(3), 327-363.

Aprianti, E., 2017. A huge number of artificial waste material can be supplementary cementitious material (SCM) for concrete production–a review part II. *Journal of Cleaner Production*, 142, pp.4178-4194.

Brown, L., Perera, S. and Rodrigo, M.N.N., 2018. Brownfield Redevelopment: A Dual Currency Analysis of Soil Stabilisation Methods. *7th World Construction Symposium 2018: Built Asset Sustainability: Rethinking Design, Construction and Operations*, Colombo, Sri Lanka, 29 June-1 July 2018, pp.116-125.

Crossin, E., 2015. The greenhouse gas implications of using ground granulated blast furnace slag as a cement substitute. *Journal of Cleaner Production*, 95, pp.101-108.

International Energy Agency. 2019. Cement Emissions, *Cement Industry Federation.* Available from: http://cement.org.au/SustainabilityNew/ClimateChange/CementEmissions.aspx [Accessed 8 October 2019]

Islam, M.M. and Islam, M.S., 2013. Strength and durability characteristics of concrete made with fly-ash blended cement. *Australian Journal of Structural Engineering*, 14(3), pp.303-319.

Jones, R., McCarthy, M. and Newlands, M. 2011. Fly ash route to low embodies CO_2 and implications for concrete construction. In: Robl, T. and Adams, T. (Eds.) *World of Coal Ash Conference*, Denver, USA, 9-12 May 2011, pp.1-14.

Joseph, P. and Tretsiakova-McNally, S., 2010. Sustainable Non-Metallic Building Materials. *Sustainability*, 2(2), pp.400-427.

Joshi, R.C. and Lothia, R.P., 1997. Fly ash in concrete: production, properties and uses. In: *Advances in concrete technology*, *vol. 2.* Canada: Gordon and Breach Science Publishers.

Juenger, M. and Siddique, R., 2015. Recent advances in understanding the role of supplementary cementitious materials in concrete. *Cement and Concrete Research,* 78, pp.71-80.

McLellan, B., Williams, R. and Lay, J., 2011. Costs and carbon emissions for geopolymer pastes in comparison to ordinary portland cement. *Journal of Cleaner Production*, 19(9), pp.1080-1090

Mehta, P. and Gjorv, O., 1982. Properties of Portland cement concrete containing fly ash and condensed silica-fume. *Cement and Concrete Research,* 12(5), pp.587–595.

Mehta, P.K., 2002. Greening of the concrete industry for sustainable development, *Concrete International*. Available from: http://maquinamole.net/EcoSmartconcrete.com/docs/trmehta02.pdf [Accessed 22 March 2018]

NRMCA, 2008. *Concrete CO_2 Fact Sheet*. USA: NRMCA.

Rodrigo, M.N.N., Perera, S., Senaratne, S., and Jin, X., 2019. Embodied Carbon Mitigation Strategies in Construction Industry. *CIB World Building Congress 2019*. Hong Kong SAR, China. 17-21 June 2019, pp.1-10.

Sentowski, J.T., 2009. *Concrete materials: properties, performance and applications*. New York: Nova Science Publishers.

Sharif, M.B. and Alvi, M.H., 2016. Performance of locally available slag cement as supplementary cementitious material. *NED University Journal of Research*. 13(2), pp.23-30.

Shi, C., Meyer, C. and Behnood, A., 2008. Utilisation of copper slag in cement and concrete. *Resources, Conservation and Recycling*, 52(10), pp.1115-1120.

Siddique, R., 2011. Utilization of silica fume in concrete: Review of hardened properties. *Resources, Conservation and Recycling,* 55(11), pp.923-932.

Telford, T. 1988. *Condensed silica fume in concrete*. London: Thomas Telford Ltd.

Worrell, E., Price, L. and Martin, N., 2001. Energy efficiency and carbon dioxide emissions reduction opportunities in the US iron and steel sector, *Energy*, 26(5), pp.513-536.

Van Oss, H.G., 2011. *USGS Minerals Information: Cement. Statistics Information.* United States Geological Survey.

Yuan, J., Lindquist, W., Darwin, D., and Browning, J., 2015. Effect of slag cement on drying shrinkage of concrete. *ACI Materials Journal,* pp.267-276.

Premachandra, G.D.S., Francis, M. and Dewagoda, K.G., 2019. Investigating the problems in hotel refurbishment projects. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 378-389. DOI: doi.org/10.31705/WCS.2019.38. Available at: https://2019.ciobwcs.com/papers

INVESTIGATING THE PROBLEMS IN HOTEL REFURBISHMENT PROJECTS

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ABSTRACT

Hotel industry is one of the major contributors to the national economy in most countries including Sri Lanka. Due to the high tourist attraction in Sri Lanka, demand for modifying and upgrading the hotel industry to keep pace with the trend is inevitable. Refurbishment thus covers a wide range of activities originating from decoration to conversion. However, numerous problems are encountered in refurbishment projects and further the industry lacks in-depth investigations on strategies to minimise such problems associated. Hence this research was aimed at studying the problems prevailing in hotel refurbishment projects and thereby suggesting strategies to minimise such. A qualitative research approach was followed inclusive of three cases of recently completed hotel refurbishment projects in order to explore the causes and respective strategies to curtail the problems in connection with hotel refurbishment projects. Accordingly, most common problems are the percentage of services work, obstruction by occupancy, unrealistic time pressure and risk in health and safety. Subsequently, the study explored the main causes for those to be guest disturbances, operation of the hotel, unforeseen work and reluctance to wear safety accessories. Key strategies that could be adopted are planning ahead, separating the noisy working areas, carrying out feasibility studies and making compulsory to wear safety accessories. Through this study, it is recommended to follow up the strategies to minimise the problems in hotel refurbishment projects in Sri Lanka to enhance the lifespan of a hotel building effectively.

Keywords: *Causes; Hotels; Refurbishment; Sri Lanka; Strategies.*

1. INTRODUCTION

Building works can be classified either as newly built or other types of activities such as upgrading, renovation, repair, expansion or maintenance (Olanrewaju and Abdul-Aziz, 2014). Lawrence and Werna (2009) emphasised that equivalent and utmost consideration must be given to on the renovation and maintenance of existing structures as much as new constructions. However, it is difficult to identify the absolute boundaries of the physical process under refurbishment (Mansfield, 2002). Furthermore, the use of each word could be misleading and may cause an obstacle for the implementation of each concept (Zolkafli *et al.*, 2012). Thus, the research identified the refurbishment as building work consists of any reconstruction, renovation, upgrading, restoration, renewal, conservation, rearrangement, alteration and conversion, expansion excluding new building or regular repair and maintenance works.

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According to Ali (2009), once the existing buildings are getting old, maintenance and refurbishment works are done in order to prolong the life of those buildings. In addition to that, Construction Industry Research and Information Association (CIRIA, 1994) stated that even the buildings with good working conditions, also subjected to refurbishments due to the requirement of owners to accommodate new technologies or to change the role of the business operation. In a nutshell, Aikivuori (1996) stated that failures in buildings (corrective refurbishment), change in use (space altering refurbishment), optimisation of economic factors (optimising refurbishment), subjective features (pleasure refurbishment) and change of circumstances (opportunity refurbishment) are the main reasons for refurbishment.

According to Langdon and Everest (2002), generally hotels undergo refurbishment once in five to ten years. Hotel industry is one of the major contributors of the income of most of the countries including Sri Lanka. As findings represent, as the contribution of 57% of Gross Domestic Product (GDP) of Sri Lanka is from the services sector (Department of Census and Statistics, 2017). When considering Sri Lankan context, Ekanayake *et al.* (2018) found that the number of hotel refurbishments is higher than other building types. Also, the authors provided reasons as Sri Lanka possesses more tourist attraction and because of that, the hotel needs to be upgraded and modified with the up to date requirements. In addition, due to day to day operation throughout the years, hotels are easily subject to degradation than other types. However, limited researches have addressed refurbishment sector, specifically the hotel industry. One research study, which was conducted by Ekanayake *et al.* (2018) focused on challenges in hotel building refurbishment in Sri Lanka which was found the topmost challenges as budget overruns and time overruns due to superficial design and construction activities. Furthermore, Athapattu and Gunawardena (2010) studied on delaying causes of hotel refurbishment projects as a resultant of actions of project participants and identified the most significant causes under five categories as causes pertinent to clients, consultants, contractors, project condition, and external causes.

In order to minimise adverse effects of the problems in refurbishment projects to the cost, time and quality targets, suitable approaches should be adopted. Beforehand, it is required to identify the problems that are inherent. Thus, this study focused on the identification of problems that are present in refurbishment projects due to the inherent characteristics of refurbishment concept and thereby identification of causes and strategies to mitigate those problems in hotel refurbishment projects in Sri Lanka.

2. LITERATURE REVIEW

2.1 OVERVIEW OF REFURBISHMENTS

Buildings are being physically deteriorated over time and while subjecting to different forms of obsolescence (Babangida, 2014). Thomsen *et al.* (2015) explained obsolescence as the process of declining the performance of buildings. The stage of obsolescence is important to get the decision whether to refurbish or completely redevelop (Kangwa and Olubodun, 2004). Conversely, CIRIA (1994) mentioned that refurbishment could be done not only in case of deterioration, but also with the building being in an authentic condition whereas the owner decides to accommodate new technology. Refurbishment projects are complex and less predictable projects within the construction industry (Rahmat and Ali, 2010). Arain (2005) identified problems in construction stage as improper site surveys, concurrent operation by owners, selection of contractor etc. Procurement route is another aspect to be considered in managing refurbishment projects (Ali *et al*., 2014). Thereby the research tended to investigate the causes of problems in refurbishment projects in terms of stages of project, specifically the procurement phase and construction phase.

2.2 PROBLEMS ASSOCIATED WITH REFURBISHMENT PROJECTS

Mansfield (2009) identified that comparatively more technical and economic risks are involved in refurbishment projects than new build. Furthermore, Kulkarni *et al*. (cited in Prabhakar, 2008) mentioned that project stages can be grouped into main three stages as the procurement phase, execution/construction phase and operation and handover phase. However, the study basically focussed on the procurement phase, execution/construction phase, which are considered to constitute a higher effect on successful completion. These stages are used as a base to manage refurbishment projects while identifying problems encountered along with identifying responsible parties and thereby applying suitable approaches to minimise those problems in each stage.

Studies have identified several problems associated with refurbishment projects as in Table 1.

Table 1: Problems encountered in refurbishment projects

Problem		Source												
		A	B	C	D	E	F	G	H	I	J	K	L	M
Procurement stage														
1	Lack of accurate and complete design information	✓	✓	✓	✓		✓							✓
2	Level of involvement of parties in design stage				✓	✓		✓			✓			
3	Determining client's needs												✓	
4	Percentage of services work	✓					✓			✓				
5	Percentage of provisional sum													
6	Percentage of structural work						✓					✓		
7	Difficulty in determining amount of contingency						✓							
8	Statutory requirements						✓	✓						✓
Execution stage														
1	Obstruction by occupancy	✓					✓	✓				✓		
2	Noise, vibration, fumes and dirt							✓						
3	Restricted access, temporary circulation and site boundary	✓					✓	✓	✓					
4	Reduced space for material storage											✓		✓
5	Uncertainty over availability of materials						✓							✓
6	Restriction on plant usage imposed by site location						✓							
7	Security							✓						
8	Risk in health and safety						✓	✓	✓					✓

	Problem	A	B	C	D	E	F	G	H	I	J	K	L	M
9	Variation of scope						✓							✓
10	Unrealistic time pressure						✓							

Sources: A- (Ali, 2009) , B- (Ali, 2010), C- (Ali, 2014), D- (Ali and Rahmat, 2009), E- (Arain, 2005), F- (Babangida, 2014), G- (CIRIA, 1994), H- (Ikpe *et al*., 2006), I- (McKim *et al*., 2000), J- (Mitropoulos and Tatum, 2000), K- (Rahmat, 1997), L- (Shen *et al*., 2004), M- (Ekanayake *et al*., 2018)

Referring to Table 1, most of the problems were identified in more than one literature sources. This emphasises that those problems are generally observed in refurbishment projects. Considering the frequency of each problem, it seems that the problems of lack of accurate and complete information and obstructions by occupancy were highly quoted. Moreover, level of involvement of parties in design stage; risk in health and safety; restricted access, temporary circulation and site boundary; percenage of services works and statutory requirements were also considered to be common. Services complicate the problems in the accuracy of the designs and obviously affect the smooth running in the construction process. According to Ali (2009), once the proportion of services work is increased, more problems are likely to be encountered in services designs. Ali (2009) stated that the building has to be shared among occupants and project teams, which thereby affects the sequence of work. According to Hughes and Ferrett (2007), safety is the most important investment of construction projects. The responsibility regarding safety of refurbishment projects is higher than on newly built, as well the presence of client's personnel makes complicated safety problems in the progress (CIRIA, 1994).

3. RESEARCH METHODOLOGY

Considering the nature of the background evidences and the aim of this study, as it required to reveal subjective exploratory in-depth views of the phenomenon, a qualitative approach was selected for the research. Yin (2014) emphasised the advantages of using multiple case studies over single case studies, as it can be obtained independent conclusion of each case and those become more powerful information than obtained from a single case. Considering above factors, case study was selected as the research strategy inclusive of three hotel refurbishment projects. Table 2 indicates the general information of the selected cases.

Table 2: Profile of the cases

Description	Case 1	Case 2	Case 3
Type	5-star rated hotel located in Colombo	5-star rated hotel located in Colombo district	5-star rated hotel located in Galle district
Work status	Completed	Completed	Completed
Duration	Planned: 6 months (Phase 1) Actual: 7 months	Planned: 1 year Actual: 1 year+ 18 months	Planned: 1 year Actual: 1year+ 6 months
Cost	Contractor's perspective Budgeted (Rs.): 500Mn+120Mn	Contractor's perspective Budgeted (Rs.): 1000Mn Actual (Rs.): 1000Mn	Budgeted (Rs.):52 Mn Actual (Rs.): 56Mn (including variations)

Description	Case 1	Case 2	Case 3
	Actual (Rs.): 620 Mn		
Procurement method	Traditional	Traditional	Traditional
Contract type	Re-measurement fixed rate	Lump sum fixed rate	Lump sum fixed rate
Scope	Renovation of guest rooms, public areas and banquets, including Mechanical, Engineering and plumbing (MEP) work and finishes. Phase 1- refurbishing 85 keys-guest rooms, lobby and bar and external lodge	Renovation of old wing, including all both architectural and MEP works	Refurbishment work includes demolition work, breaking and reconstruction, alteration and prepared to the existing, floor and wall finishes, painting, plumbing, hot water and cold-water supply system, Extra Low Voltage (ELV) system

In terms of the extent of refurbishment, case 1 involved soft refurbishment in comparison to case 2. Besides, case 3 involved mainly an interior refurbishment. Furthermore, face to face semi-structured interviews facilitate the capability of requesting additional questions if required while clarifying doubts (Fellows and Liu, 2003). Thus, face to face semi-structured interviews were conducted with the representatives of contractor and consultant of each case (Refer Table 3) to identify how each problem affects each party to the contract in their own perspectives. However, the employer was not interviewed as the consultant acts on behalf of the employer. Hsieh and Shannon (2005) mentioned content analysis as the commonly used technique for analysing qualitative data as it generates logical and also reliable conclusion from the gathered data. Thus, content analysis was adopted to this research.

Table 3: Profile of interviewees

Interviewee code	Years of experience	Scope of work	Educational and professional qualifications
C1/CS	9	Consultant quantity surveying in post-contract management, contract administration	BSc. in Quantity Surveying, Chartered QS
C1/CN	10	Contractor quantity surveying in pre- and post-contract management, project management	BSc. in Quantity Surveying and MSc. in Project Management, Chartered QS
C2/CS	25	Consultant quantity surveying in pre- and post-contract management, project management	BSc. in Quantity Surveying and MSc. in Project Management, Chartered QS
C2/CN	14	Contractor quantity surveying in post-contract	BSc. in Quantity Surveying, Chartered QS

Interviewee code	Years of experience	Scope of work	Educational and professional qualifications
		management, contract administration	
C3/CS	25	Consultant quantity surveying in pre- and post-contract management, project management	BSc. in Quantity Surveying and MSc. in Project Management, Chartered QS
C3/CN	15	Contractor quantity surveying in pre- and post-contract management, project management	BSc. in Quantity Surveying and MSc. in Project Management, Chartered QS

As per Table 3, a total of six experienced professionals were involved in the current research. In terms of years of experience, all the interviewees were possessed with adequate industry experience in pre and post contract phases to contribute the study with their technical and professional knowhow. Moreover, all the interviewees are chartered quantity surveyors and had exposure to the fields of project management and contract administration, so that they were able to enlighten the study with their peculiar expertise. Thus, this profile of information of research participants gives an indication that the collected data are reliable.

4. RESEARCH FINDINGS

4.1 EXPOSURE TO PROBLEMS IN HOTEL REFURBISHMENT PROJECTS IN SRI LANKA

The interviewees were asked to indicate the exposure to problems in each case. The responses are provided in Table 4.

Table 4: Exposure to the problems

Problem		Exposure to the problems		
		Case A	Case B	Case C
Procurement stage				
1	Lack of accurate and complete design information	✗	✓	✓
2	Level of involvement of parties in design stage	✗	✗	✓
3	Determining client's needs	✗	✓	✓
4	Percentage of services work	✓	✓	✓
5	Percentage of provisional sum	✗	✓	✗
6	Percentage of structural work	✗	✓	✓
7	Difficulty in determining amount of contingency	✗	✓	✗
8	Statutory requirements	✓	✓	✗
Execution stage				
1	Obstruction by occupancy	✓	✓	✓
2	Noise, vibration, fumes and dirt	✓	✓	✗
3	Restricted access, temporary circulation and site boundary	✓	✓	✗

	Problem	Exposure to the problems		
		Case A	Case B	Case C
4	Reduced space for material storage	✓	✓	×
5	Uncertainty over availability of materials	×	×	✓
6	Restriction on plant usage imposed by site location	✓	✓	×
7	Security	✓	✓	×
8	Risk in health and safety	✓	✓	✓
9	Variation of scope	×	✓	✓
10	Unrealistic time pressure	✓	✓	✓

According to the exposure of each problem within each case, considering the procurement stage, percentage of services work is the only problem prominent in all the three cases. In consideration of the construction stage, obstruction by occupancy, unrealistic time pressure and risk in health and safety are the problems which were observed in all the three cases. Therefore, the said four factors were considered to be four of most common problems associated with hotel refurbishment projects in Sri Lanka. Accordingly, the four most common problems in the above three cases are discussed in-depth in terms of underlying causes and strategies to mitigate such. Furthermore, the discussed underlying causes and strategies to mitigate are the most cited by the sources and the interviewees.

4.2 UNDERLYING CAUSES OF PROBLEMS

Table 5 demonstrates the underlying causes of problems associated with hotel refurbishment projects in Sri Lanka.

Accordingly, guest disturbances was identified as a major cause in all problems except in 'Risk in Health and Safety'. In most of the hotel refurbishments, part of the hotel is functioning at the time of the refurbishment is going on. The employer expects the refurbishment to be done at the required level of quality, cost and time requirements while not disturbing the revenue generating through the occupancy of the other part of the hotel. In contrast, from the contractor's point of view, the presence of the occupancy leads to make disturbances and obstruction to the sequence of the work. Consequently, another cause for percentage of work identified by C1/CS is, company policy restrictions to not to close the hotel in whole during refurbishments. Therefore, if more services are present, refurbishment has to be done with the minimum disturbance to operation. Normally in hotel industry, many of the bookings are done in advance while focusing on specific months, seasons that more tourism arrivals are expected. In that case, employer expects to get finished such refurbishments on time. Therefore, in such conditions, employer would pressure contractor and consultant to get the work done. Most of the time, this problem seems to present at the latter part of the construction program. If thoroughly considered, the aggregate of other problems affect the work sequence would ultimately become cause for this problem. On the other hand, C1/CN, C2/CN, C2/CS and C3/CN mentioned that the main cause for 'Risk in Health and Safety' is reluctant to wear safety accessories. Accordingly, labourers tend to refuse and be reluctant to get used for these health and safety aspects which ultimately become a problem and a risk in hotel refurbishments.

Table 5: Underlying causes of problems

Problems	Percentage of Services Work	Obstructions by Occupancy	Unrealistic Time Pressure	Risk in Health and Safety
Causes	Work stoppage due to guest disturbances	Work stoppage due to guest disturbances	Work stoppage due to guest disturbances	Reluctance to wear safety accessories
	Hotels being in the operation	Hotels being in the operation	Unrealistic time targets	Demarcation and guest and construction areas
	Unforeseen work		Unforeseen work	Uncontrollable dust
	Compatibility problems with the existing structure		Risk transfer to the contractor	Minimal temporary covering
	Budget constraints			Contractor's responsibility of indemnification
	Company policies			
	Difficulties in upgrading current specifications			
	Difficulties in working with existing fittings			

4.3 STRATEGIES TO MITIGATE THE PROBLEMS

Table 6 tabulate different strategies to overcome or minimise the problems associated with hotel refurbishment projects in Sri Lanka.

As it is required to work with the existing structure and already running services, much care is critical, since otherwise, it has the potential of affecting the whole operation of the hotel. According to C1/CS, although cost would increase to some extent due to the shift of the work time, it is essential to bear it, otherwise, it may incur more time and cost due to the work delay and disruptions. Moreover, C1/CS gave another suggestion of adhering to alternative ways in case of disturbance to the sequence of work. Majority of the interviewees specified plan ahead as the best strategy to be adopted. C2/CS and C3/CN specified that changing the working schedule as another strategy. Besides, C3/CS and C3/CN identified another two strategies as providing separate access for guests and covering refurbishment areas with painted walls in order to mitigate 'Obstructions by Occupancy'. An important point to be highlighted is that the problem of noise, vibration would indirectly support 'Unrealistic Time Pressure'. Thus, planning ahead would be a strategy for mitigating both problems. Continuing assessment of feasibility would be helpful in identifying deviation and could be used as a guide to take steps to make the project feasible. Majority of the interviewees identified compulsory wear of safety accessories on the site as a beneficial strategy. Another important strategy highlighted by C1/CN, C1/CS and C3/CN is maintaining and adhering to a safety manual. Moreover, C1/CN highlighted introducing a fining system as this is a kind of strict process to think of at last if no other possible strategy could be adopted.

Table 6: Strategies to mitigate the problems

Problems	Percentage of Services Work	Obstructions by Occupancy	Unrealistic Time Pressure	Risk in Health and Safety
	Planning ahead	Planning ahead	Planning ahead	Planning ahead
	Checking compatibility		Checking compatibility	Designating compulsory wear of safety accessories at site
		Providing separate access to guests		Adhering and maintain a safety manual
	Informing hotel operation	Demarcating noisy working areas (wings)	Conducting feasibility studies	Providing separate access to guests
	Seeking alternative sequences	Informing hotel operation	Risk transfer to the contractor	Preliminary allocations for health and safety
Strategies	Preparing a detailed BOQ	Covering refurbishment areas with painted walls	Client and contractor compromising	Introduction of a fine system
	Involvement of an interior contractor	Changing the work schedule		Proper education on health and safety at construction sites
	Careful removal and repair	Providing temporary covering or protection		Providing adequate insurance coverage
	Providing reasonable time and contingencies in the contract	Sectional completion on pricing basis		
	Improved supervision			

5. DISCUSSION

In generic refurbishment projects, obstructions by occupancy (Rahmat, 1997; Arain, 2005; Ali, 2009; Babangida, 2014), risk in health and safety (CIRIA, 1994; Ikpe *et al.*, 2006; Babangida, 2014; Ekanayake *et al.*, 2018), and percentage of services works (McKim *et al.*, 2000; Ali, 2009; Babangida, 2014) were some the most quoted problems. The same were identified as specific to the hotel refurbishments in the study, and as well recognised as the most common problems associated in all the three cases that were studied. However, lack of accurate and complete information (Ali, 2009; Ali and Rahmat, 2009; Ali, 2010; Ali, 2014; Babangida, 2014; Ekanayake *et al.*, 2018), level of involvement of parties in design stage (CIRIA, 1994; Mitropoulos and Tatum, 2000; Arain, 2005; Ali and Rahmat, 2009), restricted access, temporary circulation and site boundary (CIRIA, 1994; Ikpe *et al*., 2006; Ali, 2009; Babangida, 2014), that were recognised as common issues in refurbishment projects, were not identified to be most common in hotel refurbishment projects in Sri Lanka. The reason is that due to the constraint on time availability, the most common problems were ought to be the problems that were common in all the three cases. Furthermore, on April 21, 2019, four tourist hotels and in Colombo and three Catholic churches were attacked by Islamic extremists (Anderson, 2019). This is anticipated to take a new shift in the hotel refurbishment projects in Sri Lanka. The circumstance established a varied reason for hotel refurbishment apart from repairs, altered use, optimisation and owners' decisions. Furthermore, such refurbishment would emerge particular problems, which need to be addressed by adopting different strategies.

6. CONCLUSIONS AND RECOMMENDATIONS

In Sri Lanka, hotel industry is in a boom in the economic perspective and demands modifications and upgrading in order to fulfil changing requirements of tourists and the trends. Thus, focusing on hotel refurbishment would be much more worth and minimising the problems as much as possible leads the smooth running of the project. The study is focused on hotel refurbishment projects in Sri Lanka based on problems and strategies to minimise the problems in relation to the selected case studies. Referring to the literature review, the problems associated with refurbishment projects were basically identified, mostly focused on the global context. Subsequently, through case studies therein, each of the problems relating to the hotel refurbishment in Sri Lankan context were inferred.

Considering the problems, percentage of services work and obstruction by occupancy are the topmost challenging problems revealed through both literature review and research findings. Other than that, unrealistic time targets and risk in health and safety are other elaborated problems to be addressed in relation to the Sri Lankan context. Percentage of work is basically caused by guest disturbances and compatibility issues which can be minimised by planning ahead and checking the compatibility. Obstruction by occupancy is caused due to operation of the hotel and work stoppage due to guest disturbances. Such can be avoided by planning ahead, separating the noisy working areas, allowing a separate access for guests and such. Unrealistic time targets are caused basically due to unforeseen work and having had to complete work before specific seasons which can be minimised via planning ahead, carrying out feasibility studies and checking the compatibility. Risk in health and safety is caused by reluctance to wear safety accessories, issues in demarcating guest vs. construction areas and due to dust issues, which are supposed to be minimised by making compulsory to wear safety accessories and maintaining and adhering to a safety manual. However, the best practice is to adopt strategies without waiting until the problem would appear in the refurbishment project. Implementing strategies in initial stages would help to minimise a lot of problems which would otherwise appear in later on within the construction.

7. REFERENCES

Aikivuori, A., 1996. Periods and demand for private sector housing refurbishment. *Construction Management and Economics*, 14(1), pp.3-12.

Ali, A. S., 2009. Complexity in refurbishment of services system for historical buildings in Malaysia. In Proceedings of *International Symposium on Advancement of Construction Management and Real Estate*, Nanjing, China, pp.26-31.

Ali, A. S., 2010. Design information in managing refurbishment projects in Malaysia. *International Journal of the Physical Sciences*, 5(6), pp.768-773.

Ali, A. S., 2014. Complexity in managing refurbishment design process: Malaysian experience. In Proceedings of *MATEC Web of Conferences*. Kuala Lumpur, Malaysia: EDP Sciences.

Ali, A. S., and Rahmat, I., 2009. Methods of coordination in managing the design process of refurbishment projects. *Journal of Building Appraisal*, 5, pp.87-98.

Ali, A. S., Peng, A. Y., and Ling, S. C., 2014. Managing refurbishment projects through selection of procurement system: The case of Malaysia. *European Journal of Sustainable Development*, 3(4), pp.311-322.

Anderson, A. B., 2019. Commentary: Thoughts on the New Zealand and Sri Lanka attacks. *Journal on Ethnopolitics and Minority Issues in Europe*, 18(2), pp.72-80.

Arain, F. M., Assaf, A. A., and Low, S. P., 2004. Causes of discrepancies between design and construction. *Architectural Science Review*, 47(3), pp.237-249.

Athapattu, A. A., and Gunawardena, N., 2010. *Causes of delay in hotel refurbishment projects in Sri Lanka*. Thesis (MBA), University of Moratuwa.

Babangida, I., 2014. *Hierarchical structuring and evaluation of risks, uncertainties and technical challenges faced by building refurbishment contractors*. (Unpublished doctoral dissertation), University of Bolton, Bolton.

Construction Industry Research and Information Association, 1994. *A guide to management of building refurbishment*. CIRIA report no. 133, Construction Industry Research and Association, UK.

Department of Census and Statistics, 2017. *National Accounts of Sri Lanka*. Ministry of National Policies and Economic Affairs.

Ekanayake, B. J., Sandanayake, Y. G., and Ramachandra, T., 2018. Challenges in hotel building refurbishment projects in Sri Lanka. *The 7th World Construction Symposium 2018: Built Asset Sustainability: Rethinking Design, Construction and Operations*, Colombo, Sri Lanka, pp.145-153.

Fellows, R., and Liu, A., 2003. *Research methods for construction.* 2nd ed. Blackwell Publishing: Oxford.

Hsieh, H. F., and Shannon, S. E., 2005. Three approaches to qualitative content analysis. *Qualitative Health Research Journal*, 15(9), pp.1277-1288.

Hughes, P., and Ferrett, E., 2007. *Introduction to health and safety in construction.* Routledge.

Ikpe, E., Potts, K., Proverbs, D., and Oloke, D., 2006. The management of construction health and safety: Investigating the cost-benefit. In D. Boyd (Ed.), In Proceedings of *22nd Annual ARCOM Conference,* Birmingham, UK: Association of Researchers in Construction Management, pp.295-304.

Kangwa, J., and Olubodun, F., 2004. Modelling of owner -occupiers' perception of small-scale maintenance builders-part I. *Structural Survey*, 22(4), pp.194-200.

Langdon, D., and Everest, 2002. *Hotel refurbishment cost model* [online]. Available from: http://www.building.co.uk/story.asp/. [Accessed 10 May 2018].

Lawrence, R. and Werna, E., 2009. *Labour Conditions for Construction: Building Cities, Decent Work and the Role of Local Authorities*. John Wiley & Sons.

Mansfield, J. R., 2002. What's in a name? Complexities in the definition of "refurbishment". *Property Management*, 20(1), pp.23-30.

Mansfield, J. R., 2009. The use of formalised risk management approaches by UK design consultants in conservation refurbishment. *Engineering Construction and Architectural Management*, 16(3), pp.273-287.

McKim, R., Tarek, H., and Attalla, M., 2000. Project performance control in reconstruction project. *Journal of Construction Engineering and Management*, 126(2), pp.137-141.

Mitropoulos, P., and Tatum, C. B., 2000. Management-driven integration. *Journal of Management in Engineering, 16*(1), pp.48-58.

Olanrewaju, A.L. and Abdul-Aziz, A.R., 2014. *Building maintenance processes and practices: The case of a fast developing country.* Springer.

Prabhakar, G. P., 2008. Projects and their management: A literature review. *International Journal of Business and Management*, 3(8), pp.3-9.

Rahmat, I., 1997. The planning and control process of Refurbishment projects (Unpublished doctoral dissertation). University College London, UK.

Rahmat, I., and Ali, A. S., 2010. The effects of formalisation on coordination and effectiveness of refurbishment projects. *Facilities*, 28(11), pp.514-525.

Rudestam, K. E., and Newton, R. R., 2007. *Surviving your dissertation: A comprehensive guide to content and process*. 3rd ed. United States of America: Sage Publications.

Shen, Q., Li, H., Chung, J., and Hui, P. Y., 2004. A framework for identification and representation of client requirements in the briefing process. *Journal of Construction Management and Economics*, 22, pp.213-221.

Thomsen, A., Van der Flier, K. and Nieboer, N., 2015. Analysing obsolescence, an elaborated model for residential buildings. *Structural Survey*, 33(3), pp.210-227.

Yin, R. K., 2014. *Case study research: Design and methods.* 5th ed. Califonia: Sage Publications Inc

Zolkafli, U.K., Zakaria, N., Yahya, Z., Ali, A.S., Akashah, F.W., Othman, M. and Hock, Y.K., 2012. Risks in conservation projects. *Journal of Design+Built*, *5*(1).

Sirimewan, D.C., Manjula, N.H.C., Samaraweera, A. and Mendis, A.P.K.D., 2019. Issues in sustainable water management of irrigation systems in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 390-399. DOI: doi.org/10.31705/WCS.2019.39. Available at: https://2019.ciobwcs.com/papers

ISSUES IN SUSTAINABLE WATER MANAGEMENT OF IRRIGATION SYSTEMS IN SRI LANKA

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ABSTRACT

As the largest consumer of water, the irrigation sector has to play a critical role in managing water resources. Nevertheless, the current water management practices of irrigation are not achieving the benefits of sustainable use of water. The failure in achieving the expected performance of irrigation infrastructures urges the need for Sustainable Water Management (SWM). Therefore, the purpose of this research is to investigate the issues in existing Irrigation Water Management (IWM) practices towards SWM of irrigation systems in Sri Lanka. The research aim was approached through a qualitative survey strategy. Expert interviews were conducted as the data collection technique. Twelve experts were selected through a purposive sampling strategy, who had experience in water management and technical development in irrigation systems. The collected data were analysed using the manual content analysis method. Findings of the research revealed that though numerous techniques are being practiced in IWM, there is a failure in water management in the current context. It was identified, water losses throughout the system, improper system operation and poor maintenance of structures, inefficient practices of irrigation, dis-integration of system components and lack of government intervention as major issues to achieve sustainable use of water in the case of irrigation. The identification and assessment of issues provide a range of their impacts to reveal the constraints in achieving SWM of irrigation.

Keywords: *Irrigation Systems; Irrigation Water Management; Sri Lanka; Sustainable Water Management.*

1. INTRODUCTION

Equitable use of the available resources to manage the consumers' needs is a common problem in most of the countries (Tsirogiannis *et al*., 2017). The increasing growth of the population directly affects the current water demand due to the higher competition over the limited resources, which has led to severe water shortages (Sun *et al*., 2016). Therefore, being the largest consumer of water, the irrigation sector has to play a critical role in the sustainable use of water (Calzadilla *et al*., 2010). However, the inequity of water distribution, uneconomic and inefficient use of irrigation water and failure to achieve the expected performance of irrigation infrastructures are continuing the problem of sustainable management of water resources (Buyukcangaz and Korukcu, 2007). Even

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though the previous studies have proposed various methods for practicing Sustainable Development (SD) principles in the process of implementing infrastructure projects, the lack of effective assessment indicators presents a barrier to the effective assessment of sustainability in infrastructure projects (Greenland *et al*., 2017). Therefore, the study aims to investigate issues towards SWM of irrigation systems in Sri Lanka.

2. LITERATURE SYNTHESIS

Irrigation systems are associated with various types of structures starting from water retaining structures to water distribution channels. The requirement of water distribution systems is being increased due to the higher demand for irrigation water (Cai *et al*., 2003). As per the findings of Phadnis and Kulshrestha (2012), the total quantity of annual water consumption of irrigation systems was reported to be around 60-70% in the global context. Hence, the provision of irrigation systems remains important as it provides water for agricultural production, especially in arid and semi-arid regions, to ensure a more productive yield (Singh, 2016). Therefore, as a major consumer of water, the irrigation systems have to play a critical role in water sustainability (Greenland *et al*., 2017).

2.1 DEFINING SUSTAINABLE WATER MANAGEMENT

Water is considered a scarce and critical resource, which is a part of environmental, social and economic systems, as stated by Sun *et al*. (2016). Further to the authors, the increasing population is directly affected by the current water demand due to the higher competition over the limited resources, which has led to severe water shortages worldwide. Moreover, this is going to worsen due to the climatic changes and deterioration of the water quality (Qu *et al*., 2013). According to Peterson and Schoengold (2008), the disparity between the availability of water and the increased demand for water is a persistent issue in the world. Therefore, it is essential to move for improved management of natural water resources as a solution for this global crisis (Oelkers *et al*., 2011), which is a crucial challenge of the 21st century (Emelko *et al*., 2011).

2.2 SIGNIFICANCE OF IRRIGATION IN SRI LANKAN CONTEXT

The irrigation system plays a major role in the agricultural sector in Sri Lanka (Sivayoganathan and Mowjood, 2003). Since ancient times, the agricultural sector in Sri Lanka has been placed at a predominant place in the country's economy, a higher proportion of the public investment is given to the development of irrigation systems (Shand, 2002).

According to Sivayoganathan and Mowjood (2003), Gravity Irrigation is the main irrigation system in Sri Lanka, which can be classified according to the source of water; such as tanks and reservoirs, and size of the system as a major, medium and minor irrigation systems. Further, the authors mentioned the main components of an irrigation system as the water storage system, water conveyance system including main channel, branch channels, distribution channels, field channels and command area, which refers to the farm plots that are receiving water through the channels.

Large-scale irrigation systems, which are extensively invested by the government and foreign donors are contributing to the socio-economic development in most of the developing countries in Asia (Lam, 2006). However, Shantha and Ali (2014) reported that only around 4% out of the total irrigation investment is dedicated to the operational and maintenance purposes of the irrigation systems in Sri Lanka. Thus, the authors identified the need for an improvement in irrigation management regarding investment to achieve optimum resource allocation. Moreover, Lam (2006) reported that in most of the cases, these projects are not economically viable, since they have failed to perform at a satisfactory level. Thus, Singh (2016) recognised that the efficiency and long-term success of irrigation systems largely depend on the appropriate planning and management by the relevant authorities.

2.3 ISSUES ASSOCIATED WITH IRRIGATION WATER MANAGEMENT

Due to the higher needs of crop production, it is difficult to sustain the traditional practices of farming with the use of canals and rivers (Zhen *et al*., 2005). Hence, the expansion of the irrigation system by constructing new dams and canals is needed to cope with the high demand for crop production (Hussain and Bhattarai, 2005). Thus, Ugwu *et al*. (2006) identified the need for a sustainable assessment of those techniques and practices, which is to be implemented in different project levels, starting from conceptual design, operational process and up to the maintenance and decommissioning stages.

Most importantly, the lack of proper irrigation management in the operational and maintenance stages can adversely affect the environment and imperil to sustainability (Howell, 2006). Previous researchers have identified the issues IWM, which raise the challenge of water scarcity under different categories. Accordingly, Ahmad (1999) categorised the issues of IWM as in-efficiency, in-equity, and un-sustainability. Further, Cai *et al*. (2003) identified the issues of IWM in their case study under the risk in the water supply system, ecological system degradation, conflicts in water sharing and infrastructure deterioration. Furthermore, Buyukcangaz and Korukcu (2007) found technical, socio-economic and environmental issues with regards to the IWM in their case study. Given all, the issues identified in IWM practices in the global context are categorised into three main sections in this study namely efficiency, equity, and environmental integrity.

Water losses in conveyance channels and field applications are highly impacting the efficiency of irrigation systems (Donaldson, 2013; Poddar *et al*., 2014). The inadequate and unstable water supply is a problem towards the equity of water distribution as described by Zaman *et al*. (2017). The increasing environmental issues associated with the development and management of existing irrigation practices have led to a debate on the impacts of them on the environment (Shand, 2002). Waterlogging, salinization and groundwater depletion are common issues to the environmental integrity associated with irrigated areas. Therefore, a deep insight into the issues towards SWM in irrigation systems is highly needed in the current context. The next section elaborates the methodology adopted in this study.

3. METHODOLOGY

Qualitative research methods are representing the views, experiences, believes, and attitudes of a specific set of people and it is ideal for research on emerging conceptions through in-depth investigations (Ritchie *et al*., 2013). The concept of sustainability has been evolving over centuries. The knowledge, believes, attitudes, and opinions towards this concept are subjective. Hence, a qualitative approach was undertaken in this study.

The expert survey method was selected as the research strategy. Twelve semi-structured interviews were conducted to collect data. The experts were selected based on purposive sampling, who had knowledge and experience on water management and technical development on irrigation systems in Sri Lanka. The profile of each respondent is given in Table 1. The collected data were analysed through content analysis method.

Table 1: The profile of the respondents

Respondent	Discipline	Industry Experience
R1	Director in Technical Services Division (Engineer)	33 years
R2	Director in River Base Management (Engineer)	32 years
R3	Director in Water Management Secretariat (Engineer)	32 years
R4	Resident Project Manager (Engineer)	32 years
R5	Deputy Director of Technical Services Division (Engineer)	24 years
R6	Project Engineer	15 years
R7	Project Engineer	5 years
R8	Project Engineer	5 years
R9	Resident Project Manager (Engineer)	10 years
R10	Resident Project Manager (Engineer)	6 years
R11	Geo Technician	8 years
R12	Senior Technical officer	7 years

4. RESEARCH FINDINGS

The adoption of SWM involves various considerations such as technical aspects, economic constraints, social behaviour, institutional and legal framework, which ultimately affects the SD of the country. All the respondents used their proficient knowledge and experience gained in explaining the current practices of IWM. However, all of them agreed that the current practices of water management are not sufficient to deal with increasing water demand. Therefore, there is a need for identifying, assessing and prioritising the issues to come up with strategies to minimise the impact of them. The issues of IWM in the Sri Lankan context were identified under the following categories.

- Issues towards the efficiency of irrigation infrastructure
- Issues towards the equity of water distribution
- Issues towards environmental integrity

4.1 ISSUES TOWARDS THE EFFICIENCY OF IRRIGATION INFRASTRUCTURE

The issues will be discussed following the four major structures in irrigation systems namely, water retaining structures, water conveyance channels, water distribution channels, and field applications.

4.1.1 Issues towards the Efficiency of Water Retaining Structures

The primary uses of dams and reservoirs are to provide water for irrigation, hydropower generation, and domestic and industrial uses. In the case of irrigation, water storage is very much important, when the river flows are not enough, where there is a higher demand for irrigation water. Having adequate, reliable and secure water storage is necessary to maintain the water demand consistently.

Most of the respondents highlighted ‘silting’ as the main reason for the inefficiency of water retaining structures, which was happening due to earth collapsing in the catchment area. As a result of silting reservoirs, the water holding capacity of the structures going to be reduced. Evaporation due to exalted global warming was another issue, which reduces the efficiency of reservoirs. The reduction of water level due to evaporation depends on the size and depth of the reservoir. The large open surfaces of reservoirs easily enable water losses by evaporation.

Sedimentation was another problem, which causes the diminution in water flow while decreasing the potential water storing capacity of the structures. It decreases the carrying capacity of silt and nutrients to the down streams. Besides, the structural issues of reservoir bed and foundation lead to inefficiency of the whole system. For example, cavities in the reservoir bed is a serious problem, which often led to water leakages.

4.1.2 Issues towards the Efficiency of Conveyance Channels

The efficiency of water delivery in an irrigation system is measured by the difference between the amount of water diverted at the dam and the amount recorded in measuring devices at distribution channels. According to the literature findings, a proportion of water diverted from reservoirs was lost during its conveyance to the receivers.

All the respondents agreed that water losses, which were happening during the conveyance effects the efficiency of the channels. Due to bund erosion and leakages, water losses were happening through bunds whereas, silting and vegetation decrease the efficiency of conveyance channels by reducing the speed of water flow.

The ‘trapezoidal section’ is the optimal section for conveying water in canals, as signified by the respondents. The advantage of having a trapezoidal section is the friction force of water is less in these types of canals than the canals having a rectangular section. However, because of certain reasons such as the growth of vegetation along the canals and earth collapsing due to animal crossing the slope of canals get changed. Moreover, water losses were happening in outdated canals, which are still using in for irrigation water conveyance, especially in places having ‘single bank canals’.

4.1.3 Issues towards the Efficiency of Distribution Channels

The distribution channels convey water from main conveyance channels to the fields, which comprise open channels and pipelines or a combination of both. Through the expert survey, it was identified that ‘seepage’ as a common issue in distribution channels, which led to water losses. Though the seepage losses are less in open channels than the pipelines, channel distribution is commonly used since it consumes less capital and less maintenance cost. Nevertheless, the main disadvantage in open channels is the inability to respond to the changes in demand for water, due to the inefficient conveyance through the channels.

Silting was again identified as an issue towards the inefficiency of distribution systems. This can be happened due to drainage and corrosion of the canal bed, when flowing water inside the canal. Due to this problem, the canals may not be able to carry water for the fields in an efficient manner.

4.1.4 Issues towards the Efficiency of Field Application

The application method shall provide an adequate amount of water to meet the requirement of crops consistently without unnecessary wastage. When choosing the best method for applying water into the fields, the consideration has to be given not only for the technical viability but also for the ease of operating and maintaining such a method.

Most of the respondents agreed that the traditional practices of water application lead to huge losses of water in the fields. For example, flood irrigation method, which was commonly used in Sri Lanka was identified as a low efficient method of water application in fields. In this method, the water will be received to the topmost basin in the field through pipes or field canals. After the top basins get filled with water, it will gradually flow to the basins at the next level. In such a way, all the basins will get irrigated in the land. This method leads to a huge wastage of water than the direct application of water to each basin.

Besides, though the water has been allocated as per the crop water requirement in each area, some people are not satisfied with that system. Then they make trouble for the operators in particular authorities. Therefore, it was confirmed that the unawareness of water receivers is another problem, which raises water losses in-field applications.

Improper levelling and not following the precise contour patterns cause huge water losses in fields as highlighted by the respondents. In places having larger slopes in the land, the water will run-off rapidly without collecting and remaining in the field. Moreover, due to the low water holding capacity of the soil, a certain amount of water would be lost in the fields. Further, this low water holding capacity of soil would impact the deep percolation of water into the ground.

4.1.5 Issues towards the Equity of Water Distribution

The water shall be delivered in sufficient quantity and quality at the right time to ensure the equity of water distribution in the case of irrigation. Therefore, the system has to maintain the required flow rate up to the tail end users. According to the expert review, it was identified that the inefficiency of the system, inadequacy of water supply, inequity of canal water distribution, and the sequence of water delivering as the main causes of the inequality of water distribution.

Most of the respondents stated that deteriorated canals due to improper maintenance as a problem in this regard. The tail end water shortage was another issue for the in-equal water distribution of the system. While up-stream water receivers are getting more water, downstream users or the tail end users are troubling with water shortage. As a result, conflicts can happen among downstream water users. Water loss during the conveyance was the main cause of this problem.

The risk of water scarcity affected political risk in the country. Therefore, managing geopolitical issues regarding water scarcity are difficult in practice. Furthermore, the influences coming from various authorities and regulatory bodies troubles the integration of different sub-components in the system.

4.2 ISSUES TOWARDS ENVIRONMENTAL INTEGRITY

The irrigation systems denote modification to the existing eco-system by extracting water from available water resources and diverting water for dry zones using built structures.

Therefore, there can be impacts on the environment due to the establishment of irrigation infrastructures. Construction of irrigation infrastructures is complex since it needs advanced technologies of construction methodologies and a large number of resources. The construction of irrigation structures devastates the natural equilibrium of biodiversity in a particular region. Due to the inundation of large areas with significant hydraulic pressure, destructions can occur to the associated eco-system in such areas.

Irrigated lands receive water from surface water supplies or extracted groundwater. According to the literature findings, the quality of water in water sources and the method of delivering water to the fields affect the environmental integrity. Most of the respondents highlighted that the water pollution impacts the quality of irrigated lands and subsequently for the crops in the fields. Diversion of drainage into rivers and other streams was the main cause of water pollution during the water conveyance.

Besides, it was evident that improper management and operation of water distribution also affect environmental sustainability. As per the expert review, the raising water tables could be happened due to water losses during the conveyance. It leads to waterlogging in certain areas due to deep percolation of water into the ground.

The efficient irrigation practices and water application methods used in the fields contributes to the efficiency of irrigation systems. The poor irrigation practices impact the environment by changing the quality of water and the soil. Overuse of water and the poor IWM led to waterlogging and a rise in the ground-water table in irrigated lands. Similarly, the traditional practices of irrigation reduce the efficiency of the system and raise unnecessary wastage of water. Besides, soil erosion was another issue occurred due to improper management of irrigation water, which ultimately impact the environmental integrity.

4.3 ASSESSMENT OF ISSUES

Identification of issues provides a clear idea of the barriers that prevent managing water resources in irrigation. Assessment of issues in terms of causes for issues and their implications provide the range of their impacts and a statement of effects associated with identified issues. In addition, it demonstrates that those issues are constraints in achieving the SWM of irrigation. Table 2 signifies the assessment of identified issues with their causes and implications.

Table 2: Assessment of issues

Category	Identification of Issues	Causes for Issues	Implications of Issues
Inefficiency of water retaining structures	Silting	Earth collapsing in the catchment area	Reduces the water holding capacity of the structures
	Evaporation	Exalted global warming	Reduction of water level
	Sedimentation		Diminution of water flow
			Decrease the potential water storing capacity of the structures
	Cavities in reservoir bed	Structural failures	Water leakages

Category	Identification of Issues	Causes for Issues	Implications of Issues
Inefficiency of water conveyance channels	Silting	Earth collapsing in the catchment area	Reduces the speed of water flow
	Vegetation	Poor maintenance	Reduces the speed of water flow
			Changes in canal slope
	Earth collapsing	Animal crossing	Changes in canal slope
	Water losses in outdated canals	Single bank canals	Water losses
Inefficiency of water distribution channels	Seepage in open channels	Improper drainage lines	Water losses
	Silting	Drainage Corrosion of the canal bed	Canals may not be able to carry water for the fields in an efficient manner
Inefficiency of field water application	Low efficient methods of water application e.g. Flood irrigation	Unawareness of users Reluctant to adapt new methods	Wastage of water than the direct application of water
	Not following irrigation schedules	Unawareness	Wastage of water due to overuse
	Water run-off rapidly through the fields	Improper leveling and not following the precise contour patterns	Huge water losses
	Deep percolation of water into the ground	Low water holding capacity of the soil	Waterlogging
Inequity of water distribution	Deteriorated canals	Poor maintenance	Water losses
	Geo-political issues regarding water scarcity	Tail end water shortage	Conflicts among water users Political risk for country
	Influences coming from various authorities	Political issues	Troubles the integration of different sub-components in the system
Impact to environmental integrity	Devastate the natural equilibrium of biodiversity	Inundation of large area with a significant hydraulic pressure	Destructions to the natural eco-system
	Water pollution	Diversion of drainage into rivers and other streams	Quality of irrigated lands and subsequently for the crops in the fields

Category	Identification of Issues	Causes for Issues	Implications of Issues
	Waterlogging	Water losses	Deep percolation of water into the ground
	Poor irrigation practices	Unawareness	changing the quality of water and the soil
	Overuse of water	Rise in ground-water table in irrigated lands	Waterlogging
	Soil erosion	Improper management of irrigation water	

5. CONCLUSIONS

This paper presented the findings on the identification and assessment of issues towards SWM of irrigation systems in Sri Lanka. A literature review was carried out to identify the need for SWM of irrigation systems in the global context. According to the previous studies, the issues in IWM were categorised into three main components namely, efficiency, equity and environmental integrity. The issues towards the efficiency were further categorised into another three sub-components namely, the efficiency of water retaining structures, water conveyance channels, water distribution channels, and field applications.

The performance of irrigation systems is measured by its efficiency. Further, it can be applied to each subsystem of irrigation infrastructures such as water retaining structures, water conveyance channels, water distribution channels, and field applications. As a whole, the expert review revealed that the water losses in canal conveyance and field application as major issues, which reduce the efficiency of irrigation systems. The improper maintenance of structures and associated catchment area was the reason for water losses in channels. Further, inefficient water application methods in fields worsen the problem of water loss.

The water shall be delivered in sufficient quantity and quality at the right time to meet the needs of the users. Nevertheless, the inequity of water allocation affected the water sharing rights of the users. Conflicts among water users, especially the people down-stream, aggravate the problem of water sharing rights. Moreover, the establishment of irrigation infrastructures destructs the natural eco-system of irrigated areas. In addition, depletion of groundwater and waterlogging were recognised as major issues towards environmental integrity due to poor practices of IWM.

The identified issues were assessed to give an idea of their impact on the achievement of SWM in irrigation. The findings can be helpful for the decision-makers to identify the drawbacks of their system management. Therefore, it can be recommended that to investigate more on them to identify the burning issues, which need urgent solutions to mitigate their influence on the management of irrigation water. Further, the issues can be prioritised by comparing the information collected based on their extent of the impact on system management. Then the industry practitioners can implement strategies to overcome the issues based on their relative importance in achieving the ultimate goal of SWM in irrigation.

6. REFERENCES

Ahmad, S., 1999. Achievements and issues of irrigation in the 20th century. In: *National Workshop on" Water Resources Achievements and Issues in the 20th Century and Challenge of the Next Millennium",* pp.28-30.

Buyukcangaz, H. and Korukcu, A., 2007. Integrated approach for water resources and irrigation management in Turkey. *Water International*, 32, pp.710-719.

Cai, X., McKinney, D. C. and Rosegrant, M. W., 2003. Sustainability analysis for irrigation water management in the Aral Sea region. *Agricultural Systems*, 76(3), pp.1043-1066.

Calzadilla, A., Rehdanz, K. and Tol, R. S. J., 2010. The economic impact of more sustainable water use in agriculture: A computable general equillibrium analysis. *Journal of Hydrology,* 384(3), pp.292-305.

Donaldson, M., 2013. Rehabilitation and modernisation of irrigation schemes. *Proceedings of the Institution of Civil Engineers - Water Management*, 166(5), pp.242-253.

Greenland, S. J., Dalrymple, J., Levin, E. and O'Mahony, B., 2017. Improving agricultural water sustainability: Strategies for effective farm water management and encouraging the uptake of drip irrigation. *The Goals of Sustainable Development*, pp.111-123.

Howell, T., 2006. Challenges in increasing water use efficiency in irrigated agriculture. Available from: https://www.researchgate.net/publication/228360952_Challenges_in_increasing_water_use_efficiency_in_irrigated_agriculture [Accessed 15 February 2018]

Hussain, I. and Bhattarai, M., 2005. Comprehensive assessment of socio-economic impacts of agricultural water uses: Concepts, approaches and analytical tools [online]. Available from: https://core.ac.uk/download/pdf/6405101.pdf [Accessed 21 March 2018]

Lam, W. F., 2006. Designing institutions for irrigation management: Comparing irrigation agencies in Nepal and Taiwan. *Property Management*, 24(2), pp.162-178.

Phadnis, S. S. and Kulshrestha, M., 2012. Evaluation of irrigation efficiencies for water users' associations in a major irrigation project in India by DEA. Benchmarking: *An International Journal*, 19(2), pp.193-218.

Poddar, R., Qureshi, M. E. and Shi, T., 2014. A comparison of water policies for sustainable irrigation management: The case of India and Australia. *Water Resources Management*, 28(4), pp.1079-1094.

Ritchie, J., Lewis, J., Nicholls, C. M., and Ormston, R. (Eds.). (2013). *Qualitative research practice: A guide for social science students and researchers*. London: Sage.

Shand, R., 2002. Irrigation and Agriculture in Sri Lanka [Online]. Available from: http://www.ips.lk/irrigation-and-agriculture-in-sri-lanka/ [Accessed 02 July 2018]

Shantha, A. A. and Ali, B. G. H. A., 2014. Economic value of irrigation water: A case of major irrigation scheme in Sri Lanka. *The Journal of Agricultural Sciences*, 9(1), pp.44-57.

Singh, A., 2016. Hydrological problems of water resources in irrigated agriculture: A management perspective. *Journal of Hydrology*, 541, pp.1430-1440.

Sivayoganathan, C. and Mowjood, M. I. M., 2003. Role of extension in irrigation water management in Sri Lanka. *Tropical Agricultural Research and Extension*, 6, pp.49-55.

Sun, S., Wang, Y., Liu, J., Cai, H., Wu, P., Geng, Q. and Xu, L., 2016. Sustainability assessment of regional water sources under the DPSIR framework. *Journal of Hydrology,* 532, pp.140-148.

Tsirogiannis, I. L., Orsini, F. and Luz, P., 2017. Water management and irrigation systems. In F. Orsini, M. Dubbeling, H. Zeeuw and G. Gianquinto (Eds.), *Rooftop Urban Agriculture* (pp. 129-146). Retrieved from https://doi.org/10.1007/978-3-319-57720-3_9 [Accessed 10 January 2018]

Ugwu, O. O., Kumaraswamy, M. M., Wong, A. and Ng, S. T., 2006. Sustainability appraisal in infrastructure projects (SUSAIP): Part 1. Development of indicators and computational methods. *Automation in Construction*, 15(2), pp.239-251.

Zaman, A., Zaman, P. and Maitra, S., 2017. Water resource development and management for agricultural sustainability. *Journal of Applied and Advanced Research*, 2(2), p.73.

Zhen, L., Routray, J.K., Zoebisch, M.A., Chen, G., Xie, G. and Cheng, S., 2005. Three dimensions of sustainability of farming practices in the North China Plain: a case study from Ningjin County of Shandong Province, PR China. *Agriculture, Ecosystems & Environment*, *105*(3), pp.507-522.

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LEAN ENABLING HUMAN CAPACITY BUILDING OF SMALL AND MEDIUM CONTRACTORS IN SRI LANKA

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ABSTRACT

Lean construction is still at the premature stage of the small and medium contractors (SMCs) in Sri Lanka. Lack of focus on human capacities required to implement lean has hindered its implementation. Thus, human capacity building is a paramount factor for successful lean implementation of SMCs in Sri Lanka. However, there is a lack of empirical investigation on human capacities and strategies to build human capacities for lean implementation in Sri Lankan SMCs. This paper investigates the lean enabling human capacities and strategies, and hence develops a framework to build those human capacities for successful lean implementation in Sri Lankan SMCs. The research adopts interpretivism stance and uses the qualitative survey strategy. The empirical data collection technique adopted is semi-structured interviews with 24 experts who are having experiences both in SMCs and lean implemented projects. The code based content analysis was used as the data collection technique, which was supported by NVivo10 and interactive data visualisation tool, Power Bi was used to present the analysed data. The research identified team working skills, critical thinking, leadership, communication skills, work ethics, knowledge and positive attitudes as lean enabling human capacities in SMCs. Training, learning and using existing capacities were identified as the most significant individual level strategies, where education and training, and financial support for SMCs were recognised as strategies that can be used by external environment entities to build the above capacities. The developed framework further highlighted that use of existing capacities, proper recruitment, proper investments, networking, maintain a lean culture and learning by doing as organisational strategies to build the lean enabling capacities. Industry practitioners can use this framework to develop lean enabling human capacities in order to accelerate the lean implementation in Sri Lankan SMCs.

Keywords: *Human Capacity Building; Lean Construction; Small and Medium Contractors; Sri Lanka.*

1. INTRODUCTION

Small and medium contractors (SMCs) are well-known for the increase of non-value adding activities (NVAA) in construction industry (Tazel *et al*., 2017; Ranadewa *et al*., 2018). This has highlighted the importance of SMCs to implement lean and reduce the NVAA among their projects. Yet, implementation of lean among SMCs is not free from

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barriers (Ankomah *et al*., 2017; Rymaszewska, 2014) and thus, the researchers highlighted the need of enhancing human capacities for successful lean implementation. Although, Ranadewa *et al*., (2017) highlighted that human capacity building as a key to success in lean implementation among SMCs in Sri Lanka, there is a lack of research with this regard. Thus, the aim of this study is to develop a framework to build lean enabling human capacities in Sri Lankan SMCs. The objective of the research is to investigate lean enabling human capacities and identify the strategies to build them by the SMCs. This paper begins with a literature review on why lean implementation fails in and the need of building lean enabling human capacities. The next section discusses the methodology used in this study. The findings of the research are presented under lean enabling human capacities and strategies for building those human capacities. Finally, a framework for lean enabling human capacities is developed for SMCs in Sri Lanka.

2. LITERATURE REVIEW

2.1 WHY LEAN IMPLEMENTATION FAIL?

Applying lean concept by construction organisations and construction projects during both design and construction phases is becoming an important trend. Prior studies reveal that SMCs do not have the capacity to implement lean concept (Chiarini, 2012; Ankomah *et al*., 2017). SMCs and the industry as a whole, have been criticised by many researchers for limited collaborative working philosophies, slow uptake of new technologies and processes and issues with organisational management (Miller *et al*., 2002). Considering the investment levels of the construction industry and the development needs of most developing countries, attention to these matters is long overdue. SMCs constitute the largest group in the construction industry and their performance impacts greatly on the performance of the industry. Nevertheless, there is a significantly lower rate of adoption of lean principles by SMCs than by large contractors (Rymaszewska, 2014). Moreover, most of the SMCs are still unfamiliar with lean concept (Ankomah *et al.*, 2017; Rymaszewska, 2014).

According to lean construction deployments of SMCs, unlike the manufacturing industry, the researches that investigate lean in SMCs has remained scarce (Zhou, 2016; Antosz and Stadnicka, 2017). Although Rymaszewska (2014) and Chiarini (2012) highlighted the importance of implementing lean in SMCs, it is still at its infancy. Tasel *et al*. (2017) differentiated the current status and future direction of lean construction in SMCs and stated that unavailability of implementable framework focusing on individuals of the SMCs have hinder the lean implementation. Although the challenges of lean implementation in construction and solutions to overcome them have been previously explored (Shang and Pheng, 2014; Aziz and Hafez, 2013) even in Sri Lanka (Senaratne and Wijesiri, 2008; Senaratne *et al*., 2010), there is a dearth of research on lean implementation and how to overcome the barriers of lean implementation in Sri Lanka through proper management of individuals in SMCs in Sri Lanka.

According to Koskela *et al*. (2014), lean construction requires changes in individual behaviour. Thus, building individual capacities will accelerate the lean implementation. Simultaneously, building capacities for successful lean implementation will add a value for SMCs to better perform in the industry. Hence, SMCs must identify necessary capacities to obtain the full benefit of lean implementation. However, lean is not just a set of tools and techniques, but its heart is the people (Bhasin, 2012). It is the people, whose knowledge, intelligence and desire to improve that steers organisations to new levels of continuous improvement (Bhasin, 2012). Therefore, lean relies heavily on the knowledge and skills of the people and how they respond to changes (Sawhney and Chason, 2005). Hence, the transformation towards lean construction will lead to changes in the culture and in its people (Green *et al.*, 2008) and thus require a considerable reflection on human capacity building for successful lean implementation.

2.2 LEAN ENABLING HUMAN CAPACITIES

Human capacity refers to the will and ability of an individual to set objectives and to achieve them using one's own knowledge and skills (Matachi, 2006). However, Kululanga (2012) specified that contributions at this level in capacity building for construction industry refer to how individuals in the industry are equipped with relevant education, training and continual professional development. Nevertheless, OECD (2012) defined individual capacity as knowledge and skills to set and achieve objectives. These capacities explicitly focus on skill development, building stronger relationships, knowing how, knowing what and co-creation of meaning and understanding (Preskill and Boyle, 2008). Similarly, Enemark and Ahene (2002) identified human resources in terms of knowledge, skills, personal and group attitudes for developing and managing certain areas, which ensure long-term sustainability.

Although many researchers have discussed about human capacities in the construction industry, there is a lack of studies focusing on human capacities required for successful lean implementation. Table 1 presents the capacities highlighted by the researchers as required for successful lean implementation.

Table 1: Human capacities required for successful lean implementation

Human Capacities Necessary for Lean Implementation	**References**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Knowledge	x	x	x	x	x		x	x		x	x	x
Relevant education	x	x	x	x	x		x	x	x	x		
Technical skills		x			x						x	x
Managerial skills	x	x			x		x	x	x	x		
Values and attitudes	x	x		x						x		x
Willingness to set and achieve objectives		x				x						
Capacity to build relationships	x		x		x		x					
Trust and legitimacy		x										
Experience	x	x		x		x		x				x
Sufficient training	x	x	x	x	x	x	x	x	x	x		x
Continual professional development	x					x					x	

Sources: (1) Achanga *et al.*, 2006; (2) Alves *et al*, 2016; (3) Ankomah *et al.*, 2017; (4) Antosz and Stadnicka 2017; (5) Tazel *et al.*, 2017; (6) Basil, 2007; (7) Chiarini, 2012; (8) Ranadewa *et al.*, 2017; (9) Dora and Gellynck, 2015; (10) Jin and Ling, 2005; (11) Kululanga, 2012; (12) Rymaszewska, 2014

Accordingly, many researchers agreed that sufficient knowledge and relevant education are paramount for individuals in SMCs. Similarly, they required to improve the managerial and technical skills through a proper training to accelerate lean implementation. One of the lean implementation barriers identified by several researchers (Tazel *et al*., 2014; Shang and Pheng, 2014), is the resistance to change by SMCs. Thus, proper values and attitudes are required among the individuals of the organisation. They further specified that access to resources and experiences that can develop individual capacity are largely shaped by the organisational and environmental factors, which in turn are influenced by the degree of capacity development in each individual. Kululanga (2012) and Lopes and Theisohn (2003) focused on human capacity building for successful lean implementation. They identified training individuals as a strategy to improve the required lean capacities. Kululanga (2012) and Karunasena and Amaratunga (2016) further included specific trainings such as training aligned to construction industry needs, life-long learning driven by an individual employee within a firm, training for individual employees supported by a construction firm or the industry for construction workforce as some of other strategies for building lean human capacities. Similarly, construction organisation as well as the external environment needs to support in building lean enabling human capacities.

3. METHODOLOGY

This research aimed to develop a framework to build lean enabling human capacities in SMCs in Sri Lanka. A literature review was carried out to explore the theoretical identification. There is a need to ascertain different views of the experts with regards to SMCs on lean enabling human capacities and human capacity building strategies in Sri Lankan context. Therefore, the study valued and encouraged the free flow of ideas, opinions, perceptions and experience of people within the research environment thus, considers the human interaction as the main driver of the study. Hence, the study skewed the ontological assumption of 'reality is not pre-determined, but socially constructed' and the epistemological assumption of 'the knowledge is gathered by examining the views of the people' as per Saunders *et al*. (2009). Similarly, in terms of the axiology, the study takes the value laden stance as it is believed that the researcher would add value to the study. Thus, the research is in line with the interpretivism stance.

The research strategy followed by the study is 'qualitative survey strategy'. The empirical data collection technique adopted is semi-structured interviews with experts in Sri Lanka selected through purposive sampling. Employing semi-structured interview method is preferred in qualitative approach since the respondents have a structured flow to ask questions from interviewees. 24 experts, who are having experiences both in SMCs and lean implemented projects in Sri Lanka were interviewed as per Mason (2010)'s suggestion on the sample sizes. Interviewees included Managing Directors and a Chairmen of SMCs, lean consultants, Senior Project Managers and Senior Quantity Surveyors, who have more than 20 years' experience in the construction industry.

The code based content analysis was used to produce a uniform schema of categories, which facilitated the comparison (Flick, 2009) and NVivo10 was used to analyse the data, which can help to organise, explore and speed up the time taken for doing the data analysing of unstructured data. Further, interactive data visualisation tool, Power Bi was used to present the analysed data through the final framework of the research.

4. RESEARCH FINDINGS

This study investigated the human capacities necessary for enabling lean and strategies to build lean enabling human capacities in SMCs. Following sub-sections elaborate findings of this research study.

4.1 LEAN ENABLING HUMAN CAPACITIES IN SMCS

The human capacities that enable lean in SMCs were asked during the interviews with experts. Many of the respondents specified that proper verbal, non-verbal and visual '***communication skills***' of employees are essential for lean implementation within the SMCs. Similarly, critical analysis of a problem and deriving a solution are crucial for continuous improvement. Hence, lean experts suggested '***critical thinking***' as one of the most important capacities that need to be improved by employees. People need to be adoptable for the changing conditions. Hence, there is a requirement to think out of the box. One of the important lean capacities that individuals in SMCs should have is the '***leadership***' which has a major role to play in the individual lean capacity lexicon. The leader needs to be accountable, appreciate people, drive changes, motivate and shares the big picture with others. The respondents added proper conflict management and willingness to help as essential qualities of a leader. However, leadership is not limited to the top or middle management. Even the shop floor level workers must become self-leaders. Therefore, there is a need to change the working philosophy. It is necessary to change the way people think and the way people approach the project. This necessitate building up '***positive attitudes***' among the individuals. Many parties need to be effectively involved to be succeeded with the lean implementation. It requires different level of attentions to detail than what the rule of thumb target and hence required proper '***team working***'. Employees need to be collaborative, accept feedback and should have the capacity to handle challenging situations. Moreover, there is a need to establish interpersonal relationships and networking with the team members.

Workers need to be dedicated, highly organized, reliable, resilient and results oriented. The respondents added that workers need to be self-directed, self-monitoring, self-supervising, stay on task and trainable to achieve the objectives of the lean implementation. Otherwise, lean implementation will fail in the initiation stage. Therefore, corporate '***work ethics***' can be identified as another category of human lean capacities of SMCs. One of the major lean implementation barriers is the lack of lean awareness within the organisation. Therefore, lean consultants especially highlighted the need of lean knowledge and the technical know-how for SMCs. They need to be trained to ascertain knowledge by doing and get sufficient training. Thus, ability to learn by doing and applying what is learnt is important. Moreover, top management should not be very conservative when recruiting employees and must ensure that the selected employees are qualified not only with relevant education. Hence, '***sound knowledge***' is identified as another individual lean enabling capacity for individuals in SMCs.

Therefore, communication skills, critical thinking, leadership, positive attitudes, team working and work ethics can be identified as lean enabling human capacities in SMCs where literature incidentally agreed. Yet, most of the researchers (Tazel *et al*., 2017, Ankomah *et al*., 2017, Alves *et al*., 2016, Ranadewa *et al*., 2017) agreed that knowledge is an essential capacity that enables lean among SMCs.

4.2 STRATEGIES TO BUILD LEAN ENABLING HUMAN CAPACITIES

The following sections present the strategies that individuals, organisations and external environment parties can use to build the above identified lean enabling human capacities of SMCs in Sri Lanka as identified by the experts.

4.2.1 How can Individuals Build Lean Enabling Human Capacities?

The respondents highlighted the importance of getting proper training for employees of the organisation. As SMCs are having few numbers of employees, providing training for them is stress-free compared to large contractors. However, to build up lean capacities, SMCs should encourage their employees as well as top management to be trained in order to improve their ability to perform functions. It necessitates encouraging employees to be vigilant to identify the available programs and attend them to gather knowledge. The respondents further added that most of the government programs are conducted free of charge or at very low rates for SMCs. Therefore, they need to get the benefit of being SMCs in the construction industry. However, the respondents added the importance of attending CPDs to get lean awareness. Therefore, continuous **'*training*'** marked as an individual level strategy. One of the major characteristics of lean implemented organisations is continuous urge on **'*learning*'**. All the respondents had unanimously agreed that there are good learning opportunities available in the construction industry, which will support SMCs in building lean human capacities. Development of soft skills will improve the problem solving skills of employees. Similarly, SMCs can **'*develop soft skills*'** by attending in-house trainings on corporate etiquette. As discussed in section 2.1, the most difficult factor to change is the mind set of people. The respondents agreed the need of motivation requirement to change the attitudes of people in SMCs. Thus, there is a need to analyse the ways of motivating the workers to change their attitudes towards lean implementation. During the interviews, lean experts clearly indicated the importance of **'*start lean*'** with pilot projects. Therefore, SMCs first need to make better '***use of existing capacity***' to start lean implementation. Thus, the individuals required to develop their existing capacities in the first instance to encourage the lean implementation. Further, SMCs need to **'*monitor and report the individual progress*'** in continuous improvement. The continuous improvement of processes will demonstrate the achievability of these individual level lean capacities. Nevertheless, all the respondents undeniably stressed the importance of proper strategies for SMCs to build individual lean capacities.

4.2.2 How can Organisation Build Lean Enabling Human Capacities?

As SMCs lack human resources, there is a need to employ the best in order to get the maximum benefit to the organisation. One of the respondents from top management highlighted that there is a need to recruit qualified people who are practical in nature. Thus, top management has to play a vital role with this regard during the recruitment process. Respondents emphasised the need of having a lean expert in the organisation. This person will be the change agent for the organisation who can develop the pathway towards proper lean implementation. Therefore, to gain more benefits within the organisation, experts suggested that top management need to promote research and development in the organisation. Although, research and development marked as one of the ways to build lean capacities, single handed researches cannot be taken as the best practices within the organisation. Hence, the respondents articulated that a group of people would be ideal for researching to develop the capacities. Hence, as an initiation, they need to pursue partnerships in working with others in the organisation. Thus, there is a need to encourage networking. Correspondingly, organisations need to rethink the usage of existing capacities for building new capacities. According to the research findings, many lean experts expressed the need of proper financial allocation to build the lean enabling human capacities.

Most of the individual lean capacities can be achieved through maintaining a lean culture within the organisation thus required to maintain a culture for improvement and a no-blame culture. Similar to strategies at individual level, training, learning by doing, starting lean with pilot projects and monitor and report the progresses of SMCs will help to build lean enabling human capacities.

4.2.3 How can External Environment Entities Build Lean Enabling Human Capacities?

The respondents agreed that lean enabling human capacity building in SMCs can be driven by the construction industry, including Construction Industry Development Authority (CIDA), non-government institutes, professional institutes, large construction organisations as well as the government. Educating and training of construction workforce is one of the prominent strategies that can be accelerated to build lean enabling human capacities. Although there is a need to increase the number of training programs, one of the respondents doubted about the quality of these training programs conducted at the construction industry level. Many respondents contended the lack of continuous professional development in the construction industry. Thus, construction industry needs to take necessary actions to encourage the professional development. Moreover, human capacities can be built by encouraging inter/intra-industry research activities. The construction industry can encourage dissemination and exhibitions of research activities. The research conducted on lean construction need to be publicised to identify the new trends and solutions offered for lean constructions. This can be achieved through conducting research conferences. Respondents specified the importance of developing a code of good working practice for sites and SMCs and particularly developing a lean code of conduct for SMCs. Therefore, this code of conduct will guide SMCs in proper implementation of lean concept.

Similarly, the experts highlighted that the government must financially support the SMCs for lean implementation. The government can allocate funds for lean awareness programmes and provide loans at concessional interest rates for SMCs who try to implement lean by considering the monetary and fiscal policies of the government.

5. DISCUSSION OF FINDINGS

As the final step, this research mapped lean enabling human capacities with the strategies required for building those capacities. Figure 1 presents the summary of findings.

According to Figure 1, lean enabling human capacities such as critical thinking, positive attitudes and work ethics can be improved by attending the in-house trainings on corporate etiquette programs. Moreover, they can attend training programs available for individual employees supported by large construction firms. Moreover, non-government organisations as well as construction institutes are willing to assist SMCs with the help of large construction firms to implement lean in order to develop the industry as whole.

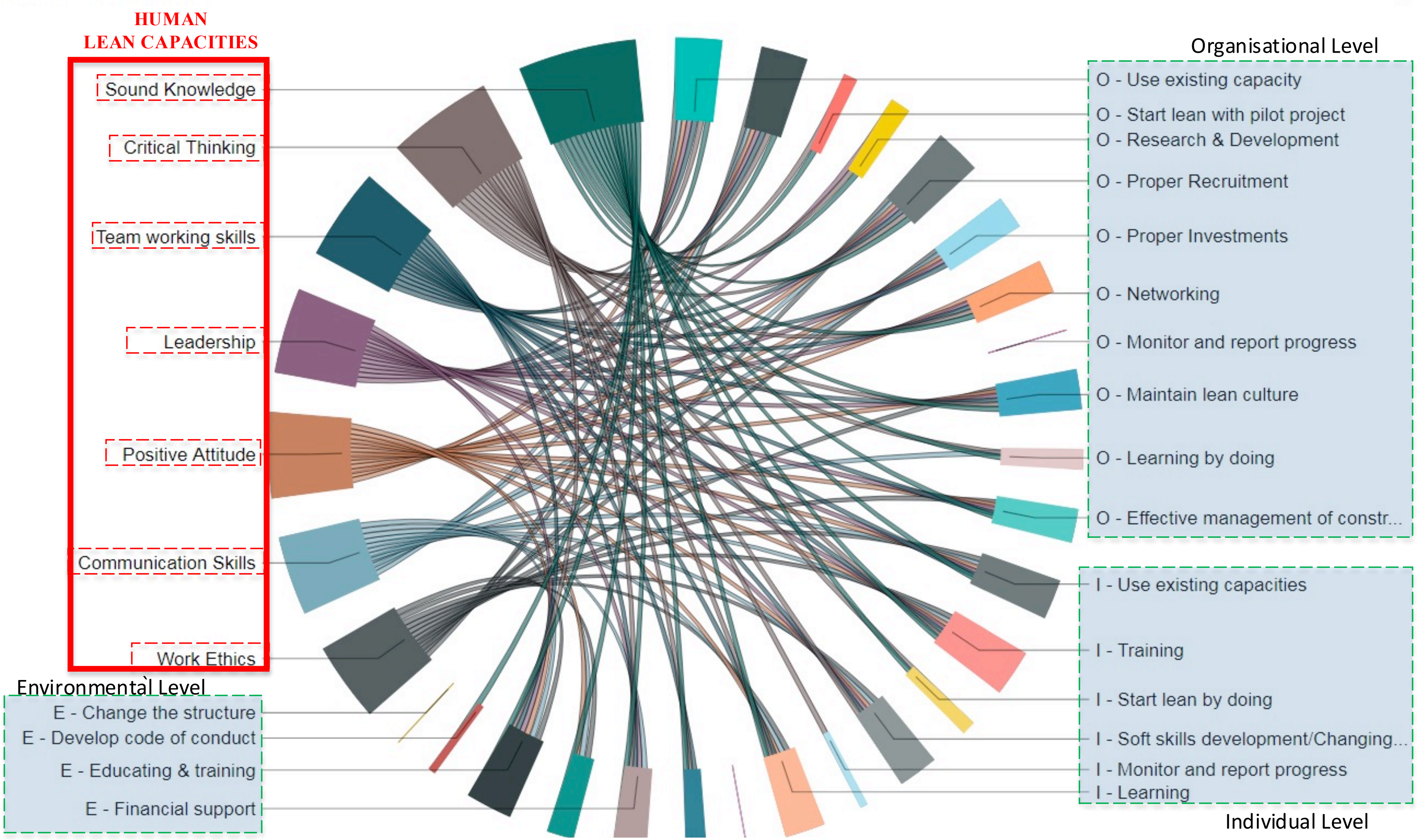

Figure 1: Framework for lean enabling human capacity building

Moreover, employees can attend training programs, which help improving their soft skills, leadership qualities, team working skills and communication skills. This was further proven by Lopes and Theisohn (2003) in literature. Moreover, training sessions are paramount to improve lean capacities such as critical thinking, positive attitudes and work ethics. Thus, training, soft skills development and start lean by doing counted as the most critical factors to be considered in building lean enabling human capacities of SMCs.

As suggested by Kululanga (2012) and Karunasena and Amaratunga (2016) the employees must get proper learning through training. Hence, voluntary learning, with genuine commitment and interest will ensure that the individuals are packed with required lean capacities. Hence, experts admired continuously maintaining the acquired skills and knowledge to build lean human capacities. Conversely, they suggested the development of new capacities among the available workers at site rather recruiting new workers for the site. Yet, there is a need of organisational and external environmental entity capacities to get the maximum use of existing individual capacities. SMCs must have good knowledge on lean capacities required for their projects. Thus, they can build or strengthen existing capacity to implement new lean tools and techniques. However, the findings highlighted that progress monitoring after attending lean awareness programs is important. Yet, it is difficult to check the progress after attending skill development program. It is time consuming and organisations need to maintain a proper mechanism to monitor and report the progress of individuals in the firm. Nevertheless, SMCs as well as the external environment entities can help to build the required lean enabling human capacities. Therefore, in order to enhance the knowledge of the individuals, most of the aforementioned strategies have to be followed up.

6. CONCLUSIONS

There has been a notable growth in lean implementation in construction industry. To implement lean in SMCs, there is a need to identify the lean enabling human capacities. This paper investigated the lean enabling human capacities for SMCs and the strategies to build the identified capacities. This study identified critical thinking, leadership, positive attitudes, team working skills, work ethics and sound knowledge as the lean enabling human capacities for SMCs in Sri Lanka. Hence, the research findings will guide SMCs to explore the required lean enabling human capacities of SMCs in Sri Lanka. However, these capacities need to be built with the help of individuals, SMCs as well as the external environment entities. Training, learning and using existing capacities were identified as the most significant individual level strategies, where education and training, and financial support for SMCs were recognised as the strategies that can be used by external environment entities to accelerate the lean implementation. The findings further highlighted that use of existing capacities, proper recruitment, proper investments, maintain lean culture, networking, and learning by doing as organisational strategies to build the identified lean enabling capacities. The framework developed in this study will guide the SMCs to understand the strategies to build lean enabling human capacities and therefore to accelerate the successful lean implementation of SMCs in Sri Lanka. Hence, the findings will pave the path to investigate the organisational and environmental lean capacities for successful lean implementation among SMCs, which will be the focus of the next phase of the research.

7. REFERENCES

Achanga, P., Shehab, E., Roy, R. and Nelder, G., 2006. Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management*, 17(4), pp.460-471.

Alves, T.C.L., Azambuja, M.M. and Arnous, B., 2016. Teaching lean construction: a survey of lean skills and qualifications expected by contractors and specialty contractors in 2016. *In: Proceedings of the 24th Annual Conference of the International Group for Lean Construction*, pp.13–22.

Ankomah, E. N., Ayarkwa, J. and Agyekum, K., 2017. A theoretical review of lean implementation within construction SMEs. In: *6th International Conference on Infrastructure Development in Africa 2017*. Africa. pp.71-83.

Antosz, K. and Stadnicka, D., 2017. Lean philosophy implementation in SMEs - study results. *Procedia Engineering*, 182, 25–32. Doi.org/10.1016/j.proeng.2017.03.107.

Aziz, R.F. and Hafez, S.M., 2013. Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal,* 52(2013), pp.679–695.

Basil, A.N.O., 2005. *Small and medium enterprises (SMES) in Nigeria: problems and prospects*. (Doctoral dissertation, St. Clements University). Available from http://stclements.edu/grad/gradonug.pdf.

Bhasin, S., 2012. An appropriate change strategy for lean success. *Management Decision*, 50(3), pp.439-458.

Chiarini, A. (2012). Lean production: mistakes and limitations of accounting systems inside the SME sector. *Journal of Manufacturing Technology Management*, 23(5), pp.681-700.

Dora, M. and Gellynck, X., 2015. House of lean for food processing SMEs, *Trends in Food Science and Technology*, (2015), pp.100-112.

Enemark, S. and Ahene, R., 2002. Capacity building in land management– implementing land policy reforms in Malawi. In *FIG XXII International Congress*, Washington, D.C. USA, April 19-26.

Flick, U., 2009. *An Introduction to Qualitative Research*. 4th ed. London: Sage publications.

Green, S.D., Harty, C., Elmualim, A.A., Larsen, G.D. and Kao, C.C., 2008. On the discourse of construction competitiveness. *Building Research and Information,* 36(5), pp.426-435.

Jin, X. and Ling, F.Y.Y., 2005. Model for fostering trust and building relationships in China's construction industry. *Journal of Construction Engineering and Management*, 131(11), pp.1224-1232.

Karunasena, G. and Amaratunga, D., 2016. Capacity building for post disaster construction and demolition waste management; A case of Sri Lanka. *Disaster Prevention and Management*, 25(2), pp.137-153.

Koskela, L.J., Howell, G.A., Ballard, G. and Tommelein, I., 2014. *The foundations of lean construction*. 211-226. Available at: http://www.researchgate.net/publication/28578914.

Kululanga, G., 2012. Capacity building of construction industries in Sub-Saharan developing countries: A case for Malawi. *Engineering, Construction and Architectural Management*. 19(1), pp.86-100.

Lopes, C. and Theisohn, T., 2003. *Ownership, leadership and transformation: can we do better for capacity development?* Earth Scan Publications. UNDP: New York.

Matachi, A., 2006. *Capacity building framework; UNESCO-IICBA*. United Nations Economic Commission for Africa: Ethiopia.

Miller, C.J., Packham, G., Pickernell, D. and Morse, L., 2002. Increasing Entrepreneurial Capacity Through E-Learning: An Opportunity for Small Construction Firms in South Wales. *WEI Working Paper Series Paper 28*, Pontyprid; Welsh Enterprise Institute.

OECD., 2012. *The challenge of capacity development: working towards good practice*. OECD Publication Service: Paris

Preskill, H. and Boyle, S., 2008. A multidisciplinary model of evaluation capacity building. *American Journal of Evaluation*, 29(4), pp.443-459.

Ranadewa, K.A.T.O., Sandanayake, Y.G. and Siriwardena, M., 2017. What does lean capacity mean? *6th World Construction Symposium 2017 (CIOB*), Colombo, Sri Lanka. pp.485-494.

Ranadewa, K.A.T.O., Sandanayake, Y.G. and Siriwardena, M., 2018. Enabling Lean among Small and Medium Enterprise (SME) Contractors in Sri Lanka, In: *Proc. 26th Annual Conference of the International. Group for Lean Construction (IGLC)*, Chennai, India, pp.392–401.

Rymaszewska, A.D., 2014. The challenges of lean manufacturing implementation in SMEs. *Benchmarking: An International Journal*, 21(6), pp.987-1002.

Saunders, M., Lewis, P., and Thornhill, A., 2009. *Research methods for business students.* 5th ed. Essex: Pearson Education Limited.

Sawhney, R. and Chason, S., 2005. Human behaviour based exploratory model for successful implementation of lean enterprise in industry. *Improvement Quarterly*, 18(2), pp.76-96.

Senaratne, S., Ekanayake, S. and Siriwardena, M., 2010. Lean prefabrication: A sustainable approach. CIB 2010 Wld Cong Proc: *Building a Better World*, (11), pp.33-44.

Senaratne, S. and Wijesiri, D., 2008. Lean construction as a strategic option: Testing its suitability and acceptability in Sri Lanka. *Lean Construction Journal*, 4(1), pp.34-48.

Shang, G. and Pheng, L.S. 2014. Barriers to lean implementation in the construction industry in China. *Journal of Technology Management in China*, 9(2), pp.155-173.

Tezel, A., Koskela, L. and Aziz, Z., 2017. Lean Construction in Small-Medium Sized Enterprises (SMEs): An Exploration of the Highways Supply Chain. In: *25th Annual Conference of the International Group for Lean Construction*, (July), pp.845-851.

Zhou, B., 2016. Lean principles, practices, and impacts: a study on small and medium-sized enterprises (SMEs). *Annals of Operations Research*, 241(1/2), pp.457-474.

Samaraweera, P.D.P., Perera, B.A.K.S. and Dewagoda, K.G., 2019. Management of payment delays in government funded construction projects in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 411-421. DOI: doi.org/10.31705/WCS.2019.41. Available at: https://2019.ciobwcs.com/papers

MANAGEMENT OF PAYMENT DELAYS IN GOVERNMENT FUNDED CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

The successful completion of a construction project will depend on the timeliness of the payments made by the employer, which benefits both the project as well as the parties involved in it. If the payments get delayed, the resulting financial burden will go down the supply chain to reach even the subcontractors and suppliers, thereby further complicating the situation. Since payment delays are common in Sri Lankan construction projects as well, especially when the projects are funded by the government, the proper management of payment delays is important. This research was, therefore, conducted to identify how the consequences of payment delays in government funded projects in Sri Lanka could be properly managed. A literature review and sixteen semi-structured expert interviews were carried out to collect the required data, which were subsequently analysed using manual content analysis. The study identified 77 causes of payment delays in government funded projects and 51 strategies that can minimise them. The study recommends the enactment of the Construction Industry Payment Act, enforcement of regulations that make it mandatory to have a sum of money deposited in an independent escrow account, getting the employers to work only within the stipulated budgets, and getting them to provide payment bonds.

Keywords: *Causes; Delayed Payments; Government Funded Projects; Strategies.*

1. INTRODUCTION

Payments are considered as the life blood of construction projects as they often involve very large capital investments (Ameer-Ali, 2006). Francis and Ramachandra (2014) have recognised issues relating to payments as one of the major causes of disputes in the construction industry. Nevertheless, the notion 'early delivery and late payment' has become habitual and routine, specifically in the construction industry (Andalib *et al*., 2018). It has been reported by Badroldin *et al*. (2016) that in Malaysia, the government has received many complaints from contractors and service providers about the delays they experience in receiving payments from government agencies. It is the view of most consultants and contractors that delays in making payments by the employers cause projects to suffer (Shaban, 2008). According to Fong (2005), fortunately there are various options available to overcome the delays in making payments in construction projects and some of the developed countries have already made use of some of these options.

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Ramachandra *et al*. (2013) have found that less developed countries require only the minimum level of construction output for their long term and sustainable growth. United Nations (2018) have also stated that in most developing countries, the capital formation in construction accounts for only 7-13% of the Gross Domestic Product (GDP), whereas in most of the industrialised countries, it accounts for as much as 10-16% of the GDP.

In Sri Lanka, construction is the fourth largest sector of the national economy and the average contribution of construction to the GDP during the last decade has been around 6.7-8.3% (Central Bank of Sri Lanka, 2010; 2016). Although according to Francis and Ramachandra (2014), the government has recently implemented a large number of infrastructure development projects in the country, according to Sirimanna (2012), the government owes the consultants and contractors of these projects billions of rupees. The delays in making the payments have even tarnished the image and standard of the construction industry of the country (Francis and Ramachandra, 2014). Francis *et al*. (2016) have stated that more than 60% of the main contractors and subcontractors involved in these projects have suffered cash flow problems and that consequently there have been delays in the completion of the projects.

When payments for work done get delayed, it will affect almost all those who have been involved in the work (Artidi and Chotibongs, 2005). Often the financial burden passes down the supply chain to reach the subcontractors and suppliers compounding the situation (El-adaway *et al*., 2017). This situation could even cause the entire project to fail by making the contractor bankrupt and insolvent (Amoako, 2011) and compelling him to abandon the contract (Nasser, 2013). The result will be simply a waste of public money. Many researchers in the past have explored the issue of delayed payments in the global context. Only a few researchers have, however, studied these issues in relation to government funded projects in Sri Lanka. Therefore, it is important to identify the factors that cause payment delays in government funded construction projects in Sri Lanka and strategies that can manage those payment delays. Accordingly, the aim of this study was to find ways of improving the management of payment delays in government funded construction projects in Sri Lanka by identifying separately the factors causing payment delays by employers, consultants, contractors and others and the strategies that can minimise those payment delays.

2. LITERATURE REVIEW

2.1 PAYMENT DELAYS

According to Ye and Rahman (2010), payment issues are endemic to construction and have to be recognised explicitly as they tend to recur. Hasmori *et al*. (2012) have found that payments have always been a major concern of the construction industry and that a majority of the contractors handling government funded projects have experienced payment delays with some experiencing them even in privately funded projects. Hasmori *et al*. (2012) have also found delayed payments to be common in government funded projects. According to Francis *et al*. (2016), delayed payments are common in the construction industry of any country, with most of the large-scale government funded projects in Sri Lanka too experiencing such delays. However, according to the National Construction Association of Sri Lanka (2009), the unsatisfactory payment issues experienced by contractors involved in construction projects in Sri Lanka are not specifically dependent on the source of funding of the projects.

Hussin and Omran (2009) have identified delays in making advance payments as a common issue and Singh (2003) has identified that issues arise when there are delays in issuing interim payment certificates. In many countries, the rapid increase in the delays experienced in closing the final accounts of contractors has adversely affected the good image of the construction industry (Zakaria *et al*., 2012). Issues related to the closing of final accounts occur during the rationalisation of rates and when the contract administration team fails to rationalise the rates on time (Sambasivan and Soon, 2007).

2.2 CAUSES OF PAYMENT DELAYS

Delayed payments will never bring justice to any party in the construction industry (Artidi and Chotibongs, 2005). Wiguna and Scott (2005) have found that delayed payments cause construction delays and cost overruns. There can be numerous factors responsible for delayed payments (Nazir, 2006). Hughes *et al*. (1998) believed that delayed payments are basically due to the 'cannot' or 'would not' pay attitude of the employers. Nasser (2013) found that a delayed payment by one party can affect the whole supply chain of payment. This cascade system of payment starts at the financial institution and goes to the main contractor and subcontractor in that order and from the subcontractor moves further down the chain (Ansah, 2011). The insolvency of one party in the payment chain can, therefore, cause severe impacts on parties down the contractual chain (Ansah, 2011).

2.3 STRATEGIES TO MANAGE PAYMENT DELAYS

Several researchers have explored ways of minimising payment issues in various countries. Ramachandra and Rotimi (2011) have identified the strategies used in New Zealand, which included "placing of charging orders and registering caveatable interest on properties, lodging bankruptcy and liquidation proceedings, holding money in trust accounts and getting the sureties to make the payments directly" (p.31). A study conducted in Malaysia has revealed that contractual provisions in the standard forms of a contract, including the right to regular periodic payments, right to a defined time frame for payments and right to a speedy dispute resolution mechanism could minimise payment issues to a certain extent (Danuri *et al*., 2012). Francis *et al*. (2016) have found that in Sri Lanka, contractors tend to use contractual provisions while subcontractors tend to adopt various other strategies. The authors further recommend obtaining a security from the employer through a bank in the form of a 'payment bond' and to use a schedule of payments as a part of the contract to ensure regular payments to contractors.

2.4 IMPORTANCE OF MANAGING PAYMENT DELAYS IN GOVERNMENT FUNDED CONSTRUCTION PROJECTS

The National Construction Association of Sri Lanka (2009) has reported that there are many foreign contractors who are keen on investing in property development projects in Sri Lanka, which could benefit the economy of the country. These foreign contractors can afford such investments as they can obtain financial support from the government through low interest loans. However, any payment delays they encounter can adversely affect their growth and development. Moreover, these contractors are obliged to take care of their employees by providing them with on the job training or in-house training, recreation facilities, welfare facilities, work safety, job security and job satisfaction to ensure the quality and speed of construction. Thus, the management of payment delays in government funded projects in Sri Lanka is critical.

3. RESEARCH METHODOLOGY

Given the benefits and flexibility of the qualitative approach, this research used the qualitative approach to evaluate the management of payment delays in government funded construction projects using expert interviews. Interviews are considered as the best option for data collection as they help to obtain the opinions of the interviewees in detail (Punch, 2014). Fellows and Liu (2015) also believed that expert interviews are best suited to collect data using the experience of the interviewees. This study used 16 semi structured face-to-face interviews. Each interview lasted for 45 to 60 minutes. The interviewees were selected using purposive sampling, based on their exposure to issues related to delayed payments in government funded building construction projects in Sri Lanka. Out of the 16 interviewees selected, 10 were from the quantity surveying field while the rest were from the civil engineering field. The sample represented client, consultant and contractor organisations. All of the interviewees had more than 15 years of experience in large scale building construction and project management in the state sector. Using the literature review findings, a list of general causes of delayed payments and the strategies that can be used to overcome them was prepared and the interview guideline was prepared based on that list to achieve the research objectives. The data collected were analysed manually using content analysis. Content analysis is a technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use (White and Marsh, 2006).

4. RESEARCH FINDINGS

4.1 CAUSES OF PAYMENT DELAYS

One of the major objectives of the study was to identify the factors that delay the payments made by parties involved in government construction projects in Sri Lanka. For this, information that was gathered from the literature was validated through the expert interviews. The interviewees had to go through the literature review findings and identify specifically the causes of delayed payments in the government funded projects in Sri Lanka. Table 1 presents the most significant causes of these delayed payments.

Table 1: Factors causing delayed payments in the construction projects in Sri Lanka

Employer	Consultant	Contractor	Others
Involvement of too many parties in payment certification	Delay in certifying the payment application	Insufficient documentation and information provided for the valuation	Instability of the financial market
Further evaluation of the payment applications made by the contractor	Slow processing of the variation orders	Poor communication among the parties	Frequent changes in the exchange rates
Poor financial and business management	Heavy workload involved in evaluating the work done	Mistakes found in the claims	Political/Policy changes
Delays in payment certification	Frequent design changes	Cost overruns and contract failures	Local payment culture/attitude
Failure to agree on the valuation of work	Disputes over the quality of the work	Delay in submitting claims	Political involvements

Employer	Consultant	Contractor	Others
Government bureaucracy	Not having meetings frequently to address work problems	Failure to agree on the valuation of work	Highly competitive market conditions
Withholding of the payments	Internal conflicts/disputes	Low labour productivity	Legislative procedures (Construction Contracts Act)
Lengthy procedures that delay the granting of approvals by the internal departments	Misinterpretation of the employer's requirement for variation orders	Improper supervision and financial control	Delay in obtaining approvals from external authorities
Budgetary allocations made by the treasury	Disputes over payment claims and responses	Failure to follow contractual procedures	Lack of resources like labour, materials etc.
Underpayment or non-payment of certified payments	Underpaid claims	Main contractor's failure to pay subcontractors	
Contract is too complicated to be understood by the two parties	Standard of the quantity surveyor management system	Improper payment applications	
Assumption that the contractor would finance the project in advance in the event of delayed payments	Poor technical and managerial skills of the staff	Capital lock up/ Cash flow difficulties due to lack of initial capital	
Long internal auditing procedures	Inaccurate bills of quantities	Poor quality of the work	
Contract being not sufficiently comprehensive with regard to payments	Inaccurate preliminary/ engineer's estimate	Delaying of the payments to the subcontractors until the receipt of the interim payment certificate	
Liquidated damages claimed by the employer	Lack of a proper quantity surveying management system	Invalid claims	
Procurement system	Poor coordination between the engineer and employer	Lack of knowledge and experience in the field	
Hidden agenda that facilitates malpractices	Malpractices of the engineer	Acceptance of generous payment terms offered by the employer to win the tender	
Delay in issuing the taking over certificate	Certification of the % payment being not proportionate to the actual work done	Nomination of subcontractors without considering the quality of their work / past experience	

Employer	Consultant	Contractor	Others
Dragging the payment even after its certification	Disregard of the Liability Act	Failure to understand the contract agreement	
Misleading payment procedure due to privity of contract	Inaccurate/erroneous tender document	Lack of qualified staff at the site	
Employer 's representatives disregarding the Liability Act		Delay in submitting interim payment applications	
Failure to return the retention		Misinterpretation of the employer's requirement for variation orders	
Lack of decision making capabilities			
Payments for variations and extra works made only with the final payment			

Introduced at the Expert Interviews

The highlighted factors were identified by the expert interviewees as being of particular relevance to Sri Lanka. Among the factors caused by the employer, budgetary provisions made by the treasury was recognised as a critical factor. In this regard, Francis and Ramachandra (2014) have disclosed that the government does not have adequate funds in the treasury to make the payments and that an extensive procedure has to be followed when making payments. According to the literature and the majority of the interviewees, the most critical factor that causes payment delays is the delay on the part of the consultant in certifying the payment applications. Ramachandra and Rotimi (2015) have highlighted that consultants often make discretionary deductions from the payments due to contractors, withhold their payments unreasonably or delay the issuance of their payment certificates. On the other hand, the two most common causes of payment delays for which the contractors are responsible are the insufficient documentation and information provided for valuation and the submission of erroneous claims. Although most of the past studies have attributed payment delays to the local payment culture/attitude, only nine of the interviewees were in agreement with it. Pettigrew (2005) highlighted that the industry has a 'work first, and get paid later' attitude, which worsens the situation. Furthermore, some of the factors causing payment delays, such as the delaying of the payment certification; failure to agree to the valuation of work; poor coordination among parties; failure to follow contractual procedures related to payments; and lack of an efficient quantity surveying management system were factors common to all the parties involved with all of them having a significant influence on the payment delays.

4.2 Strategies that can be Adopted to Manage Payment Delays

In order to identify the strategies that can be adopted by employers, consultants and contractors to minimise payment delays in government funded construction projects, the strategies adopted in other countries were identified from the literature and the expert interviews were used to ascertain their relevance to government funded projects in Sri Lanka. Table 2 below presents these strategies.

Table 2: Strategies suitable for managing delayed payments

Employer	Consultant	Contractor	Others
Working within the stipulated budget	Setting a defined time frame for payments	Submitting timely and accurate invoices complete with all required documentation	Action taken by professional bodies and government agencies
Understanding and studying the payment requirements of the project	Initiating a speedy dispute resolution mechanism	Negotiating payment terms with the consultant to ensure a healthy cash flow	Introducing payment-related legislation
Negotiating payment terms with the contractor to ensure a healthy cash flow	Removing the "Pay when Paid" Clause in the contract	Using an on account payment	Giving publicity to the poor payment practices of the employers
Using an on account payment	Getting periodic budgetary allocations from the employer	Obtaining a right to slow down work until the payment is received	Introducing standard bidding documents for the main contractors and subcontractors
Taking appropriate security measures in the form of a payment bond	Sticking to the Conditions of Contract and issuing drawings, approvals, instructions, etc., on time	Creating a mandatory trust account or keeping retention money	Amending the possible disputes related to Methods of Measurements
Requiring the owner to provide a payment guarantee or bond	Being punctual and impartial to the employer	Setting a defined time frame for payments	
Eliminating bureaucracy	Allowing flexibility for the minimum payment when payments get delayed	Requesting a right to suspend the work until the payment is received	
Having an appropriate budgetary allocation updated with variations	Defining the level of work done	Charging interest on the delayed payments	
Getting the internal audit unit to have a better understanding of the payment terms	Allowing flexibility for recovering the advance payment when payments get delayed	Applying for a term loan from a bank to cover the consequences of late payments	
Having an advisory team for major contracts	Getting an overdraft facility	Removing the "Pay when Paid" Clause from the contract	
Getting the approvals of the relevant authorities at the		Sending a letter of notice through the lawyer	

Employer	Consultant	Contractor	Others
initial stage of the project itself (e.g.: EIA, TIA etc.)			
Trying to keep the work unchanged or minimizing variations		Chasing the payment relentlessly	
Requesting a credit facility from the contractor in the name of the contract		Transferring funds from other projects	
Using stage payments to simplify payment procedures		Opening an escrow account for the project, particularly for transactions between the employer and the contractor	
Releasing a part payment for the interim payment application when the payment is delayed		Releasing pending payments by getting a bond from the contractor	
Granting an additional advance payment when needed		Including a provision in the contract to refer to the financial status of the employer	
Minimizing the amount of provisional sum stated in the contract		Increasing the interest rate for late payments	
		Monitoring the cash flow of the subcontractors	
		Giving timely notification to the engineer about the additional works required and the lack of details of same	

Introduced at the Expert Interviews

The strategies that are highlighted were proposed by the expert interviewees and the others were those identified from the literature and accepted by the interviewees. The interviewees emphasised the need to provide a payment guarantee or bond similar to what was proposed by Fong (2005), to ensure payments even when there is a default by a paying party. This payment guarantee can be even in the form of a promissory note which is a promise a client makes to the relevant party to pay a specific amount of money upon request or at a specified future date. Several strategies, such as "negotiating payment terms to ensure a healthy cash flow"; "use of an on account payment" and "defining a time frame for payment" were found to be common to all the parties. Amoako (2011) proposed the setting up of a defined time frame for payment as a strategy that can eliminate payment delays. The time frame can be defined under certain conditions based on previous experience. According to Ameer-Ali (2006), many sub-contracts or sub-sub contracts contain "pay when paid" or "pay if paid" clauses. However, according to most of the interviewees, "pay when paid" or "back to back" payment clauses are not contractual and are unofficially used by main contractors and sub-contractors to withhold payments. The interviewees suggested to remove this "pay when paid" clause from the contract being the third most important strategy that will help a client to manage payment delays. They were also of the view that the strategies "right to slow down the work until payment is received", "right to suspend the work until payment is received" and "charging interest on late payments" mentioned in the literature are general contract provisions which have to be followed by parties involved in any government project. However, they were of the view that the rate of finance charges stated in ICTAD/SBD/02 has to be increased as then the employer will not be hesitant to release the payments without delay to avoid the payment of high finance charges to the contractor. Construction Industry Payment and Adjudication Act, which is expected to be enacted shortly, would help in reducing payment-defaults and increasing dispute resolution (Ameer-Ali, 2006) and the interviewees also highlighted the need to enact this legislation.

5. CONCLUSIONS AND RECOMMENDATIONS

When payments get delayed in a project, disputes can arise among the parties involved in the project. Therefore, the factors that can cause delayed payments by the different parties involved within and outside a contract were identified. These factors can cause a significant ripple effect on the parties, particularly when the projects are in developing countries like Sri Lanka. As the work progresses, the timeliness of payments has to be ensured through a regular flow of cash to ensure that all involved parties are financially stable. Thus, it is important to enhance the management of payment delays in government funded construction projects in Sri Lanka. Based on the research findings, the following recommendations can be made to assist the decision makers in the construction sector to prevent delayed payments in government funded construction projects in Sri Lanka:

1. Speedy formulation and enactment of "Construction Industry Security of Payment Act" to safeguard the construction industry and ensure its advancement.
2. Introduction of a payment bond/promissory note, which basically requires a third party, such as a bank or an insurance company, to guarantee the payment in the event of default by the paying party.
3. Establishment of an overall quality assurance system to be used as a check list to prevent the employer from issuing flawed or poorly prepared tender documents.
4. Introduction of milestones or stage payments whereby a pre-agreed sum is paid when the work has reached a certain milestone.
5. Making it a mandatory requirement to set aside a sum of money in an independent escrow account.
6. Making it a right of the contractor to refer to employer's financial status during the bidding stage and to be aware of the actual funding provided the project.

6. REFERENCES

Ameer-Ali, N. A. N., 2006. A construction industry payment and adjudication act: Reducing payment-default and increasing dispute resolution efficiency in construction. *Master Builders*, 3, pp.4-14.

Amoako, K.B., 2011. *The effect of delayed payment on cash flow forecasting of Ghanaian road contractors*, (Unpublished thesis). Kwame Nkrumah University of Science and Technology.

Ansah, S.K., 2011. Causes and effects of delayed payments by clients on construction projects in Ghana. *Journal of Construction Project Management and Innovation*, 1(1), pp.27-45.

Andalib, R., Hoseini, A. and Gatmiri, B., 2018. A stochastic model of cash flow forecasting considering delays in owners' payments. *Construction Management and Economics,* 36(10), pp.1-20.

Artidi, D. and Chotibongs, R., 2005. Issues in Subcontracting Practice; the Placing and Management of Contracts for Building and Civil Engineering Work. *Journal of Construction Engineering and Management,* 8, pp.866-876.

Badroldin, M.K.A., Hamid, S.A.R., Zakaria, R. and Mohandes, S.R., 2016. Late payment practices in the Malaysian construction industry. *Malaysian Journal of Civil Engineering,* 28(3), pp.149-162.

Central Bank of Sri Lanka, 2010 – 2016. *Central Bank Annual Report*, Colombo, Central Bank of Sri Lanka

Danuri, M.S.M., Ishan, Z.M., Mustaffa, N.E., and Jaafar, M.S., 2012. A revisit on the current practice of dispute resolution and ADR in the Malaysian construction industry. *Journal of Design and Built Environment*, 10(1).

El-adaway, I., Fawzy, S., Burrell, H. and Akroush, N., 2017. Studying payment provisions under national and international standard forms of contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction,* 9(2), pp.1-10.

Fellows, R., and Liu, A., 2015. *Research Methods for Construction*. 4th ed. Sussex: John Wiley and Sons.

Fong, L.C., 2005. Malaysian construction industry - The present dilemmas of the unpaid contractors. *Masters Builders,* 4, pp.80-82.

Francis, M. and Ramachandra, T., 2014. A Study of payment issues to constructors in the Sri Lankan construction industry. *7th FARU International Research Symposium*.

Francis, M., Rotimi, J.O.B. and Ramachandra, T., 2016. Strategies to minimize the effect of delayed payments. *Proceedings of the Institution of Civil Engineers*.

Francis, M., Ramachandra, T. and Rotimi, J.O.B., 2016. Strategies to minimize the effect of delayed payments. *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law,* 169(5), pp.199-207.

Hasmori, Muhammad F., Ismail I. and Ilias S., 2012. Issues of late and non-payment among contractors in Malaysia. In*: 3rd International Conference on Business and Economic Research (ICBER 2012)*, 12-13 March 2012, Bandung, Indonesia.

Hughes, W.P, Hillebrandt, P. and Murdoch, J R., 1998. *Financial protection in the UK building industry*. London: E & FN Spon.

Hussin, A. A. and Omran, A., 2009. *Advance payment: To what extend it "save" the construction works?*. Romania, Faculty of Administration and Business, University of Bucharest, Romania.

Zakaria, Z., Ismail, S. and Yusof, A.M., 2012. Cause and impact of dispute and delay the closing of final account in Malaysia construction industry. *Journal of Southeast Asian Research*, *2012*, p.1.

Nasser H., 2013. *The Effect of Payment Delay on Construction Projects in Gaza Strip*. The Islamic University – Gaza Deanery of Higher Education Engineering Projects Management.

National Construction Association of Sri Lanka, 2009. *Report on Payment Delays in Sri Lankan Construction Industry*. National Construction Association of Sri Lanka, Battaramulla, Sri Lanka.

Nazir, N.Z., 2006. *Late payment problems among contractors in Malaysia*. A Masters Dissertation (Construction Management) submitted to the Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Malaysia.

Pettigrew, R., 2005. *The legal and contractual background*. In: Payment under construction contracts legislation. Heron Quay: Thomas Telford.

Punch, K., 2014. *Introduction to social research: Quantitative and qualitative approaches*. 3rd ed. CA: Sage: Thousand Oaks.

Ramachandra, T. and Rotimi, J. O., 2011. The nature of payment problems in the New Zealand construction industry. *Australasian Journal of Construction Economics and Building*, 11(2), pp.22-33.

Ramachandra, T. and Rotimi, J.O.B., 2015. Causes of Payment Problems in the New Zealand Construction Industry. *Construction Economics and Building*, 15(1), pp.43-55.

Ramachandra, T., Rotimi, J. O. and Rameezdeen, R., 2013. Direction of the causal relationship between construction and the national economy of Sri Lanka. *Journal of Construction in Developing Countries*, 18(2), pp.49–63.

Sambasivan, M., and Soon, Y. W., 2007. Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25(5), pp.517–526.

Singh K.S., 2003. *Engineering and Construction Contracts Management – Post Commencement Practice*. Singapore: Lexis Nexis Business Solutions.

Sirimanna, B., 2012. *Construction industry plagued by delayed payments* [online]. Sunday Time, Available from: http://www.sundaytimes.lk/120318/BusinessTimes/bt02.html [Accessed 10 September 2018].

Shaban, S.S.A., 2008. *Factors affecting the performance of construction projects in the Gaza Strip*, Gaza Strip: Islamic University of Gaza.

United Nations Report, 2018. *Developing Countries 2018*. United Nation.

White, M. D., and Marsh, E.E., 2006. Content Analysis: A Flexible Methodology. *Library Trends*, 55(1), pp.22-45.

Wiguna, I. P. A. and Scott, S., 2005. Nature of the critical risk factors affecting project performance in Indonesian building contracts. *21st Annual ARCOM Conference*, 7-9 September 2005, SOAS, University of London. Association of Researchers in Construction Management, 1, pp.225-35.

Ye, K. M. and Rahman, H. A., 2010. Risk of late payment in the Malaysian construction industry. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 4(5), pp.503-511.

Abeysinghe, N.S.D., Senaratne, S. and Andaraweera, A.K., 2019. Managing knowledge through social networks within multi-national real estate consultancy firms: A literature review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 422-430. DOI: doi.org/10.31705/WCS.2019.42. Available at: https://2019.ciobwcs.com/papers

MANAGING KNOWLEDGE THROUGH SOCIAL NETWORKS WITHIN MULTI-NATIONAL REAL ESTATE CONSULTANCY FIRMS: A LITERATURE REVIEW

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ABSTRACT

Multinational Real Estate Consultancy Firms (MNRECF), as "knowledge-based entities", has progressively distributed their operations to their branches all around the world. Disseminated knowledge expertise across borders may, on the one h, benefit MNRECFs due to its' multiplicity, but, on the other h, may be difficult to orchestrate. Thus, orchestration of the knowledge across dispersed unit's conversion of those into innovation competences has become a crucial capability for MNRECFs. Transferring knowledge through one-to-one conversations has been threatened by the increasing movement of the consultants of MNRECFs across different countries. Since the evolution of network relationships has impacted most companies in the modern economy setting, Social Network concept has become the focus of many companies. Organizations' tacit knowledge sharing is mainly structurally supported by the social networking. In MNRECFs, members belong to one category or department dispersed in widespread locations. Therefore, there is a wide adoption of Enterprise Social Networking (ESN) as a collaborative Knowledge Management (KM) tool. The paper suggests the KM efforts within MNRECFs should identify the 'Influencers' in the social network in order to introduce encourage the participation of more actors to the ESN. Therefore, the paper details social networks' features provide an account of relevant combination of ESN SNA facilitated KM initiatives within MNRECFs.

Keywords: *Enterprise Social Networks; Influencers; Knowledge Management; Multinational Real Estate Consultancy Firms; Social Networks; Social Network Analysis.*

1. INTRODUCTION

Multi-National Real Estate Consultancy Firms (MNRECF) largely depends on the specialised knowledge of their expert professionals, nature of the business requires them to move across different locations, countries, knowledge transferring using one-one-conversation has become challenging as a result (Senaratne *et al*., 2018). Therefore, a need has arisen in these organizations for the knowledge to be systematically managed in order to overcome the limitations arising from the common uneven distribution of knowledge (Senaratne *et al*., 2018).

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Tacit knowledge sharing in Companies are mainly supported by the social networking (Churchill and Halverson, 2005). As stated MNRECFs' consultants are spread across several countries, therefore there is a strong requirement for flexible easy to deploy collaborative KM tools (Senaratne *et al*., 2018).

The aim of this research is to review the role of social networks in knowledge management in the business context of multi-national real estate consultancy firms. The aim is accomplished by following the subsequent steps: reviewing the concept of Knowledge Management in Multinational Companies and Multinational Real Estate Consultancy Firms, identifying Enterprise Social Networks as a key ingredient of knowledge management in multi-national real estate consultancy firms, identifying discussing benefits of adopting Enterprise Social Networks as a Knowledge Management Tool in MNRECFs providing a set of relevant collaborative knowledge management tools for Influencer identification in ESN of the MNRECFs using SNA in the context of multi-national real estate consultancy firms. Since nature of knowledge is not well defined in MNRECFs context, the role of social networks in knowledge management in the business context of MNRECFs is not well understood. This created the knowledge gap for this research emerged the research question for the study. Accordingly, the research question for the study is, 'What is the role of social networks in knowledge management in the business context of multi-national real estate consultancy firms?'.

2. RESEARCH METHODOLOGY

Among the several Literature review methods available 'integrative review' is selected for this research. Integrative review, reviews, analyses, critiques synthesizes data about a research topic in an integrated way such that new frameworks viewpoints on the topic are produced (Russell, 2005). The 5 Stage integrative review process includes 1) problem formulation, (2) data collection or literature search, (3) evaluation of data, (4) data analysis, (5) interpretation presentation of results (Russell, 2005). The nature of the research requires a comprehensive methodological approach of reviews in order to analysis the problem to create a consistent comprehensive view of the concepts, problems most importantly to fully underset the research areas addressed. Integrative review method clearly facilitates the aforesaid requirement as it is the most comprehensive procedural approach of reviews, it allows including experimental non-experimental studies to fully understand the phenomenon analysed. It also combines data from theoretical empirical literature, has a wide range of purposes, such as definition of concepts, review of theories evidence, analysis of methodological problems of a particular topic (Russell, 2005).

3. KNOWLEDGE MANAGEMENT IN MULTINATIONAL COMPANIES

Within the past few years, Multi-National Companies (MNC) have identified KM as one of the main sources of competitive advantage (Scott, 1991). MNC provide the ideal platform which is required for the implantation of KM process (as depict in Figure 1) as its' resources are spanned across several courtiers (Alavi and Leidner, 2001). KM processes enable MNC's knowledge to be used in an optimum way while creating value (Ferraris *et al*., 2017).

Crespo, Griffith and Lages (2014), describes MNC as a corporation "formed by multiple knowledge units, where each subsidiary serves as a key knowledge node (refer Figure 1) capable of acquiring, converting, transferring knowledge throughout the firm". Globalisation is the main driver for resource distribution in MNCs which can be used to obtain competitive advantage (Scott, 1991). Knowledge internal capabilities of subsidiaries of MNCs' most often poses competitive advantage not only for the subsidiary itself but throughout the whole MNC, shown in Figure 1 (Inpken *et al.*, 2018).

4. KNOWLEDGE MANAGEMENT IN MULTINATIONAL REAL ESTATE CONSULTANCY FIRMS

Corporate Real Estate (CRE), as a discipline is continuously evolving in order to cater the deems of emerging markets of developing countries which have experienced a fast-economic growth over the last two decades (Mutreja *et al.*, 2015). As a result, MNRECFs in the emerging markets has continued to flourish, which has resulted in rapid increase of number of CRE professional who are deployed in all aspects of real estate consultancy; transactions, facilities management, project management portfolio planning management (Piscitello and Rabbiosi, 2004).

For MNRECFs availability of updated reliable data obtained from wide variety of sources are crucial in providing real estate solutions to their Clients as Client services related decision making requires incisive analysis of market trends, key market practices, risks opportunities (Gupta and Govindarajan, 1991). Suitable research is required for Scenario building good forecasting as well (Gupta and Govindarajan, 1991). In order to address the above needs MNRECFs have established dedicated market research teams in central dispersed locations, with the main duty of issuing regular reports to all other entities in different geographies (Meyer *et al.*, 2011).

Main source of receipt of knowledge for CRE professional in MNRECFs is through the internal networks mainly through parent firm subsidiaries (Ferraris, Santoro and Dezi, 2017). Hence, value-creation opportunities throughout the firm are generated mainly through knowledge creation in subsidiaries knowledge transfer which occurs within between subsidiaries (Asakawa and Lehrer, 2003). Importance of knowledge flow in MNRECFs has been highlighted in many recent studies (Nielsen and Michailova, 2007). The studies have also demonstrated how the roles of subsidiaries have changed from being merely the receivers of knowledge to becoming knowledge creators for the rest of the MNRECF's network (Bartlett and Goshal, 1989).

According to Seufert *et al*. (1999), "the key to obtaining long-term competitive advantage is not to be found in the administration of existing knowledge, but in the ability to constantly generate new knowledge." Therefore, it is crucial that branches of MNRECF acts as knowledge creators which enable them to introduce the new, exclusive, valuable knowledge, which can then be used by the rest of the MNRECF's network (Cantwell and Mudambi, 2004).

5. SOCIAL NETWORK AND SOCIAL NETWORK ANALYSIS (SNA)

A "Social Network" can be seen as: "a specific set of linkages among a defined set of actors, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behaviour of the actors involved" (Seufert *et al.*, 1999).

Social Network Analysis (SNA), in a many modern research fields it is considered as a key technique (Churchill and Halverson, 2005). It analyses social networks through network theory, which views social relationships in terms of nodes ties (Senaratne *et al*., 2018). Organizations are starting to include social networking features in their knowledge management structure in order to capture tacit, social, individual knowledge (Senaratne *et al*., 2018).

6. ENTERPRISE SOCIAL NETWORKS AS A KNOWLEDGE MANAGEMENT TOOL

Knowledge creation in organizations are largely depended on the interactions (Ellison, Gibbs and Weber, 2014). Enterprise Social Network (ESN) enable Organizations to involve users from all levels of the organization to interact share knowledge (shown in Figure 1), it comprises with an emerging set of software processes which provide a platform which is similar to social media (Bhatt, 2002). It has the capabilities designed to capture knowledge from social engagements within the platform (Nonaka *et al*., 2009). By offering a common platform for discussing novel concepts sharing experiences between individuals ESN facilitates continuous sharing of knowledge by linking facilitating actors in the network (Bhatt, 2002). ESN can contribute to the transferability of knowledge (Grant, 1996), which contributes to convert individual knowledge into organizational knowledge (Nonaka and Von Krogh, 2009).

ESN's functions includes broadcasting messages throughout the organization enable actors to communicate with particular co-workers easily securely; post, edit, sort text files linked to themselves or others; view the messages, connections, text, files communicated, posted, edited sorted by anyone else in their organization at any time of their choosing (Leonardi *et al*., 2013).

Many MNRECFs are starting to use ESNs applications such as Yammer, Ning, Jive, or Telligent; enterprise social media tools. Implementing ESN can benefit largely for Organizational process as it provides easy access to new expertise knowledge (DiMicco and Millen, 2007).

7. ENTERPRISE SOCIAL NETWORKS AS A KNOWLEDGE MANAGEMENT TOOLS IN MNRECFS

ESN provides diverse benefits to Organizations; provides different levels of controls (individualistic/collectivistic) level of interaction with respect to the creation of content (Razmerita *et al*., 2014). Individuals in control of content creation tools such as microblogs social network sites, allow people to efficiently accomplish tasks interactions (Razmerita *et al*., 2014). Tools with a collective focus, such as content community's wikis, offer a higher level of interaction in content creation (Steinfield *et al*., 2008).

Diversity of knowledge can be increased by creation of interactive content which in turn contribute to the externalization of knowledge (Ellison, Gibbs and Weber, 2014). As an outcome, knowledge sharing in an organization is generally followes an centralized intermittent knowledge management process, when using ESN it generates opportunities to covert the process it to an continuous knowledge conversation sharing that results in unexpected rousers, interpretation, dynamic emergence (Majchrzak *et al*., 2013).

CRE professionals have a limited free time under an immense pressure to deliver services on time (O'Leary, 2015). Hence, in case if an information or a knowledge gap they prefer the least time-consuming route in order to fill the gap to get the job done (Steinfield *et al*., 2008). Therefore, unsurprisingly, practitioners will reject cumbersome or time-consuming knowledge sources use relevant, useful, and easy to access content (O'Leary, 2015). In an ESN which is based on information technological platform user-generated content are disseminated real-time using short-texts (O'Leary, 2015). Due to that, time taken to share information across ESN is very limited (Majchrzak *et al*., 2013). Therefore, implementing information technology-based ESN platforms can add a lot of value to MNRCFs (O'Leary, 2015).

8. CHALLENGES

Although there has been a wide adoption of ESNs within MNCs, some potential concerns other issues are also been identified. One of the biggest challenges include the reluctance of some of the members to be active on the network (share information) presented in Figure 1, although they use the information which is available, the contribution to the knowledge from them is minimal (Aral *et al*., 2013). It restricts also the opportunity to learn new things for others (Aral *et al*., 2013). In addition to this, there is trend that members in the social network tend to follow members whom they already know (refer Figure 1), it creates a disadvantage that if those are been followed are not active members it prevents users from being open to new updated knowledge (Aral *et al*., 2013). This in turn may make the system appear "unengaging" and thereby discourage future active use limiting social capital benefits (Aral *et al*., 2013).

In order to enjoy the benefits of ESNs to its fullest, participation of large number of percentage of actors is required (Piscitello and Rabbiosi, 2004). However, as noted by Stewart (2012), *"about 30 to 40 percent of employees where registration is required won't even register of the ones who do register another 40 to 50 percent will neither post very often or even read other people's comments when they are sent out"* (refer Figure 1). The effectiveness of the KM process is been challenged if the density of the network is relatively less than the intended network density of the (Stewart, 2012). To overcome research studies in the area suggests to detect influencers in the ESN of the MNREF using Social Network Analysis (discussed below) encourage them to introduce more actors to the network to realize promised benefits of ESN (Stewart, 2012).

9. INFLUENCER IDENTIFICATION IN ESN OF THE MNRECF USING SNA

There are numerous descriptions of influencer, example: the most active participants, the participants who mostly answers other participants' questions, members who inspire others to participate in discussion topics projects (Fulk and Yuan, 2013). Influencer identification (refer Figure 1) is important to ensure full functionality of an ESN as those are the key players of a network who contribute largely in keeping ESN active alive (Ellison *et al*., 2014). Social networks impact is increased by the content created shared by the Influencers such as tutorials, subject related videos etc. hence, it is vital for Organizations to identify the Influencers encourage them to continue their tasks (Fulk and Yuan, 2013). Where there are only few members small ESNs are used, identification of influencers can be done easily by checking the members their posts manually (Ellison *et al*., 2014). In such a situation everyone know who-is-who in the network (Fulk and Yuan, 2013). However, in a context which large number of members publish large number of posts daily computations tools becomes vital in identification of influencers (Ellison *et al.*, 2014).

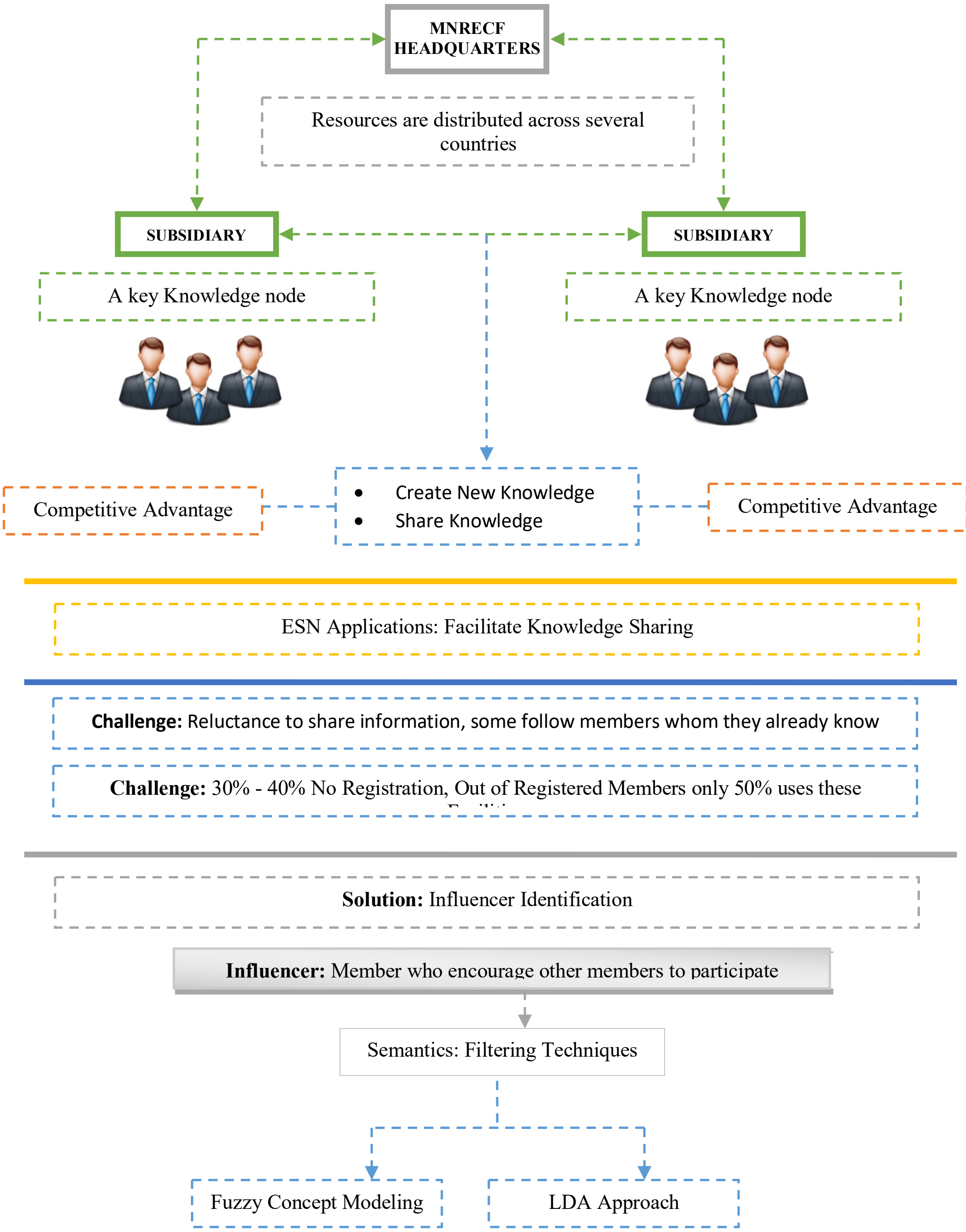

Figure 1: Social networking in MNRECFs

Common interest of a set of users can be understood by using information filtering systems which were developed by several researchers recently (Fang and Chiu, 2010). After the identification of common interest in a particular group those can be then be utilized to disseminate relevant content for those interest groups (Fang and Chiu, 2010). Same filtering techniques can be used to identify influencers in a network based on the semantics (Fang and Chiu, 2010). Semantics is the relevant information inferred from knowledge bases related to the content in short text, which can be used to facilitate better undersetting processing (Fang and Chiu, 2010). Rios *et al*. (2017), proposed two kinds of semantic filtering in order to spot the influencers in a social network, shown in Figure 1; one based on fuzzy concept modelling the other on topics discovered by LDA approach. When it comes to large networks the capability to scale up the detection method is important (Rios *et al*., 2017). Rios *et al*. (2017) is a research which proposed an approach which advances the scalability of the primary key-member recognition algorithm, in which the complexity is directly relational to the quantity of nodes actors, this could be explored in a further research. All findings are summarised in Figure 1.

10. CONCLUSIONS

Growth of Multi National Real Estate Consultancy Firms (MNRECF) in the emerging markets have resulted a phenomenal rise in the number Corporate Real Estate (CRE) professionals deployed in all aspects, increasing globalization has influenced an increasing number of MNRECFs to cross their local boundaries to establish branches in other countries. CRE professionals deem for relevant, useful, easy to access content, quickly and will reject sources that are cumbersome or time consuming. MNRECFs are starting to include social networking features in their knowledge management infrastructure to capture tacit, social, individual knowledge (O'Leary, 2015). In this context implementing ESN which is based on information technological platform is proposed as a solution for the consultants in MNRECFs.

Participation of a large number of members of the enterprise is requires to fully obtain the "network" benefits (Majchrzak *et al*., 2013). Effectiveness of the KM process is been challenged if the density of the network is comparatively less than the designed network density of the ESN which is made up of with the comparatively less set of social actors (Stewart, 2012). Influencer identification is crucial as those are the individuals who keep the ESN alive (Ellison, Gibbs and Weber, 2014). The research proposes two comprehensive ways to influence actors' behavior through overall operational features of social networks' (Fang and Chiu, 2010. Finding out the Influencer in a specific ESN requires application of influencer identification algorithms (Fang and Chiu, 2010).

11. REFERENCES

Alavi, M. and Leidner, D. E., 2001. Knowledge management knowledge management systems: Conceptual foundations research issues. *MIS Quarterly*, 25(1), pp.107-136.

Asakawa, K. and Lehrer, M., 2003. Managing local knowledge assets globally: The role of regional innovation relays. *Journal of World Business*, 38(1), pp.31-42.

Aral, S., Dellarocas, C. and Godes, D., (2013). Introduction to the Special Issue-Social Media Business Transformation: A Framework for Research. *Information Systems Research*, 24(1), pp.3-13.

Bartlett, C.A. and Ghoshal, S., 1989.*Managing across Borders: The Transnational Solution*. Boston: Harvard Business School Press.

Bhatt, G. D., 2002. Management strategies for individual knowledge organizational knowledge. *Journal of Knowledge Management*, 6(1), pp.31–39.

Cantwell J. A. and Mudambi R., 2004. Multinational enterprises competence-creating knowledge flows: a theoretical analysis. *Knowledge Flows, Governance Multinational Enterprise*. London: Palgrave Macmillan.

Churchill, E. F. and Halverson, C. A., 2005. Social Networks Social Networking. *IEEE Internet Computing*, 9(5), pp.14–19.

Crespo, C.F., Griffith, D.A. and Lages, L.F., 2014. The performance effects of vertical horizontal subsidiary knowledge outflows in multinational corporations. *International Business Review*, 23(5), pp.993-1007.

DiMicco, J. M. and Millen, D. R., 2007. Identity management. *Proceedings of the 2007 International ACM Conference on Conference on Supporting Group Work - GROUP '07,* New York, pp.383-386.

Ellison, N. B., Gibbs, J. L. and Weber, M. S., 2014. The Use of Enterprise Social Network Sites for Knowledge Sharing in Distributed Organizations. *American Behavioral Scientist*, 59(1), pp.103–123.

Fang, Y. H. and Chiu, C. M., 2010. In justice we trust: Exploring knowledge-sharing continuance intentions in online communities of practice. *Computers in Human Behavior*, 26, pp.235-246.

Ferraris, A., Santoro, G. and Dezi, L., 2017. How MNC's subsidiaries may improve their innovative performance? The role of external sources knowledge management capabilities. *Journal of Knowledge Management*, 21(3), pp.540–552.

Fulk, J. and Yuan, Y.C., 2013. Location, motivation, social capitalization via enterprise social networking. *Journal of Computer-Mediated Communication*, 19(1), pp.20-37.

Grant R. M., 1996. Toward a Knowledge-based Theory of the Firm. *Strategic Management Journal*, 17, pp.109-22.

Gupta, A. K. and Govindarajan, V., 1991. Knowledge Flows the Structure of Control Within Multinational Corporations. *Academy of Management Review*, 16(4), pp.768-792.

Inkpen, A., Minbaeva, D. and Tsang, E. W. K., 2018. Unintentional, unavoidable, beneficial knowledge leakage from the multinational enterprise. *Journal of International Business Studies*, 50(2), pp.250-260.

Leonardi, P. M. and Meyer, S. R., 2014. Social Media as Social Lubricant. *American Behavioral Scientist*, 59(1), pp.10–34.

Leonardi, P. M., Huysman, M., and Steinfield, C., 2013. Enterprise social media: Definition, history, prospects for the study of social technologies in organizations. *Journal of Computer-Mediated Communication*, 19, pp.1-19.

Majchrzak, A., Faraj, S., Kane, G.C. and Azad, B., 2013. The contradictory influence of social media affordances on online communal knowledge sharing. *Journal of Computer-Mediated Communication*, 19(1), pp.38–55.

Meyer, K.E., Mudambi, R. and Narula, R., 2011. Multinational enterprises local contexts: the opportunities and challenges of multiple embeddedness. *Journal of Management Studies*, 48(2), pp.235-252.

Mutreja, R., Chua, M.L., and Guha, A., 2015. The role of corporate real estate in developing countries of the Asia-Pacific region. *Corporate Real Estate Journal*, 4(4), pp.314-322.

Nielsen, B. B., and Michailova, S., 2007. Knowledge Management Systems in Multinational Corporations: Typology Transitional Dynamics. *Long Range Planning*, *40*(3), pp.314-340.

Nonaka, I. and Von Krogh, G., 2009. Perspective-tacit knowledge conversion: Controversy advancement in organizational knowledge creation theory. *Organization science*, 20(3), pp.635-652.

O'Leary, D. E., 2015. Knowledge Management Enterprise Social Networking: Content versus Collaboration. *Intelligent Systems Reference Library*, 95, pp.45–74.

Piscitello, L. and Rabbiosi, L., 2004. The impact of MNCs; foreign activities on the innovative performance of the parent companies, *DRUID Summer Conference*, Elsinore 14-16 June 2004.

Razmerita, L., Kirchner, K. and Nabeth, T., 2014. Social Media in Organizations: Leveraging Personal Collective Knowledge Processes. *Journal of Organizational Computing Electronic Commerce*, 24(1), pp.74-93.

Ríos, S.A., Aguilera, F., Nuñez-Gonzalez, J.D. and Graña, M., 2019. Semantically enhanced network analysis for influencer identification in online social networks. *Neurocomputing*, *326*, pp.71-81.

Russell, C. L., 2005. An overview of the integrative research review. *Progress in transplantation*, 15(1), pp.8-13.

Scott, J., 1991. Networks of Corporate Power: A Comparative Assessment. *Annual Review of Sociology*, 17(1), pp.181-203.

Senaratne, S., Abeysinghe, N.S.D. and Andaraweera, A.K., 2018. Social Networks for Knowledge Management in Multinational Real Estate Consultancy Firms – A Literature Review. *11th International Conference of Faculty of Architecture Research Unit*, 08 December 2018, Galle: Faculty of Architecture Research Unit-University of Moratuwa, pp.9-16.

Seufert, A., von Grogh, G. and Bach, A., 1999. Towards knowledge Networking. *Journal of Knowledge Management*, 3(3), pp.180-190.

Steinfield, C., Ellison, N. B., and Lampe, C. 2008. Social capital, self-esteem, use of online social network sites: A longitudinal analysis. *Journal of Applied Developmental Psychology*, 29, pp.434–445.

Stewart, D., 2012. *Enterprise social networks: useful tool, not a Panacea* [Online]. Available from: https://deloitte.wsj.com/cio/2013/02/21/enterprise-social-networks-another-tool-not-a-panacea/ [Accessed 02 January 2019].

Disara, S., Samaraweera, A. and Shanika, V.G., 2019. Managing post disaster reconstruction projects through a cultural perspective: A literature review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 431-441. DOI: doi.org/10.31705/WCS.2019.43. Available at: https://2019.ciobwcs.com/papers

MANAGING POST DISASTER RECONSTRUCTION PROJECTS THROUGH A CULTURAL PERSPECTIVE: A LITERATURE REVIEW

Senuri Disara[1], Aparna Samaraweera[2] and V.G. Shanika[3]

ABSTRACT

Post Disaster Reconstruction (PDR) is a very important, complex and highly demanding process, including well planned set of activities done by well experienced construction professionals. Strength in terms of sustainability, particularly in the PDR of developing countries, is undoubtedly still not at an adequate level. One of the main challenges that affecting for the success of the PDR project performance is that not managing community cultural continuity properly while affording development opportunities in PDR projects which end up with cultural incompatible solutions, which are unsustainable in the long run. The success of PDR project performance is based on the success of their main 4 components: site, layout, construction and policies. The study identifies how those components of PDR projects are affected by the community culture with the lessons learned by past PDR project experiences all around the world. Further, the cultural factors which affect for each feature of PDR has been identified through the findings. Besides the thorough literature findings, the study has presented with proposed methodological aspects in order to continue the study in future.

Keywords: *Community Culture; Cultural Factors; Post Disaster Reconstruction.*

1. INTRODUCTION

Sri Lanka has a very unique culture with a vast cultural diversity and it is highly disturbed by different types of natural disasters such as Tsunami, floods and landslides (Amaratunga *et al*., 2015). Post Disaster Reconstruction (PDR) is not just a good opportunity to convert the destructive zone into a sustainable community with a long-term developmental guidance, but also a favourable moment to get prepared for the next disaster (Ye and Okada, 2002). Advantages of sustainability, especially in the PDR of developing countries like Sri Lanka, is definitely not at a sufficient level (Sridarran *et al*., 2008). The same mistakes are repeated over and over again and most of those mistakes arise due to low level of consideration given to social- cultural dimensions, while undertaking PDR. This matter should be carefully addressed by studying the cultural context of the country (Jaygasu, 2002).

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The previous researches have been highlighted that, one of the key challenges is to reinforce social and cultural stability through the development opportunities that are offered by PDR, without people ultimately ending up with culturally inappropriate solutions, which lead to long term unsustainability (Boen and Jigyasu, 2005). But, a detailed study on the impact of culture has not been done yet to identify the real reasons for those challenges. Furthermore, there is a necessity to identify that, to what extent a cultural impact can affect to a PDR project performance (Ismail *et al*., 2014). In order to successfully implement these PDR projects in Sri Lanka, construction professionals should find out the social cultural impact to the project properly and they should have a proper knowledge to manage them. Sri Lankans attitudes on cultural concepts are in very high level and their life styles are hardly bound to the community culture. Sri Lanka has a very unique, proud cultural identity as well. Since the community culture impact on the PDR projects in Sri Lankan context is different from other countries, carrying out a study to analyse this impact will be very important for the success of the future PDR projects in Sri Lanka (Sridarran *et al*., 2008).

Hence, this paper intends to bring in literature synthesis addressing the importance of the community culture to PDR projects, the community culture impact for the PDR projects and the cultural factors affect for the PDR projects. Ultimately a conceptual framework is developed to understand the community cultural impact on PDR projects.

2. METHODOLOGY

An extensive literature review facilitates the researcher to strengthen the base of the research by congregating the prevailing knowledge around the research area. Furthermore, Saunders *et al*. (2016) illustrated that a strong literature can facilitate the researcher to make sure that the existing knowledge related to research area is contemporary and the researcher is developing an original knowledge that is not existing in the current literature. Thus, a comprehensive literature review is vital for research to collect prevailing knowledge on the research area to pave the path to move beyond it to discover a piece of new knowledge.

Hence a comprehensive literature review is conducted addressing the importance of the community culture to PDR projects. Furthermore, the community culture impact for the PDR projects and the cultural factors affect for the PDR projects were identified through the literature synthesis. Thus, a robust literature review is conducted by accompanying books chapters, journal publications and conference proceedings. Compiling the extensive literature findings, a conceptual framework was developed to understand the community cultural impact on PDR projects.

3. IMPORTANCE OF COMMUNITY CULTURE TO PDR PROJECTS

As in Ismail *et al*. (2004), PDR projects can be defined as the modification, or entirely replacement of a facility in stages (involving extensions, renovation, additions or advancement of the functional performance of a facility), which is completely or partially destroyed due to catastrophic event. Success factors (CSFs) can be used to improve the effectiveness of the current and future projects (Davies, 2002). ‘‘Project success is a function of project-related factors, project procedures, project management actions, human-related factors and external environment and they are interrelated and interrelated'' (Chan *et al*., 2004, pp.75)

Ismail *et al*. (2014) have listed critical success factors that affect to PDR projects by analysing previous literatures According to their findings political local needs and culture has obtained the highest frequency and level of community control has the second highest as the success factors. Combination of these two success factors suggest the impact on community culture on PDR projects. Therefore, it can be said that community cultural impact is critical in success of PDR projects among other success factors. The rising interest for the studies can be seen in the past few years over the areas like community culture of the PDR, the relationship between culture and PDR project success, the community cultural effects including national cultural differences on PDR projects (Ross and Kivrak, 2009).

Community culture is a combination of attitudes, values, beliefs and assumptions that people share about themselves, others and about the natural world, in which they live (Little, 2012). Culture covers aspects as a way of life of a group, as a specific way of behaving and as a set of strategies adopted for existence linked to the ecological setting (Jaygasu, 2002). There are still many cultural considerations in many Asian countries that have to be considered when building a house, or other infrastructure to the community and this can vary from one country to another country or even from area to adjacent area (Ophiyandri, 2008). It incorporates patterns of communication that people have created to meet their needs, everyday behaviour, social etiquette, religion, policies and education (Adams, Goldbard and Ybarra-Frausto, 2002). According to Axner (2012), there are many physical and social components which are highly interconnected, in developing countries, where the system of social life at the village or community level is very complex.

Identifying the systems of local reconstruction projects and lifestyle of the end users are very important in order to define successful PDR that fit better with the requirements and desires of people, regarding their culture, traditions, habits, and values (Félix *et al*., 2015). Cultural consideration for the PDR projects may always restore the confidence of the people whose life has been completely changed due to the disaster (Max Lock Centre, 2006).

4. THE COMMUNITY CULTURE IMPACT TO PDR PROJECTS

Post Disaster Reconstruction (PDR) projects need to be more human oriented comparing to other construction projects. Gunawan (2008) has identified that there are 4 components in post disaster reconstruction projects which have proved to be crucial in determining successful or unsuccessful outcomes in terms of community cultural influence. These components are known as site, layout, housing and popular input policies. The author further described that these four components are closely related to how the community react to a given PDR project based on the culture, either in terms of kinship, rituals or values.

4.1 SITE

All cultures exist within their environmental context. Appropriate site identification and selection for a PDR projects is very essential for the community and time-consuming procedure, because it is bound with numerous dimensions including the community culture (Sridarran *et al*., 2008; Barakat, 2003). Therefore, poor choice of site for the new settlement can result the re-settlement programs unsuccessful (Gunawan, 2008). Housing relocation projects are delayed mainly due to the difficulties of finding suitable land areas to build large number of housing schemes, which are compatible with the disaster affected community culture, unwillingness of beneficiaries to be relocated and inadequate provision of infrastructure by government.

After the reduction of buffer zone some people tend to return back to their previous lands, even though they were offered with the houses constructed by donor driven projects. (Boen and Jigyasu, 2005). This is mainly due to their reluctance to change their usual lifestyle. Bouraoui and Lizarralde (2013) have stated in their research that in relocation after floods in Bousalem city, communities were dissatisfied with the new location by comparing the level of well-being experienced in their previous location in Bousalem. The major issue of this relocation was that relocated area was far away from the earlier village of Bousalem, which leads to a high level of dissatisfaction.

Moreover, the relocation is highly disturbing to the social and traditional structure based on family backgrounds. Relocated people face the difficulties while familiarising with the systems of urban life ending up homeless and unemployed (Lin and Lin, 2016). Author provides examples from the Typhoon Morakot case in Taiwan in 2006. In another post tsunami case in Tamil Nadu, India, more than 80% of the affected people within fishing communities, refused relocation due to their livelihood is related with their location and it was impossible to find satisfactory land to reconstruct all coastal houses in new locations and project was not successful (Barenstein and Pittet, 2007).

4.2 LAYOUT

The second factor that plays an important role in the PDR projects is the layout or design of the settlement (Gunawan, 2008). The space designs for the relocated villages should be fully compatible with the lifestyle of the villagers. Traditional resettlements need to be highlighted with narrow streets, open spaces in both public and private areas which can be used for the activities such as religious functions and clusters of housing with different typologies characterized by traditional lifestyles (Boen and Jigyasu, 2005).

Past researchers have been highlighted that most of the PDR housing projects are build up without considering these cultural impacts. According to Gunawan (2008) the village, Flores in Indonesia, after the earthquake could not function well like the previous village because the plan was in accordance to uniform national criteria by the government, instead of the local culture and tradition. As a result, no space was allocated for the social gatherings and the general rituals of villagers as in their original environments. The design was failed due to the whole 'city-like' plan which includes wide roads creating a grid pattern and row housing (Gunawan, 2008). This suggests that it is needed to provide space for social interaction and rituals while designing the villages after disaster.

While designing housing reconstruction, residence in extended families (family background) is still the norm. The designs based on the assumption of occupancy by a nuclear family arise problems in extended family lives because the designs are inappropriate to their needs (Barakat, 2003). Lin and Lin (2016) highlighted in their research that Thaiwan villagers faced lot of difficulties due to inadequate kitchen facilities and lack of space to expand the families. In the South Indian reconstruction project, the master plan for the houses that was developed, followed the concept of clusters. Later on, villagers were dissatisfied with the design as they couldn't have pooja room for their rituals, and the designed scheme was smaller than the previous plot (Tauber, 2015). In the Tamil ethnic culture, people use detached toilets. In Marathwada reconstruction in India, the provision of attached toilets was useless as Tamil people use detached toilets according to their ethnic culture. Later, those attached toilets were used to store grain by the communities (Jaygasu, 2002). These designs may lead the community to long time exhaustion as well as disorders.

The designs of houses should be considered the requirements of women too, mainly due to female headed families (women become widows due to disaster). Therefore, sanitation facilities, privacy and high security should be provided in designs for the women and children in order to prevent sexual assaults.

4.3 CONSTRUCTION

Construction process is also one of the most important components for the success of PDR projects. The community organizations tend to construct projects by implementing locally feasible cost-effective technologies, whereas through the participative, clear and accountable systems (Jayaraj, 2008). The utilization of local resources is a good choice than the other solutions (Lizarralde and Davidson 2006; Barakat 2003). Further, those materials that can be found locally are culturally, and socially more suitable, since they are familiar with the community and those materials can be obtained in low costs as transportation costs are not incurred. Even innovative technologies should be used in a proper manner, whereas combination of traditional and modern construction methods can be used (Bouraoui and Lizarralde, 2013).

Hughes (1987) has studied the situation after three years of the reconstruction projects which were done due to the, devastating earthquake in Turkey. The author observed that there were so many changes done to those reconstruction later by the local people in order to suit with their traditional culture. Traditional structures and temporary storage sheds were attached to the reconstructed houses and used traditional techniques again. These houses were built using the stone and timber, found out from the destroyed houses with fresh soil roofs derived from the surroundings (Huges, 1987). Communities have considered the aesthetic appearance and social status while constructing according to their culture. Such examples show clearly how people adapt themselves and change the surroundings accordance with their lifestyle.

In another post tsunami reconstruction project in India the community didn't satisfied with the reinforced concrete houses built by Non-Governmental Organizations (NGOs), without any veranda due to their failure to address the climatic and socio-cultural requirements of the space (Gunawan, 2008). At the village reconstruction in Marathwada, India, the government have provided large infrastructure, which were more than enough for the community. But the village committee could not maintain those infrastructures with their financial resources. The villagers face economic difficulties due to paying higher taxes for these infrastructures, which were kind of useless (Jaygasu, 2002).

Therefore, the construction professionals need to identify the housing standards with social structure determinants and size; culture affects forms, function, and aesthetics.

4.4 POLICIES

The last factor is policy making, which is a popular input for the success of PDR projects. Much effort has been gone into developing disaster reconstruction policies and institutions on a global scale from the past years. While some countries may have existing legislation, regulation and policies in place, to review and amend in a disaster occasion, some countries have to enact new legislations and regulations in the relocation, planning and construction stages in PDR projects (Bilau *et al*., 2018). Project failures or partially successful projects are mostly characterized by policies, which focus less on consultation with the disaster affected community (Smith, 1991). These policies highly disregarded cultural factors of the community. The decisions made by government or aid agencies need to consider needs and values of the resettled populations (Kulatunga, 2011).

Barenstein (2006) explored how the government policies failed to pay proper attention to the social-cultural and environmental conditions of reconstruction projects after the tsunami in 2004 at Tamil Nadu, destroying peoples’ cultural identity and livelihood resources. These policies adopted, repeatedly neglect the various types of households and the diversity of their needs which lead the failures to consider the affected residents differently (Aldrich, 2012).

Delays were occurred while initiating the housing projects due to the changes of the policy decisions from the Government of Sri Lanka (GoSL), regarding relocation of affected community and the rights of those displaced persons. The GoSL has enforced a buffer zone of 100m restricting any construction or development within this limit, which affected for the occupation of most people living in the coastal areas, and they loss their source of income. The government had to revise the policy, which delayed the reconstruction programmes and some donors were loss due to this delay.

On the other hand, some policies were positively affected for the reconstruction projects. In PDR in Kathmandu Valley, Nepal, the government removed the existing constraints on the forest usage so that the people may make use of the local resources like timber for reconstruction, which provided economic benefits for the community (Jaygasu, 2002).

5. CULTURAL FACTORS AFFECTING PDR PROJECTS

Cultural factors impact community with the nature, timing, tasks, and rituals of lifestyle transitions, as well as the significance the family attaches to each transition (Dude, 2014). The cultural factors refer to cultural dimensions through which a community can be recognized by others (Cross, 1978). Communities make an identity within their living environment through these cultural factors. These factors can be identified as follows:

Ethnicity - Many authors have suggested that the common origin and decent of the people makes the group an ethnic group. Ethnic identity differs from other identities as this is history distinguished (Verkuyten, 2005).

Religion and Spirituality- This is a set of communal beliefs and practices which are shared and organized with the aim of spiritual development. (Hodge and Derezotes, 2008).

Livelihoods- The lifestyles of a particular community are very important in community culture. The day to day lifestyle, occupation systems are the components that are overviewed under livelihood.

Family Background- How the community identify the arrangement of the family and their primary believes as a family which has a cultural identity (McGoldrick, 2005).

Rituals- Rituals guide the behaviour of small sets of people or celebrated across the entire community. Most of these rituals are bound with ethnicity and the religions of communities.

Attitudes- Related with the feelings about any given thing and reflection of values we hold (Fishbein and Ajzen, 1975) believe that attitude is a learned tendency to respond to a given entity in a favourable or unfaourable way.

Social interaction- The way people contact with their community and how they behave with the other people in their living environment and interaction with outside communities.

Social Status- Social class, an external variable influences cultural identity based on how one understands one's place in a system, the environment one grows up in, and how others perceive a person (Anderson and Collins , 2007).

From the lessons learned in past disaster scenarios in global context which have been found through the literature, the cultural factors that affect each component of the reconstruction projects can be determined as given in Table 1.

Table 1: Examples for the cultural impact from past disaster scenarios

Feature	Cultural Factor	Case
Site	Ethnicity	• Flores in Indonesia
	Religion and spirituality	• Flores in Indonesia
	Livelihoods/Occupation	• Post flood relocation in Bousalem city, • Post tsunami case in Tamil Nadu, India
	Family background	• Typhoon Morakot in Taiwan
Layout	Livelihoods	• Typhoon Morakat in Thaiwan
	Rituals	• Flores in Indonesia, • South Indian reconstruction project
	Social interaction	• Flores in Indonesia
	Family background	• Typhoon Morakat in Thaiwan
	Habitats	• Marathwada reconstruction in India
	Gender	
Construction	Livelihoods	• Earthquake in Turkey, • Post tsunami reconstruction in India
	Social interaction	• Post earthquake reconstruction in Italy
	Social status	• Marathwada reconstruction in India
	Economy	• Reconstruction in Marathwada, India
Policies	Livelihoods/Occupation	• Tsunami in 2004 at Tamil Nadu, • Tsunami reconstruction in Sri Lanka
	Family Background	• Typhoon Morakat in Thaiwan
	Social Interaction	• Typhoon Morakat in Thaiwan

	Economy	• Kathmandu Valley, Nepal
	Gender	• Reconstruction of Dibbulapalem

(Sources: Jaygasu, 2002: Bouraoui and Lizarralde, 2013: Barenstein and Pittet, 2007: Lin and Lin, 2016: Gunawan, 2008: Tauber, 2015: Hughes, 1987: Geipel, 1991: Barenstein, 2006)

6. CONCEPTUAL FRAMEWORK

The findings through the comprehensive literature review for the areas mentioned in the objectives for the community cultural impact on post disaster reconstruction project performance, are mapped together using a conceptual framework (see Figure 1). The framework can be applied to find out the relationship between community culture and the success for the PDR projects.

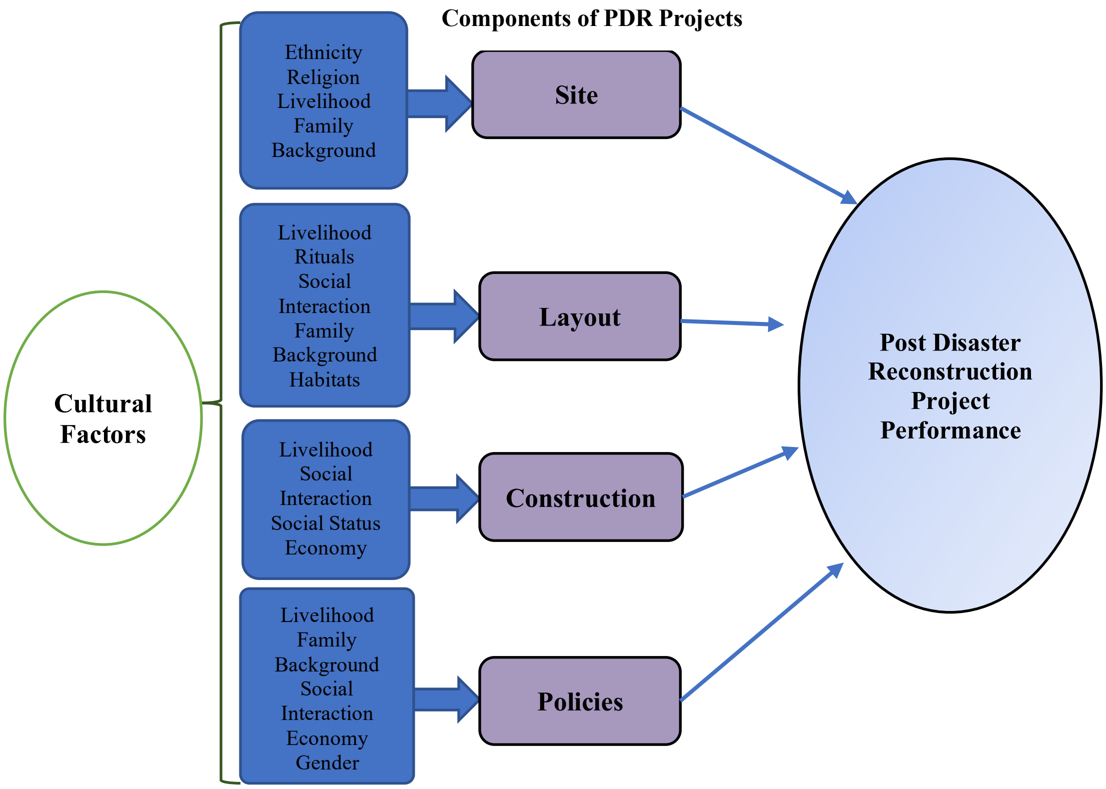

Figure 1: Conceptual framework

The conceptual framework shows how the community culture affects for the PDR project performance through the cultural factors and how it should be led to the success. Through the literature review four main components of the PDR projects that are affected by the community culture, have been identified as Site, Layout, Construction and Policies (Refer Section 3). Those are shown in the middle of the framework. Combination of those four components lead to decide the PDR project performance. While achieving the project performance through those components, each and every component has the influence by the community culture. Every component is affected by set of cultural factors which has been identified in the sub sections of Section 3. Site selection has the impact on cultural factors like ethnicity, religion, livelihood and family background. Livelihood, rituals, social interaction, family background, habitats and gender impact for the design of the PDR project. Construction of PDR projects depends on the cultural factors like livelihood, social interaction, social status and economy. Policies have the impact on livelihood, family background, social interaction, economy and gender (Refer Table 2). Those cultural factors which are described in the section 4 have been shown at the left side of the framework. The PDR performance is determined through the success of its components which are affected by those cultural factors. This framework clearly shows how the community cultural factors affect to the performance of PDR projects indirectly. Therefore, this framework summarises that PDR project success depends on the success of their components which are the part of PDR process. It is clear that those components can't be succeeded unless the community cultural impact positively effect on those components. This relationship shown in the framework suggest that community cultural impact on post disaster reconstruction projects. Finally, this framework has been developed from the literature findings considering the global context.

7. CONCLUSIONS AND RECOMMENDATIONS

In the past decades, several disastrous events have occurred and caused severe damages to people and infrastructure all over the world. Opportunities occurring from disasters break the current limitations and barriers and the traditional scope by creating a blank slate for building houses and infrastructures. The successful performance of a PDR project depends on how well the initial decisions respond to the needs of the affected people. In terms of the planning and implementation of reconstruction programmes social cultural appropriateness of recovery measures have been a recurring challenge and continue to cause project failures in disaster reconstruction.

The PDR project components like site, layout, construction and policies are closely related to how the community react to a given PDR project based on the culture, either in terms of kinship, rituals or values. The previous researches have been highlighted that, one of the main challenges is to reinforce cultural continuity through development opportunities that are afforded through PDR, so that one does not end up with cultural incompatible solutions, which are unsustainable in the long run. Therefore, managing cultural factors properly in previously mentioned stages of PDR projects is a must in order to succeed in the PDR project performance.

The main solution to manage the cultural impact on PDR projects is that, increasing community participation for these projects. The beneficiaries should have the control and responsibility of their own decisions (type of house to be built, type of technology to be used, contribution in self-help, hired activities, etc); however, these decisions should be framed by contractual clauses that attempted to guarantee that the resources offered were efficiently and properly used. The professionals involve in the PDR projects should have paid more attention about community cultural conditions after disasters in order to make their projects more sustainable with cultural compatibility. Yet, the research findings were completely based on a thorough analysis of literature, which leads a way forward to continue the study to explore the community cultural impact to PDR projects in the actual scenario.

8. REFERENCES

Adams, D., Goldbard, A. and Ybarra-Frausto, T., 2002. *Community, culture and globalization*. Rockefeller Foundation, Creativity & Culture Division.

Aldrich, D.P., 2012. *Building resilience: Social capital in post-disaster recovery*. University of Chicago Press.

Amaratunga, N., Haigh, R. and Ingirige, B., 2015. *Post-Disaster Housing Reconstruction in Sri Lanka: What Methodology?*, SAGE Open.

Anderson, M. L. and Collins , P. H., 2007. *Race, class, and gender: An anthology.* Cengage Learning.

Axner, M., 2002. *Understanding culture and diversity in building communities,* Center for Living Democracy.

Barakat, S., 2003. *Housing reconstruction after conflict and disaster,* London: Humanitarian Practice Network at ODI.

Barenstein, J., 2006. Challenges and risks in post-tsunami housing reconstruction in Tamil Nadu. *Humanitarian Exchange,* 33, pp.38-39.

Barenstein, J.D. and Pittet, D., 2007. Post disaster housing reconstruction Current trends and sustainable alternatives for tsunami-affected communities in coastal Tamil Nadu. *Institute for Applied Sustainability to the Built Environment, University of Applied Sciences of Southern Switzerland, Canobbio*.

Bilau, A., Witt, E. and Lill, I., 2018. Practice Framework for the Management of Post-Disaster Housing Reconstruction Programmes. *Sustainability*, *10*(11), p.3929.

Boen, T. and Jigyasu, R., 2005. *Cultural Considerations for Post Disaster Reconstruction Post-Tsunami Challenges,* Asian Disaster Preparedness Center.

Bouraoui, D. and Lizarralde, G., 2013. Centralized decision making, users' participation and satisfaction in post-disaster reconstruction: The case of Tunisia. *International Journal of Disaster Resilience in the Built Environment*, *4*(2), pp.145-167.

Chan, A.P., Scott, D. and Chan, A.P., 2004. Factors affecting the success of a construction project. *Journal of Construction Engineering and Management*, *130*(1), pp.153-155.

Cross, W. E., 1978. The Thomas and Cross models of psychological nigrescence: A review.. *The Journal of Black Psychology,* 5, pp.13-31.

Cooke-Davies, T., 2002. The “real” success factors on projects. *International Journal of Project Management*, *20*(3), pp.185-190.

Dude, S. C., 2014. Cultural factors in rural community development. *The Journal of Asian Studies,* 6(1), pp.19-30.

Félix, D., Monteiro, D., Branco, J.M., Bologna, R. and Feio, A., 2015. The role of temporary accommodation buildings for post-disaster housing reconstruction. *Journal of Housing and the Built Environment*, *30*(4), pp.683-699.

Fishbein, M. A. and Ajzen, I., 1975. *Belief, attitude, intention and behaviour: An introduction to theory and research.* Reading, MA: Addison-Wesley.

Gunawan, Y., 2008. *The Role of Culture in Post Earthquake Housing.* 2017: Research Gate.

Hodge, D.R. and Derezotes, D.S., 2008. Postmodernism and spirituality: Some pedagogical implications for teaching content on spirituality. *Journal of Social Work Education*, *44*(1), pp.103-124.

Hughes, R., 1987. Field Report of a visit to Eastern Turkey. *Disasters*, *11*(4), pp.251-256.

Ismail, D., Majid, T.A. and Roosli, R., 2014. Project management for post disaster reconstruction project: a literature review. *Advances in Environmental Biology*, pp.103-108.

Jayaraj, A., 2008. Post disaster reconstruction experience in Andhra Pradesh in India. *Post-Disaster Reconstruction of the Built Environment: Rebuilding for Resilience,* p.16.

Jigyasu, R., 2002. Reducing disaster vulnerability through local knowledge and capacity: the case of earthquake prone rural communities in India and Nepal (Doctoral dissertation, Norwegian University of Science and Technology).

Kulatunga, U., 2011. Project management of disaster reconstruction. *Post-Disaster reconstruction of the built environment: Rebuilding for resilience*, pp.133-150.

Lin, J.J. and Lin, W.I., 2016. Cultural issues in post-disaster reconstruction: the case of Typhoon Morakot in Taiwan. *Disasters*, *40*(4), pp.668-692.

Little, W., 2012. *Introduction to Sociology.* Ministry of Advance Education - Canada.

Lizarralde, G. and Davidson, C., 2006. Learning from the poor. In *i-Rec conference proceedings 2006: Post-disaster reconstruction: Meeting the stakeholders' interest*.

Max Lock Centre, 2006. *Mind the gap! Post-disaster reconstruction and the transition from humanitarian relief,* RICS.

McGoldrick, M., 2005. Overview: Ethnicity and family therapy. In: M. McGoldrick, J. Giordano and N. G. Preto, eds. *Ethnicity and family therapy.* New York: Guilford Press, pp.1-43.

Ophiyandri, T., 2008. *Community based post disaster housing reconstruction*, pp.91-116.

Kivrak, S., Ross, A., Arslan, G., Tuncan, M. and Dainty, A., 2009, September. Impacts of cultural differences on project success in construction. In *Proceedings of 25th Annual ARCOM Conference, Association of Researchers in Construction Management, Nottingham* (pp. 7-9).

Saunders, M., Lewis, P., and Thornhill, A. 2016. *Research methods for business students*. 7th ed. Pearson Education Limited: Harlow

Smith, A. O., 1991. Success and failures in post disaster eesettlement. *Disasters,* 15, pp.12-23.

Sridarran, P., Keraminiyage, K. and Amaratunga, D., 2008. *Enablers and Barriers of Ddapting Post Disaster Resettlements.* Global Disaster Resilience Centre, pp. 125-132.

Tauber, G., 2015. Architects and rural post-disaster housing: lessons from South India. *International Journal of Disaster Resilience in the Built Environment*, *6*(2), pp.206-224.

Verkuyten, M., 2005. *The social psychology of ethnic identity.* New York: Routledge.

Ye, Y. and Okada, N., 2002, July. Integrated relief and reconstruction management following a natural disaster. In *Second annual IIASA-DPRI meeting, Integrated disaster risk management: megacity vulnerability and resilience* (pp. 1-18).

Madhusanka, N., Pan, W. and Kumaraswamy, M., 2019. Mapping and improving sustainable construction management through social network analysis: A review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 442-452. DOI: doi.org/10.31705/WCS.2019.44. Available at: https://2019.ciobwcs.com/papers

MAPPING AND IMPROVING SUSTAINABLE CONSTRUCTION MANAGEMENT THROUGH SOCIAL NETWORK ANALYSIS: A REVIEW

Nandun Madhusanka[1], Wei Pan[2] and Mohan Kumaraswamy[3]

ABSTRACT

Social Network Analysis (SNA) has been used in multidisciplinary research during the past two decades due to the unique nature of network visualisation and extensive analytical capabilities. This tool has also gained increasing attention among the researchers in the sustainable construction arena in recent years. Nevertheless, a thorough review has not yet been done to review the application of SNA in the sector of sustainable construction. This paper attempts to address this gap through a comprehensive review of previous journal publications. Accordingly, 73 journal papers were initially identified for review through the "Web of Science "publications database. Subsequently, a bibliometric analysis was done through "VOS viewer" software package to identify the research trends throughout the past years. The results show significant progress in relevant publications during 2014-2018 and a major contribution to research from China. After an extensive filtration process, 17 particularly relevant journal papers were identified which have applied both social network visualisation and analysis techniques for the sustainability aspects of construction. The contents of these papers were comprehensively analysed in terms of data collection methods, network analysis techniques, network structures and sustainability knowledge areas. Finally, this paper contributes to theoretical knowledge in this domain, by suggesting a future research direction through a SNA conceptual model to analyse stakeholder collaborations for project life cycle sustainability initiatives. The findings of this paper will serve as a good source for future researchers to comprehensively identify, compare and contrast the applications of SNA techniques for sustainability related studies in the construction sector.

Keywords: *Social Network Analysis; Sustainable Construction; Sustainability.*

1. INTRODUCTION

Heightened attention to partnerships and collaborative arrangements among different entities in the construction sector is apparent through numerous recent studies (e.g. Manley, 2002; Kumaraswamy *et al*., 2010; De Silva *et al*., 2017). Accordingly, Scott *et al*. (2008) highlighted the importance of developing collaborative networks to visualise and analyse the connectedness of entities. The widely accepted and practiced theoretical foundation for mapping and assessing collaborative networks is the theory of Social

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Network Analysis (SNA) which provides a holistic picture and enhanced capabilities to analyse complex interactions in construction projects (Borgatti and Foster, 2003). Scholars have largely incorporated SNA techniques in studying construction management practices during the past two decades and some authors have comprehensively reviewed the applications of SNA in the construction sector (Chinowsky and Taylor, 2012; Zheng *et al*., 2016; Lee *et al*., 2017). "Sustainable Construction" targets on maximising the economic value of construction projects while minimising the negative effects on the environment and society (Wu *et al*., 2018). With the rising attention to improving sustainability practices in the construction sector, scholars have progressively used SNA to develop collaborative networks and generate significant outcomes to improve and manage sustainability in construction. An in depth review of these publications can benefit scholars to identify prevailing knowledge areas and inspire future research directions. Yet, a comprehensive review has not been employed to specifically identify how SNA has been utilised to map and improve sustainability in the construction sector. Hence, this paper aims to address the aforementioned knowledge gap by employing a "bibliometric review" and a "review of SNA methods". As a final point, a SNA based future research direction is suggested focusing on stakeholder collaborations for life cycle sustainability initiatives.

2. SOCIAL NETWORK ANALYSIS (SNA)

2.1 SNA AS A MANAGEMENT TOOL

A typical network structure consists of nodes (actors/vertices) to represent entities and ties (a link, which is represented by a line connecting two nodes in a network) to represent the connectedness between entities (refer Figure 1) (Lee *et al*., 2017). Establishing this network necessitates identifying significant entities within the network and establishing relationships among identified entities focusing on a desired goal or a set of goals (Alves *et al*., 2012).

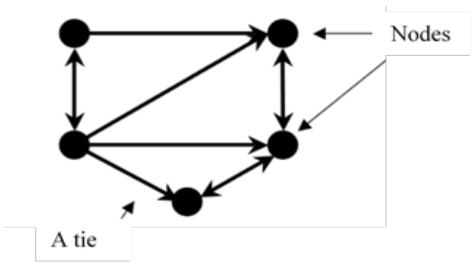

Figure 1: The structure of a social network

Initial thoughts about SNA go back to the 1930s and SNA theories have been primarily utilised to investigate informal relationships of social groups during the early stages of SNA adaption (Zheng *et al*., 2016). SNA applications for the development of organisational networks have been evident from late 1970s (Kilduff and Tsai, 2003). During this period, researchers started to use SNA theories for empirical management studies within business organisations by developing social network structures to visualise formal relational arrangements at organisational level (Tichy *et al*., 1979). After this era, an upsurge in SNA related studies is observed, largely due to the development of software based platforms with commanding network analysis tools such as UCINET, PAJEK and NETMINER (Bodin and Crona, 2009). A number of studies related to the areas like knowledge management, medicine, risk management, information and communication technology, project management, organisational management, supply chain management, etc. can be identified during the past two decades (Vechan, 2015; Lee *et al*., 2017).

2.2 SNA IN CONSTRUCTION MANAGEMENT

The application of SNA in the fields of construction management began gaining the attention of scholars during the period of 1990s (Vechan, 2015). Early studies mainly focused on the network development and analysis of intra- organisational level stakeholders in construction project environments (Loosemore, 1997). Thereafter, the studies of SNA in construction management mainly focused on the areas like analysing cross boundary relationships of organisations and stakeholders, representation of the organisational structure of projects, stakeholder associated risk management in project environments, project governance, stakeholder communication networks and health and safety management (Pryke, 2012; Zheng *et al*., 2016; Lee *et al*., 2017). Nowadays, the project environments have become more complex, hence practices and procedures are significantly affected by sociological and institutional policies and changes. Therefore, recent SNA related studies have also considered the entities in external environment and sociological factors (Chinowsky and Taylor, 2012).

3. BIBLIOMETRIC REVIEW OF SNA APPLICATIONS IN SUSTAINABLE CONSTRUCTION MANAGEMENT

3.1 REVIEW METHODS

For the bibliometric review, a database search was done to identify the previous journal publications related to the applications of SNA in sustainable construction by adapting a methodical process proposed by Hu *et al*. (2013) which discusses the key procedures in assessing the contents of previous publications. Accordingly, as the initial step, a comprehensive exploration was done through the "Web of Science" database "Topic Search" function using the keywords "Social Network Analysis" and "Sustainable Construction" which resulted in 73 journal publications during 2005 to 2018 (Figure 2). "Web of Science" is one of the largest publications databases in the world which provides access to a range of citation indexes. During the "Topic Search" function, the database searches through all the words in title, abstract and the keywords in an article to match and identify the related publications. Hence, the researchers were able to access nearly all the best matching journal publications for the intended review. Subsequently, the search results were further analysed through "VOS viewer" bibliometric analysis software package to construct the keyword co-occurrence network and co-citation network.

3.2 REVIEW RESULTS

"Web of Science" database search results emphasised a rising attention for SNA related studies in the arena of sustainable construction management. From 2005 to 2010, the number of papers published was less (9 papers) when comparing with the publications after the year 2010. Further, 58 (out of all 73) papers were published during the period of 2014-2018 (refer Figure 2). This emphasises that SNA has become a more popular analytical tool among the researchers in sustainable construction sector during the recent years.

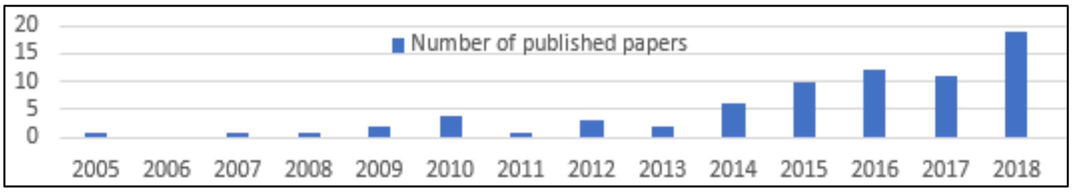

Figure 2: Number of journal publications for the application of SNA in sustainable construction

3.2.1 Keywords and Citations Distribution

Keywords co-occurrence network and co-citation network were developed to further understand the trends of SNA applications in the arena of sustainable construction management. The minimum number of occurrences of a key word was set to 5 times to reduce the complexity which resulted in a network of 16 frequently appeared keywords out of 589 total keywords. Network "A" in Figure 3 shows all 16 keywords where node sizes are arranged according to the frequency of occurrences and total strength of the co-occurrence links are visualised through line weightages. Three main keyword clusters were identified (Nodes with Red, Green and Blue) which had close co-occurrences with each other in the identified set of publications.

Network "B" in Figure 3 was developed to understand the research trends over time. Thus, the keywords related to primary database search (SNA-16 occurrences, construction-16 occurrences, sustainability-11 occurrences, sustainable development-9 occurrences) were removed from the network to clearly identify the changing pattern of topics from 2010 to 2018. Comparative analysis of node colours with the provided time scale in network "B" shows that the topics; "Innovation", "Risk", "Evolution" and "Policy" attracted rising attention recently. Interestingly, the keyword "China" also showed a heightened attention during this period, which testifies to the many significant applications in the region.

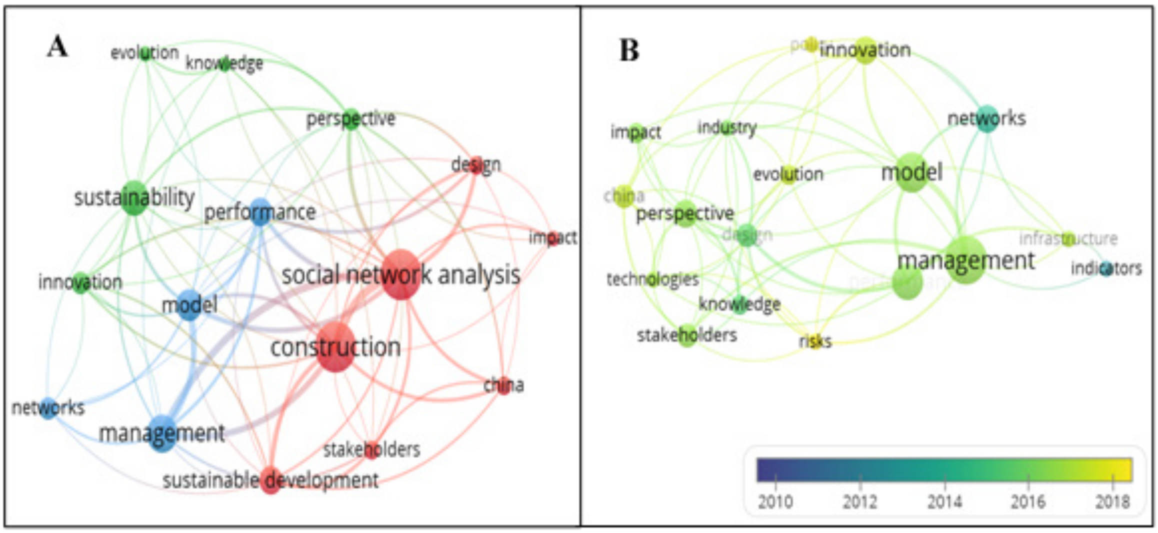

Figure 3: Keyword co-occurrence networks

For co-citation network, minimum number of publications threshold was set to 3 documents for a country. Accordingly, 10 countries appeared, while countries outside the main co citation cluster were excluded which resulted in a network of 6 countries with most number of co citations (refer to the network in Figure 4). Node sizes of the network are arranged according to the number of publications for each country. Node colours represent the time scale of publications while link weightages represent the frequency of co-citations. China leads with the highest number of publications (15 papers) in the field and the strongest co-citation link is shown between Australia and China. Further, the pie chart in Figure 4 emphasises the percentage number of publications for each country, out of the set of identified journal publications. All the aforementioned findings point to a rising attention in the use of SNA for the management and improvement of sustainable construction in the region of China.

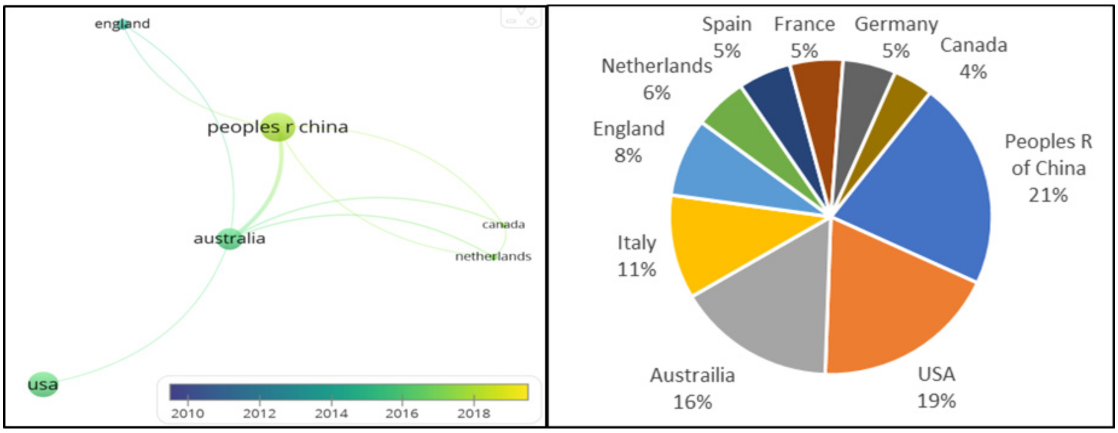

Figure 4: Co-citation network and percentage of publications

4. REVIEW OF SNA METHODS USED IN SUSTAINABLE CONSTRUCTION MANAGEMENT

4.1 REVIEW METHODS

This section is focused on comprehensively analysing the SNA methods employed in the field of sustainable construction. Therefore, the initial set of 73 publications were analysed to filter and identify the most relevant papers. Even though most of the papers showed the application of SNA theories and discussions, there were only 17 papers which constructed social network matrices through data collection processes and employed SNA quantitative methods. Though the number of papers was less, the most appropriate studies were identified to perform the intended review. The following sections describe the data collection methods, analysis techniques, network structures, knowledge areas and significant outcomes of SNA related studies in the field of sustainable construction.

4.2 REVIEW RESULTS

4.2.1 Data Collection Methods Used to Identify Nodes and Links for Social Networks

Identification of nodes and links are the main two facets in data collection essential to develop social network structures (Borgatti, 2013). Researchers use different types of techniques for the data collection in SNA related studies such as interviews, observations, surveys and data mining (Wasserman and Faust, 1994). Figure 5 shows a comparative representation of data collection methods utilised to identify nodes and links in the selected 17 papers. Literature findings, questionnaire surveys and interviews are frequently used for the identification of nodes while questionnaire surveys, workshops and interviews are commonly used to identify the links.

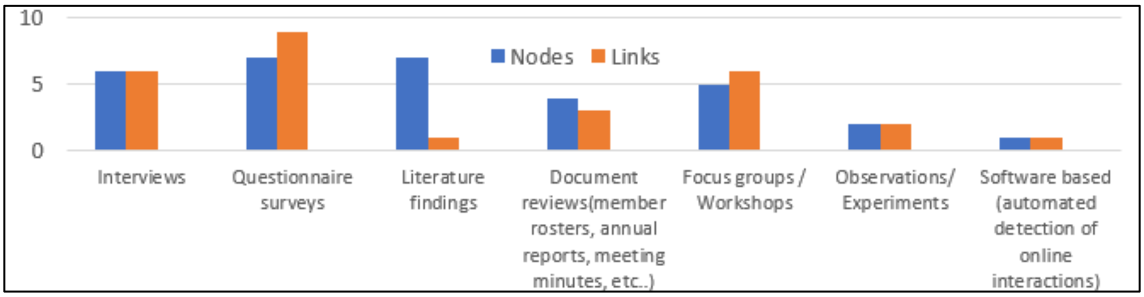

Figure 5: A comparison of data collection methods for nodes and links

4.2.2 Social Network Quantitative Analysis Methods

Scholars have utilised numerous social network based quantitative analysis methods to interpret their findings in different contexts. Among the diverse methods, Centrality and Density measures are frequently used and popular among scholars (Lee *et al*., 2017; Butts, 2018). The publications reviewed in the current study also have incorporated a number of different social network based quantitative analysis techniques. Most of the studies have adapted multiple measures depending on the projected outcomes. Thus, Table 1 shows the frequently used quantitative analysis methods in the reviewed 17 papers with the number of occurrences and a brief description of the respective method.

Table 1: SNA quantitative measures

SNA method	**Times used**	**Description** (Wasserman and Faust, 1994; Loosemore, 1998)
Degree centrality	14	Measures the level of connectivity of a node (Number of links)
Betweenness centrality	13	Measures the extent which a node lies between other nodes. (A higher value indicates a better control over the information/ impact passing across the node)
Network density	7	Ratio of the number of ties to the maximum possible ties.
Out degree	7	Number of out coming connections from a node (impact to)
In degree	6	Number of incoming connections to a node (impacted by)
Closeness centrality	6	Measures the score of each node based on the length of the path to all other nodes by calculating the shortest paths
Degree difference	3	Difference between the in-degree and out-degree values

4.2.3 Social Network Structures

Most of the existing studies show the links between same type of nodes in networks which are referred as one mode networks (e.g. “actor – actor”, refer to Network 1 in Figure 6). Further, there are some studies with two different types of entities which are identified as two mode networks (e.g. “actor-event”, refer to Network 3 in Figure 6) (Borgatti, 2009; Pryke, 2012). Networks with more than two different types of nodes are less in practice due to limited analysis capabilities. Moreover, several studies can be identified which assigned the combined effect of two entities as a node in one mode networks (refer to Network 2 in Figure 6)

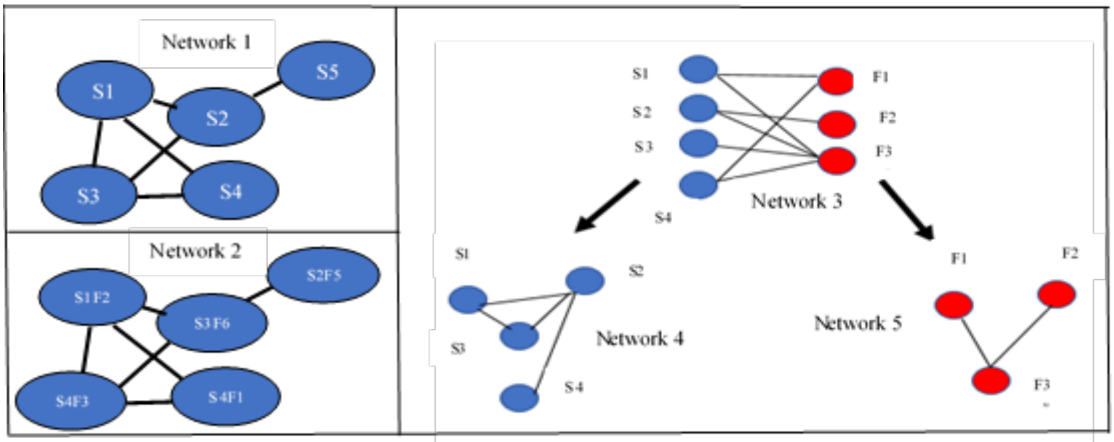

Figure 6: Network structures

To feed data into a network, a network analysis matrix should be prepared to identify interrelations among nodes, which is known as the adjacency matrix. These "actor-event" adjacency matrices can be converted into "actor-actor" and "event-event" matrices considering whether a pair of actors are associated with the similar event or whether two events are related with each other through a common actor (Borgatti, 2009; De Nooy *et al.*, 2011). Accordingly, two mode networks can be converted to one mode networks to explore the unseen relationships and results (refer to Networks 3, 4, and 5 in Figure 6)

4.2.4 Sustainability Knowledge Areas and SNA Applications

Table 2 shows the applications of aforementioned network arrangements (Figure 6) in the reviewed papers. Studies 1 to 9 utilised the structure of Network 1 while studies 10-12 and 13-15 used the structures of Networks 2 and 3 respectively. Further, two-mode to one-mode conversion and analysis techniques can be identified in the studies 16 and 17.

Table 2: Sustainability knowledge areas and SNA applications

	Authors	Areas	Applications and outcomes of SNA
1.	Zedan and Miller (2017)	Energy management	To visualise strongly linked stakeholders and information dissemination patterns influencing energy efficiency.
2.	Li *et al.* (2017)	Energy management	To assess stakeholder engagement and communication for the effective implementation of net zero energy homes
3.	El-Diraby *et al.* (2017)	Green buildings/ technologies	To visualise online stakeholder interactions in a Building Information Modelling (BIM) platform to identify patterns of green information communication.
4.	Xue *et al.* (2018)	Economical sustainability	To assess the stakeholder collaborative arrangements to compare with cost performances of projects.
5.	Schröpfer *et al.* (2017)	Knowledge management	To map the knowledge flow among stakeholders related to sustainable techniques, technologies and materials.
6.	Wang *et al.* (2018)	Social sustainability	To visualise stakeholder interactions for the improvement of social sustainability in construction
7.	Doloi (2012)	Social sustainability	To identify most influencing stakeholders for the social performance of infrastructure projects

	Authors	Areas	Applications and outcomes of SNA
8.	Cross *et al.* (2017)	Social/Energy performance	To assess the centralised participants and to identify the knowledge and information flow across the network.
9.	Korkmaz and Singh (2012)	Knowledge management	To analyse team interactions of student teams leaning sustainable construction practices
10.	Wu *et al*. (2018)	All pillars of sustainability	To assess the network of stakeholder associated indicators for evaluating mega sustainable construction projects
11.	Yang and Zou (2014)	Green buildings/Risk	To map the interactions and assess stakeholder associated risks in complex green building projects
12.	Yang *et al*. (2016)	Green buildings/Risk	To understand key risk networks by modelling networks of stakeholder associated risks in green building projects
13.	Almahmoud and Doloi (2015)	Social sustainability	To map and assess the relationships between stakeholders and social core functions
14.	Liang *et al*. (2015)	Green retrofits	To map and assess the interactions between stakeholders and critical success factors for green retrofits.
15.	Coles *et al.* (2016)	Energy management	To analyse the linkage between energy efficient microgeneration installations for buildings and associated organisations
16.	Yuan *et al.* (2018)	Social risk management	To assess the relationships between stakeholders and social risks in construction projects
17.	Xiaodong *et al*. (2018)	Green buildings	To map the factors affecting green residential building projects with project phases and analyse the connectivity between the factors by converting to one- mode networks

5. A FUTURE RESEARCH DIRECTION

The focused review of existing publications exhibited an increasing demand in SNA applications for stakeholder management in the sustainable construction sector. Yet, a lack of concern can be observed for two-mode network approaches (as described in section 4.2.3). Further, most of the studies overlook the stakeholder relationships and interdependencies without considering coalitions in different project life cycle phases (refer Table 2). Thus, a conceptual model is suggested which can be effectively utilised to visualise and analyse the integration of stakeholders with project life cycle phases focusing sustainability initiatives (refer Figure 7). This model presents a two-mode network approach with meaningful one mode conversions and analysis pathways.

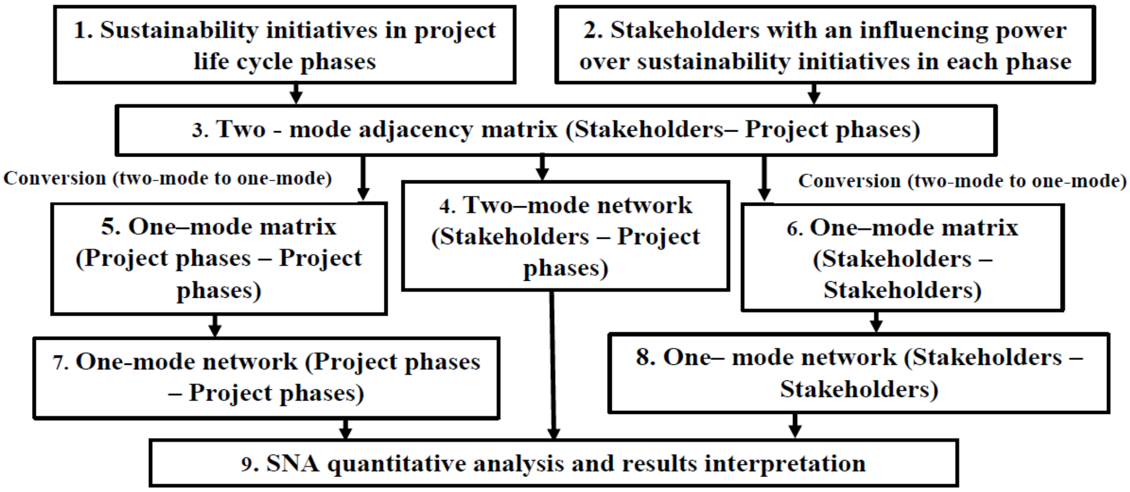

Figure 7: A conceptual model for assessing collaborative commitment for sustainability

6. CONCLUSIONS

A critical review of the existing literature revealed an increasing demand in SNA applications for mapping and improving sustainability in the construction sector. The bibliometric analysis results indicate a rising attention in China followed by USA and Australia. Subsequently, a deeper understanding of collaborative arrangements of various entities can be derived through extensive SNA measures like Centrality and Density. The review results show that researchers have utilised the network structures in numerous ways to achieve intended outcomes and the use of SNA one-mode structures is seen to be more popular than two-mode and multi-mode structures. Results further emphasised that SNA has been widely utilised in the sustainability knowledge areas like Green Construction, Energy Management and Social Sustainability. Lastly, the proposed conceptual model provides an effective platform to analyse stakeholder collaborations for life cycle sustainability initiatives. Although, SNA provides a comprehensive platform to analyse collaborative arrangements, effective data collection on the relational aspects of each node is critical for the accuracy of network development. Inaccuracy of the relational attributes of one node can significantly affect the overall network structure and outcomes. Nevertheless, SNA has provided a valuable contribution for mapping and improving the sustainable construction management. This paper enhances the existing knowledge by providing a structured review of the application of SNA in sustainable construction practices and suggesting a future research direction with a novel conceptual model. The outcomes will benefit future researchers in this field to identify previous applications and build up effective research focus areas; and also assist practitioners in gaining an overview of their present interactions in pursuing sustainable construction and also indicating any duplication, gaps or other weak areas to be addressed, so as to increase the effectiveness and efficiency of their sustainability endeavours.

7. REFERENCES

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

Alves, H., Raposo, M., and Wagner, E., 2012. A model for stakeholder classification and stakeholder relationships, *Management Decision*, 50(10), pp.1861-1879.

Bodin, Ö. and Crona, B. I., 2009. The role of social networks in natural resource governance: What relational patterns make a difference?. *Global Environmental Change*, 19, pp.366-374.

Borgatti, S. P., 2013. *Analyzing social networks*, Los Angeles: Sage.

Borgatti, S.P., 2009. Social network analysis: Two-Mode Concepts. In R. Meyers (ed.), *Encyclopaedia of Complexity and Systems Science,* Springer: New York.

Borgatti, S.P. and Foster, P.C., 2003. The network paradigm in organizational research: a review and typology. *Journal of Management*, 29(6), pp.991-1013.

Butts, C. T., 2008. Social network analysis: A methodological introduction. *Asian Journal of Social Psychology*, 11, pp.13-41.

Chinowsky, P. and Taylor, J.E., 2012. Networks in engineering: an emerging approach to project organization studies. *Engineering Project Organization Journal*, 2(1/2), pp.15–26.

Coles, A.M., Piterou, A. and Genus, A., 2016. Sustainable energy projects and the community: Mapping single-building use of microgeneration technologies in London. *Urban Studies*, 53, pp.1869-1884.

Cross, J., Shelley, T. and Mayer, A., 2017. Putting the green into corrections: Improving energy conservation, building function, safety and occupant well-being in an American correctional facility. *Energy Research and Social Science*, 32, pp.149-163.

De Nooy, W., Mrvar, A. and Batagelj, V., 2011. *Exploratory Social Network Analysis with Pajek*, Cambridge University Press: Cambridge.

De Silva, N., Weerasinghe, R., Madhusanka, H., and Kumaraswamy, M., 2017. Relationally integrated value networks (RIVANS) for total facilities management (TFM). *Built Environment Project and Asset Management*, 7(3), pp.313-329.

Doloi, H., 2012. Assessing stakeholders' influence on social performance of infrastructure projects. *Facilities*, 30, pp.531-550.

El-diraby, T., Krijnen, T. and Papagelis, M., 2017. BIM-based collaborative design and socio-technical analytics of green buildings. *Automation in Construction*, 82, pp.59-74.

Hu, Y., Chan, A.P., Le, Y. and Jin, R.Z., 2013. From construction megaproject management to complex project management: Bibliographic analysis. *Journal of management in engineering*, *31*(4), p.04014052.

Kilduff, M. and Tsai, W., 2003. *Social Networks and Organizations*, London: Sage.

Korkmaz, S. and Singh, A., 2012. Impact of Team Characteristics in Learning Sustainable Built Environment Practices. *Journal of Professional Issues in Engineering Education and Practice*, 138, pp.289-295.

Kumaraswamy, M. M., Anvuur, A. M. and Smyth, H. J., 2010. Pursuing "relational integration" and "overall value" through "RIVANS". *Facilities*, 28, pp.673-686.

Lee, C.Y., Chong, H.Y., Liao, P.C. and Wang, X., 2017. Critical review of social network analysis applications in complex project management. *Journal of Management in Engineering*, *34*(2), p.04017061.

Li, H., Patel, D., Al-Hussein, M., Yu, H. and Gül, M., 2018. Stakeholder studies and the social networks of NetZero energy homes (NZEHs). *Sustainable Cities and Society*, 38, pp.9-17.

Liang, X., Shen, G. Q. and Guo, L., 2015. Improving Management of Green Retrofits from a Stakeholder Perspective: A Case Study in China. *International Journal of Environmental Research and Public Health*, 12, pp.13823-13842.

Loosemore, M., 1997. Construction crises as periods of social adjustment. *Journal of Management in Engineering*, 13(4), pp.30-37.

Loosemore, M., 1998. Social network analysis: using a quantitative tool within an interpretative context to explore the management of construction crises. *Engineering, Construction and Architectural Management*, *5*(4), pp.315-326.

Manley, K., 2002. Partnering and Alliancing in road projects in Australia and internationally. *Road and transport research*, vol. 11, no. 3, pp. 46-60.

Pryke, S., 2012, *Social Network Analysis in Construction*, UK: Wiley-Blackwell.

Schröpfer, V. L. M., Tah, J. and Kurul, E., 2017. Mapping the knowledge flow in sustainable construction project teams using social network analysis. *Engineering, Construction and Architectural Management*, 24, pp.229-259.

Scott, N., Cooper, C. and Baggio, R., 2008. Destination networks – theory and practice in four Australian cases. *Annals of Tourism Research*, 35(1), pp.169-188.

Tichy, N.M., Tushman, M.L. and Fombrun, C., 1979. Social network analysis for organizations. *The Academy of Management Review,* 4(4), pp.507-519.

Vechan, E., 2015. Using social network analysis for civil infrastructure management. In Truax, D. D., El-adaway, I. H., Gude, V., Keith, J., Martin, J. and White, T. (ed.). ProQuest Dissertations Publishing.

Wang, H., Zhang, X. and Lu, W., 2018. Improving Social Sustainability in Construction: Conceptual Framework Based on Social Network Analysis. *Journal of Management in Engineering*, *34*(6), p.05018012.

Wasserman, S., and Faust, K., 1994. *Social Network Analysis: Methods and Applications,* Cambridge University Press, Cambridge.

Wu, G., Qiang, G., Zuo, J., Zhao, X. and Chang, R., 2018. What are the Key Indicators of Mega Sustainable Construction Projects? -A Stakeholder-Network Perspective. *Sustainability*, 10(8), p.2939.

Xiaodong, Y., Jiayu, Z. and Xianbo, Z., 2018. Factors Affecting Green Residential Building Development: Social Network Analysis. *Sustainability*, 10, p.1389.

Xue, H., Zhang, S., Su, Y., Wu, Z. and Yang, R. J., 2018. Effect of stakeholder collaborative management on off-site construction cost performance. *Journal of Cleaner Production*, 184, pp.490-502.

Yang, R. J., Zou, P. X. W. and Wang, J., 2016. Modelling stakeholder-associated risk networks in green building projects. *International Journal of Project Management*, 34, pp.66-81.

Yang, R. J. and Zou, P. X. W., 2014. Stakeholder-associated risks and their interactions in complex green building projects: A social network model. *Building and Environment*, 73, pp.208-222.

Yuan, J., Chen, K., LI, W., JI, C., Wang, Z. and Skibniewski, M. J., 2018. Social network analysis for social risks of construction projects in high-density urban areas in China, *Journal of Cleaner Production*, 198, pp.940-961.

Zedan, S. and Miller, W., 2017. Using social network analysis to identify stakeholders' influence on energy efficiency of housing. *International Journal of Engineering Business Management*, 9, pp.1-11.

Zheng, X., Le, Y., Chan, A. P. C., Hu, Y. and Li, Y., 2016. Review of the application of social network analysis (SNA) in construction project management research. *International Journal of Project Management*, 34, pp.1214-1225.

Seidu, R.D., Young, B.E., Thayaparan, M., Rodmell, S., Robinson, H., 2019. Mechanical and electrical (M&E) training for quantity surveyors to contribute to carbon reduction in buildings. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 453-463. DOI: doi.org/10.31705/WCS.2019.45. Available at: https://2019.ciobwcs.com/papers

MECHANICAL AND ELECTRICAL (M&E) TRAINING FOR QUANTITY SURVEYORS TO CONTRIBUTE TO CARBON REDUCTION IN BUILDINGS

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ABSTRACT

Estimates on the level of carbon emission varies but it is generally accepted that buildings consume about half of energy and contribute to greenhouse gas emissions. Mechanical and electrical (M&E) services accounts for a significant proportion of building projects. Apart from the cost effect, a reduction in carbon footprint can be achieved through M&E services as the capital allowances system and tax relief provides the mechanism to promote sustainability through innovation in green technologies and energy efficiency. However, the training of quantity surveyors in M&E is often ad hoc making it difficult to realise the maximum potential in carbon reduction. The aim of the study is to enhance the M&E trainings to the Quantity Surveyors (QSs) in order to better contribute to carbon reduction and sustainability of buildings. The objectives were formulated as to examine the opportunities for carbon reduction through capital allowances and tax relief and the training implications for QSs. Using an explorative survey and semi-structured interviews, the study found significant gaps in knowledge of the quantity surveyors as limited attention is given to training in M&E services. There is need for a review of training programmes to ensure that the QS professionals can maximise the potential in reducing carbon emission through the provision of appropriate cost advice on M&E services that will benefit from capital allowances and tax relief. Other countries can learn from the experience of the UK Government policy, statutory and regulatory framework that underpins the development of capital allowances and tax relief to change behaviour by providing tax and fiscal incentives that will have a positive impact on carbon reduction to mitigate climate change.

Keywords: *Capital Allowances; Carbon Emission; Mechanical and Electrical (M&E); Quantity Surveyor; Sustainability; Tax Relief.*

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1. INTRODUCTION

Climate change has been an integral part of the UK government agenda since the Rio, Kyoto and Paris Summits, and it is recognised today as one of the world's most challenging issues to address (Myers, 2005). The UK government as part of its response have created the legislative framework underpinned by policies and strategies for improving the heat efficiency of buildings responsible for significant carbon emission. Estimates on the level of emission varies but it is generally accepted that buildings consume about half of energy and contribute to greenhouse gas emissions (Miller and Buys, 2008). For example, commercial property in the UK produces 10% of greenhouse gas emissions and consumes 7% of energy. It is also estimated in the UK that by 2050 about 70% of today's buildings will be standing, with 40% built before 1985 (Dixon, 2014). The UK energy policy has been redesigned recently to respond to this challenge of minimizing the impact on climate change by creating buildings with zero carbon emissions (Stevenson, 2013). In the UK, several government initiatives encouraging reform in the construction industry have been published.

Mechanical and electrical (M&E) services are significant in construction projects in relation to the building total cost. Apart from the cost effect, issues such as energy performance, sustainability, innovation, and life cycle performance have become critical in meeting the government target of reducing carbon through decarbonisation and energy reduction in built environment. Reducing carbon footprint can also be achieved through an appropriate selection of M&E services that will benefit from tax relief as part construction expenditure. However, the industry professionals need to be trained especially those who are responsible for giving cost or procurement advice to maximize the potential in reducing carbon emission in construction projects. The Governments policy, statutory and regulatory framework are in the form of taxation and levies, reliefs and allowances such as plant and machinery allowances, enhanced capital allowances (ECAs), subsidies and other incentives (HM Government, 2011).

Concern is often expressed regarding the challenge of meeting the requirements of clients in terms of capital expenditure (Capex) and operating expenditure (Opex) of construction projects using more sophisticated project appraisal and cost control techniques that reflects life cycle costs, cash flow and indirect costs such as taxation. However, the client's requirement must be balanced against any regulation, rules, energy sources and the liquidity of the project (HM Government, 2011). Farey (2015) argued that a longer-term approach of whole life cost will provide a more balanced picture reflecting economics, energy and carbon. The challenge for professionals in the built environment, including quantity surveyors is to find an approach where economic, social and environmental factors can be effectively captured for the clients through tax relief and capital allowances for profit maximisation. The assets that benefit from tax relief and capital allowances are mainly mechanical and electrical systems, and related systems such as cold water systems, lifts, escalators and moving walkways, external solar shading, space or water heating systems. However, limited attention is given to training of quantity surveyors in M&E services to maximize the potential in reducing carbon emission through appropriate cost advice on tax relief and capital allowances available for a range of technologies. In this context this paper addresses to examine the scope and opportunities for carbon reduction through M&E services and to assess the implications for the training of quantity surveyors (QSs) in M&E services.

2. RESEARCH METHODOLOGY

The objectives of the study were to examine the scope and opportunities for carbon reduction through M&E services, with particular focus on capital-allowances and tax-relief, and to assess the implications for the training of quantity surveyors (QSs) in M&E services. The objective on examining the scope and opportunities for carbon reduction through capital allowance and tax relief was achieved through a comprehensive literature review, which has been presented in the next section. In addition, data was collected on twenty-two (22) completed high rise building projects using the Building Cost Information System (BCIS) database to assess the provision of M&E in elemental cost plans in order to highlight the significance of M&E in relation to the total building cost and to find out the scope for reducing the carbon foot print of a project. An exploratory survey was also conducted to establish the M&E related factors that are significantly contributing to the quality of cost plans. As part of this survey, fifty (50) questionnaires were distributed to industry professionals such as Project Quantity Surveyor (PQS) firms/consultancies, main contractors, M&E sub-contractors and specialist M&E sub-contractors and twenty-six (26) completed questionnaires were received, making a response rate of 52%. Finally, three (3) in-depth qualitative expert interviews were conducted to assess the training implications for the QSs.

3. LITERATURE REVIEW

3.1 SIGNIFICANCE OF M&E SERVICES IN BUILDINGS

The provision of mechanical and electrical (M&E) services is a significant component of a building's overall cost, and in determining the relative success of a project (Cunningham, 2017). The more complex the building, the greater the M&E input that will be required and often the value of M&E can easily exceed other elements of a building project. The total cost of M&E services has grown significantly over the last two decades due to rapidly developing technology, innovation and stringent BREEAM (Building Research Establishment Environmental Assessment Method) requirements (Li *et al*, 2013). For example, M&E costs for traditional buildings has risen from 15 to 30% to between 15 to 70% of the total building costs depending on the sophistication of the services (Rawlinson and Dedman, 2010). Hence, there is a need for robust cost planning procedures at both pre and post contract stages of a project to ensure the cost of M&E services is adequately controlled and managed as the design evolves (Swaffield and Pasquire, 2000).

After evaluating cost plans prepared by PQS on twenty-six different projects, Yusuf and Mohamed (2014) found that 97% of cost plans were based on incomplete design information. The more uncertain the design information is at pre-contract stage, the more risk there is for the client at tender stage (Davies *et al*., 2009). This is further complicated by the practices of some specialist M&E sub-contractors who hold back design ideas to gain competitive advantage during the tender, leading to difficulties in improving design solutions and providing reliable estimates (Mathew and Howell, 2005). Yusuf and Mohamed (2014) also noted that works not shown on M&E consultant drawings were covered with provisional items including Bills of Quantities (BQ)/pricing schedules used for tendering purposes. Potts (2008) argued this approach of lump sum provision create a significant risk for the contractor for items missed by the PQS/M&E Consultant. Odeyinka *et al* (2009) noted that this practice made it extremely difficult and created problems in determining contractors' interim valuations and pricing variations for M&E sub-contractors. Oforeh (2008) further noted that M&E services were not classified properly in sections as only 10% of the cost plans reviewed made references to the appropriate location of work i.e. external, internal or roof, to allow the tenderer to make necessary allowances. Yusuf and Mohamed (2014) also cited numerous elements such as measurement of pipework and fittings including necessary accessories not clarified in the cost plans. Potts (2008) argued that this practice defeated the idea of a BQ, which is meant to provide a uniform basis for a tenderer and process of "market tests" by the PQS. For example, items such as Conduit, Trunking, Cable Tray and Cable are measured separately in the BQ but in all the cost plans they were lumped in together.

3.2 CAPITAL ALLOWANCES AND TAXATION ON M&E SERVICES

The capital allowances and tax relief is a specialist area within the construction industry in the UK with one of the most complex and opaque tax codes (BBC, 2010). The issue becomes complicated when working to meet the sustainability target of the government on low energy and carbon reduction. The capital allowances provide some relief on capital expenditure incurred by clients and end users as they reduce taxable profits which represent real savings. Capital allowances on M&E services include: plant and machinery assets, fixtures and chattels, renovation of a business premises, expenditure on research and development and enterprises Zone allowances backed by the capital allowances Act 2001 and Finance Act 2008. Enhanced Capital Allowances (ECAs) was introduced in 2001 in responding to the Kyoto Agreement to reduce UK carbon emission. The assets which are considered are mainly mechanical and electrical systems, cold water systems, lifts, escalators and moving walkways, external solar shading, space or water heating systems. Such assets or systems are for improving the electrical efficiency of lighting and appliances, including the use of heating systems with renewable energy sources which can change building owners and occupiers' behaviour. In the UK, capital allowances can improve investment yield and reduce tax liability in property transactions, with the aim of achieving a significant reduction in carbon emissions through reducing demand for energy in buildings, reducing water usage, decarbonising heating and cooling supply (Robinson *et al*, 2015). Capital allowances are also available on expenditure incurred on refurbishment and fitting out works. Businesses are often under the misconception that becoming an environmentally responsible corporation can be costly and complicated. Nevertheless, significant savings can be achieved on energy bills through the government's Enhanced Capital Allowances (ECA) scheme (Remark Group, 2013).

Modern energy-efficient equipment can be installed into existing fittings to minimise energy bills which, coupled with the government's ECA scheme, could offer return on investment within two to three years. It is important that industry professionals such as quantity surveyors responsible for cost advice understand where saving opportunities may lie. The UK government aim to achieve 34% reduction in carbon emissions by 2020 and half of the heat used in buildings will come from low carbon technologies by 2030 which will be backed up by government statue (HM Government, 2011). As part of the government's climate change management programme, the Enhanced Capital Allowances (ECA) provides 100 per cent first year capital allowance for businesses investing in energy-saving equipment. Companies can apply for assistance with upgrades through the ECA scheme, with the tax relief also extending to parts and labour. As of 1st December 2012, there were 15,968 energy-efficient products eligible for 100 per cent tax relief (Remark Group, 2013). Eligibility is determined from the Energy Technology List

(ETL) which is typically product specific to review whether they will benefit from ECA (Farey, 2015). For residential or certain charitable developments, consideration is on energy-saving materials subject to a reduced rate of VAT. A variety of tools are available to assess carbon emission such as the Carbon Calculator (Faithful + Gould, 2012). Technologies contribute to carbon reduction on variety of M&E services. Some examples are; a high efficiency boilers increase capital cost (Capex) by £9,000 (£1/m^2), reduce annual running cost (opex) by £15,000 but significantly reduce carbon emissions (35,000 kg CO_2 per annum or 4kg CO_2/m^2); geothermal and heat pumps increase capital cost (capex) by £55,000 (£6.5/m^2), decrease annual running cost (opex) by £6,000 with significant reduction in annual carbon emission by 28,000 kg CO_2 (3.5 kg CO_2/m^2); high efficiency lighting controls initially increase capital cost (capex) by £230,000 (£27/m^2), decrease annual running cost (opex) by £4,000 with significant reduction in annual carbon emission by 12,000 kg (1.5kg CO_2/m^2); and Photovoltaics (PV) increase capital cost (capex) by £510,000 (£60/m^2), decrease annual running cost (opex) by £11,000 with significant reduction of carbon by 61,000 kg CO_2 (7.5 kg CO_2/m^2) (Lockie, 2015).

3.3 SKILLS OF PROFESSIONAL QUANTITY SURVEYOR'S (PQS)

Due to the rising and significant proportion of building cost that is represented by M&E services, the demand for measurement skills required to produce bills of quantities (BQ) for M&E services is increasing (McCaffrey, 2010). However, PQS's and main contractor QS's do not have the required skills and knowledge to provide adequate cost advice for M&E services (Olanrewaju and Anahve, 2015). Ashworth *et al*., (2013) found that most PQS firms consider M&E services as the responsibility of a specialist. Some PQS firms only provide mainstream QS services that are focused on the entire project including all specialist work packages. However, certain consultancies employ dedicated M&E specialist QSs to manage the M&E section of all projects.

Earlier studies by Swaffield and Pasquire (2000) noted that there were problems with the knowledge base and skills of quantity surveyors relating to the technologies associated with M&E services. Most recently, Mitchell (2016) identified the main barrier as the lack of technical knowledge of the PQS in the development of fully measured mechanical and electrical BQ. Mitchell (2016) also noted that M&E sub-contractors had inadequate experience with items measured in BQ by the PQS. Cunningham (2017) argued that incomplete designs and lack of M&E knowledge by PQS's has contributed to the absence of detailed measurement of M&E services in the production of bills of quantities. Mitchell (2016) noted that PQS consultancies were still best placed to control project costing but there is a need for upskilling on the technology side. It is widely acknowledged that main contractors' QS also lack M&E knowledge but their interaction with the M&E sub-contractors' QSs provide strong channels for knowledge transfer and support upstream (Olanrewaju and Anahve, 2015). Though QSs have a better understanding of M&E services compared to twenty years ago (Cartlidge, 2011), clients are increasingly frustrated with the inability of PQS's to provide accurate cost advice in their cost plans for M&E services as using lump sum approaches to price M&E services is inadequate (Olanrewaju and Anahve, 2015). It was further noted by Olanrewaju and Anahve (2015) that despite the existence of limited specialist degree programmes in place at UK universities, there are still question marks with regard to the quality and content of the programmes in terms of the required knowledge expected of M&E quantity surveyors including measurement skills in M&E works. Ashworth *et al*. (2013) argued that Quantity

Surveyors, who do not possess the required competencies, could not provide value added service for the Client, design team or their employer.

4. FINDINGS AND DISCUSSIONS

4.1 COST OF M&E SERVICES IN BUILDING PROJECTS

M&E services are categorised in the Building Cost Information Service (BCIS) database into various sub-elements. For example, 5F (Space Heating and Air Conditioning), 5H (Electrical Installations), 5K (Fire and Lightning Protection) or 5L (Communications and Security Installations). Investing in carbon efficient M&E services can significantly reduce the demand for energy and carbon footprint. Prevention is better than cure as money spent putting measures in place at the initial stage of a project by exploring the provision for enhanced capital allowances systems in meeting the government target can reduce the carbon footprint of a building over its life cycle and promote sustainable homes. Based on 22 projects analysed (See Table 1) from the BCIS database, the cost for M&E provision is significant in building projects.

Table 1: Analysis of M&E provision in projects

	Description and type	No of Storey	Building Cost (£)	Floor area (m^2)	M&E Cost (£)	M&E as % of Building Cost	M&E Cost (£/m^2)
1	New 45 Flats	6	£6,303,654	3,863m^2	£1,494,452	24	£387
2	New 11 Apartments	6	£1,274,196	845m^2	£190,880 Not explicit	15	£226
3	New 136 Flats and 13 Houses	7	£17,154,111	14,799m^2	£4,763,970	28	£322
4	New 66 Apartments	6	£7,732,617	7,367m^2	£2,002,416	26	£272
5	New 188 Flats	10	£26,909,535	20,439m^2	£5,871,855	22	£287
6	Refurbishment of 9 Luxury Flats	6	£3,366,871	1,081m^2	£891,232	27	£824
7	New 17 Flats	6	£1,370,581	1,461m^2	£333,055 Not explicit	24	£228
8	New 60 Flats	7	£6,877,891	5,798m^2	£1,506,881 Not explicit	22	£260
9	New 29 Flats	7	£2,817,140	2,161m^2	£837,498	30	£388
10	New 27 Flats	7	£2,916,416	2,343m^2	£590,868	20	£252
11	New 67 Flats	7	£8,067,258	5,995m^2	£2,286,888 Not explicit	28	£381
12	Conversion of Offices to Flats	6	£2,984,391	1,078m^2	£1,067,266 Not explicit	36	£990
13	New Flats	6	£4,296,806	3,856m^2	£1,132,466 Not explicit	26	£294
14	Apartments	8	£2,667,871	2,695m^2	£641,340 Not explicit	24	£238

	Description and type	No of Storey	Building Cost (£)	Floor area (m^2)	M&E Cost (£)	M&E as % of Building Cost	M&E Cost (£/m^2)
15	New 12 Flats	6	£1,058,579	963m^2	£176,992 Not explicit	17	£184
16	New Houses and Flats	7	£8,314,764	9,229m^2	£176,992 Not explicit	2	£184
17	New Apartment Block	10	£22,462,729	9,633m^2	£7,871,300	35	£817
18	New Holiday Apartments	6	£3,049,550	1,832m^2	£722,866	24	£395
19	Fitting Out of Flats	6	£947,798	1,851m^2	£191,555	20	£103
20	New General and Wheelchair Flats	7	£2,508,756	2,157m^2	£710,013 Not explicit	28	£329
21	New Apartment Block	10	£8,723,304	6,202m^2	£2,249,844	26	£363
22	Conversion of Office Block to Flats	9	£1,398,015	999m^2	£523,796	38	£524

Table 1 shows that the cost of M&E provision is significant in most of the projects with M&E cost of 19 out of 22 projects of at least 20% of the total building cost. In over 10 projects, the M&E cost in relation to total building cost exceeded 25%. In 8 projects, the M&E cost is 20-24% of the total building cost. However, a common barrier to the realising the potential to reducing carbon is the lack of an explicit approach to costing specific items for M&E provision in the cost plan. There is an over reliance on ad hoc approaches with limited specification that affects the accuracy of costing for M&E as well as the potential to explore sustainable technologies to reduce carbon. The findings suggest there is a need for adequate specification for M&E in the cost plan in order to strengthen the link between M&E services and carbon reduction through the enhanced capital allowances system and tax relief.

4.2 Reasons for Poor Quality in M&E Cost Advice and Cost Plan

Of the 50 questionnaires sent out 26 were completed and analysed. Most of the respondents (91%) were quantity surveyors with 83% having more than five years work experience in the construction industry, where 63% were at senior management level. About two-thirds surveyed (62.5%) were M&E specialists. The purpose of this survey was to explore the factors contributing to the improved quality of cost plan. It is vital that the QSs should be able to ascertain the costs associated with M&E services clearly in order to find out how and where the carbon reduction can be achieved. Based on Table 1, it is clearly evident that in almost half of the projects the M&E provisions are not clearly accounted or specified. Hence, the questionnaire survey identified the main causes for this lack of quality of M&E services in cost plans. The two major causes identified through the questionnaire are lack of consultant's contributions at the design stage and lack of experience or trainings on M&E services for the QSs. Half of the respondents believe the quality of initial M&E design information at RIBA (Royal Institute of British Architect) stages 1and 2 significantly impact on the quality of cost plan. Further, effective communication and level of input by the M&E Consultant at the design stage were significant factors that affect the quality and accuracy of the pre-tender cost plan. It was revealed that due to the significance of M&E costs, the clients expect to receive a better cost advice and cost plan that clearly identifies the M&E cost components. However, that aspect is still lacking among the QSs, as the M&E costs are mostly not quantified. 50% of the respondents received some training to put together an M&E cost plan and believed that the degree or short-term courses undertaken helped in their role. Over half (54%) of participants believed that gaining site experience in installing M&E services, either during graduate training or while working, would improve their ability to understand M&E services. As such, for QSs to produce good cost advice and cost plan on M&E services, improving their knowledge and experience in that filed is vital.

4.3 TRAINING OF QUANTITY SURVEYORS

Expert interviews were conducted to assess the implications of M&E related training for QSs. The findings are discussed below.

4.3.1 Demand for M&E Quantity Surveyors

All three experts interviewed agreed that more M&E QS specialists need to be employed within their organisations as there is currently a small pool of specialist in the industry. As a result, a significant number of projects do not have a specialist M&E QS involved leading to costs that is often inaccurate and unrealistic during cost planning. On smaller projects (post contract), the experts noted that M&E involvement may be limited and more often the M&E services are provided on an ad-hoc basis dealing with specific areas such as on variations etc. One of the experts noted the following:

> *"It is a risk that even on smaller projects if there is no M&E PQS then there could be risks with over-inflated valuations which could mask other more serious issues (such as cash flows) and over exaggerated variation claims".*

Expert B agreed that M&E specialists should have more involvement in the pre-tender costing process and the view of Expert C is that the variation agreements can be hindered by the non-involvement of M&E surveyors. The experts explained that in general PQS's will lean on the Consultant for technical input, however changes related to design issues will be defended by the Consultant naturally and this will slow down the process of agreeing a change and the costs associated with it. Expert A agreed with this ideology and used the phrase "*contractor opportunity*", as they often expose the contractors over inflation.

4.3.2 Need for M&E Specialist Training

All the experts agreed that there is need for significant improvement in the methods and practices used to provide M&E cost advice to improve the certainty of cost advice at pre-tender stage. Expert A referred to the fact that the industry is constantly evolving, and methods and practices need to be kept up to date. Expert B argued that their needs to be an increase in the number of M&E QS's in the industry and better liaison with the design team:

> *"I think the key to improving M&E cost advice is to increase the number of dedicated M&E QS's in the industry and this could be achieved through apprenticeships which will help improve and develop the technical knowledge earlier on. I also feel that on larger projects there can often be a discord within the project team, i.e. a lack of communication between the design team and the cost team which can often create an air of resentment and be a strain on team morale."*

All three experts explained that their undergraduate degree qualifications had no relevance to M&E services as the content of their programmes and the curriculum specifications did not reflect what is actually required to carry out work in designing, measuring and installing M&E services. However, training programme for Expert B included a sandwich year, which helped him prepare for work in industry. The Experts advised that anyone interested in taking up a career in M&E quantity surveying should obtain a job role first and undertake a degree programme through their respective companies, so they can "*learn- on- the- job*" and get a blend of experience from practice and the academic environment.

4.3.3 Developing Appropriate M&E Training Programmes for Industry

Most of the PQS completed general quantity surveying programmes instead of specialised training on M&E due to a shortage of university offering the programme with the appropriate curriculum content. There is only one university that is offering the course, but this is not accessible to students who aspire to become M&E quantity surveyors. The University of Salford offer postgraduate degree programme (PgDip/MSc Mechanical & Electrical Quantity Surveying), with the aim of "*creating reflective practitioners in quantity surveying who have a knowledge and understanding of procurement and financial management and recognise the significance of process, technology and people to the success of mechanical and electrical projects"*. The general degree course has helped PQS to undertake their role with the expectation that sufficient level of M&E on-the-job technical training will be provided. Specialist M&E QS's working for sub-contractors tend to benefit from on-the-job training due to significant site exposure but this needs to be addressed throughout the supply chain. Graduate and trainee surveyors as part of their training, should be spending a period on site, whether as a block period or intermittently. The exposure to installing M&E services on site can benefit quantity surveyors.

5. CONCLUSIONS

The study has examined the potential for reducing carbon emission through the system of capital allowances and tax relief and the implications for the training of QSs in M&E. In order to achieve carbon reduction, it is vital to understand the M&E services associated with a building at the initial stage. But it was evident that in almost half of the building cost plans analysed, there were no clear determination of ME services. A key barrier in reducing carbon in buildings is therefore, the lack of clear determination of M&E services in the cost plans. One contributing factor for this is the lack of technical knowledge of QS's in M&E. Another contributing factor is the ineffective communication with the design team for technical inputs on range of technological options that will attract capital allowances and tax relief and at the same time reduce the carbon footprint. There is a need for the introduction of M&E training programmes to improve the knowledge of QSs in providing M&E cost advice that will help in reducing the carbon footprint of buildings. Colleges, universities, companies and professional organisations including the RICS, CIOB and AMP should be providing and/or supporting through accreditation and sponsorship of M&E training programmes (such as internships, thin and thick sandwich placements, guest lectures) at both undergraduate and postgraduate levels. Through the introduction of appropriate curriculum content in terms of breadth and depth in core building services modules/credits the opportunities in carbon reduction can be achieved using fiscal and tax incentives for sustainable development. Training will ensure more clarity and confidence in dealing with M&E design options and UK complicated tax system so that clients can benefit from tax relief and allowance which will result in achieving the UK Government carbon reduction target in delivering sustainable homes. Other countries can learn from the experience of the UK changing behaviour through tax and fiscal incentives that will have a positive impact on carbon reduction to mitigate climate change.

6. REFERENCES

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

BBC, 2010. Tax system to be simplified to encourage investment [online]. Available from: http://www.bbc.co.uk/news/uk-politics [Accessed 14 March 2019].

Cartlidge, D., 2011. *New Aspect of Quantity Surveying Practice*. UK: Butterworth – Heinemann.

Cunningham, T., 2017. *What Causes Cost Overruns on Building Projects? - An Overview*. School of Surveying and Construction Management, Dublin Institute of Technology, Dublin.

Davis, P.R., Love, P.E. and Baccarini, D., 2009. Bills of Quantities: nemesis or nirvana?. *Structural Survey*, 27(2), pp.99-108.

Dixon, T., 2014. What does "retrofit" mean, and how can we scale up action in the UK sector?. *Journal of Property Investment and Finance*, 32(4), pp.443-452.

Faithful+Gould, 2012. Construction Carbon Calculator [online]. Available from: http://www.fgould.com/carbon_calculator [Accessed 2 February 2012].

Farey, P., 2015. Carbon Reduction and Fiscal Incentives for Sustainable Design. *Design Economics for the Built Environment: Impact of Sustainability on Project Evaluation*, pp.152-176.

HM Government, 2011. The Carbon Plan: Delivering our Low Carbon Future [online]. HM Government. Available from: http://www.hmrc.gov.uk [Accessed 10 March 2019].

HMRC, 2016. HM Revenue and Customs [online]. Available from: http://www.hmrc.gov.uk [Accessed 15, March 2019].

Li, Q., Syal, M. Turner, N. and Arif, M., 2013.Constructors and Innovation Credits in Green Building Projects. *Construction Innovation*, 13, pp.320-338.

Lockie, S., 2015. Life Cycle Costing and Sustainability Assessments: An Industry Perspective with Case Studies. *Design Economics for the Built Environment: Impact of Sustainability on Project Evaluation*, pp.262-283.

Matthews, O. and Howell, G.A., 2005. Integrated project delivery an example of relational contracting. *Lean construction journal*, 2(1), pp.46-61.

McCaffrey, J., 2010. What is an M&E QS?. *Royal Institution of Chattered Surveyors Students Construction Journal*, pp22-23.

Miller, E. and Buys, L., 2008. Retrofitting commercial office buildings for sustainability: tenants' perspective. *Journal of Property Investment and Finance*, 26(6), pp.552-561.

Mitchell, C., 2016. A Time for Change - An Evaluation of the Ability of the Quantity Surveyor to Measure Mechanical and Electrical Services Under the Irish Public Works Contracts (designed by the employer) using the Agreed Rules of Measurement [online]. Other Resources. Paper 61. Available from: https://arrow.dit.ie/beschreoth/61 [Accessed 23 January 2019]

Myers, D., 2005. A review of construction companies' attitudes to sustainability. *Construction Management and Economics*, 23(8), pp.781-785.

Odeyinka, H.A., Kelly, S., and Perera, S., 2009. An Evaluation of the Budgetary Reliability of Bills of Quantities in Building Procurement. *The Construction and Building Research Conference of the Royal Institution of Chartered Surveyors*, 11 September 2009, University of Cape Town. pp.435-446.

Oforeh, E., 2008. *Installation and Electrical Works in Buildings*. 2nd ed., Lagos: Cosines.

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

Potts, K., 2008. Change in the quantity surveying profession. *Collaborative Relationships in Construction*. UK: Wiley, pp.42-58.

Rawlinson., S., and Dedman, D., 2010. Specialist Costs: M&E Services [online]. Davis Langdon Building Magazine. Available from: www.building.co.uk/specialist-costs-me-services/5001903.article [Accessed 15 May 2017]

Remark Group, 2013. Government Enhanced Capital Allowance scheme befits energy-efficient businesses, reminds the Remark Group. *Business Wire (English) Regional Business News*.

Robinson, H., Symonds, B., Gilbertson, B. and Ilozor, B. eds., 2015. *Design Economics for the Built Environment: Impact of Sustainability on Project Evaluation*. John Wiley & Sons.

Stevenson, F., 2013. Reducing energy demand through retrofitting buildings. *Building Research and Information*, 41(5), pp.605-608.

Swaffield, L.M. and Pasquire, C.L., 2000. Improving early cost advice for mechanical and electrical services by considering functions and client/design team communication. *Journal of Financial Management in Construction and Property*, 5(12), pp.3-13.

University of Salford, [online]. Available from http:// www.salford.ac.uk/pgt-courses/quantity-surveying-mechanical-and-electrical [Accessed 12 December 2016]

Yusuf, G.A. and Mohamed, S.F., 2014. Perceived benefits of adopting Standard–Based pricing mechanism for mechanical and electrical services installations. *Construction Economics and Building*, 14(2), pp.104-119.

Mallawaarachchi, H., Sandanayake, Y.G., Karunasena, G. and Liu, C., 2019. Optimising the industrial symbiosis (IS): The proposed redevelopment. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 464-472. DOI: doi.org/10.31705/WCS.2019.46. Available at: https://2019.ciobwcs.com/papers

OPTIMISING THE INDUSTRIAL SYMBIOSIS (IS): THE PROPOSED REDEVELOPMENT

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ABSTRACT

Industrial symbiosis (IS) has been emerged aiming the integration of industrial complexes, in which by-products of materials and energy are using as feedstock instead of being wasted. Since organisations cooperatively increase their mutual sustainable benefits simultaneously through IS, a number of IS projects have been initiated across the whole world. However, most of the projects have been failed and discontinued in long term undermining the expected collaborative gains and efficiencies. Hence, recent studies articulate the necessity of having a standardised mechanism towards implementing the resource efficiency optimised IS designs. Thus, this paper aims to present the issues in the current process of IS development in order to propose a mechanism for redeveloping the process through resource flow efficiency optimisation. A systematic review of key literature was conducted in the areas of IS, its design and implementation procedures. The data collected through the secondary survey was then analysed manually to identify the different stages of the IS development process and related issues. As many scholars recognised, most of IS projects have been discontinued due to the shortcomings and the inefficiencies of the IS development process. Thus, the necessity of having a standardised and more robust model for optimising IS is recognised. Finally, the proposed redevelopment is conceptualised by introducing a new phase of re-evaluation and optimisation modelling to evaluate the symbiosis relationships prior implementation to consider them either for implementing or for re-planning.

Keywords: *Industrial Symbiosis; Issues; Optimisation Modelling; Re-development.*

1. INTRODUCTION

The global transition towards industrial regimes has been linked to the detonation of resource use by many scholars. The extract and dump nature of the industrial systems has burdened the reuse of resources, in which the materials and energy are dumped in a linear flow after been used (Gertler, 1995; Krausmann *et al*., 2009). The need of having efficient and eco-innovative industrial processes has been emerged to reduce the high resource consumption and raw material use encouraging the optimal use and recycling (United Nations Environment Programme [UNEP], 2009). Industrial Symbiosis (IS) has been introduced as a sub field of IE aiming the integration of industrial complexes, in which

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by-products of materials and energy are using as feedstock instead of wasting them (Frosch and Gallopoulos, 1989, Gertler, 1995; Boons *et al*., 2014). Thus, a number of IS projects have been initiated around the world expecting the mutual sustainable benefits (Chertow, 2000; European Commission, 2017; Sun *et al*., 2017; Tao *et al*., 2019). However, most of the projects have been reported as failed in long terms due to inefficiencies and improper design and development methodologies (Golev *et al*., 2015). Further, the shortcomings of the existing top-down approach applied in developing the IS has hindered the stability of IS to come to fruition with expected optimal outcomes, such as optimal resource flow efficiency, cost and environmental efficiencies (Desrochers, 2004; Chertow, 2007).

In line of thinking, this research formulated the main research question as, "How to optimise the resource flow efficiency of IS?". As a part of the above research, this paper aims to present the existing gaps in IS development process in order to justify the proposed redevelopment.

2. RESEARCH METHODOLOGY

This paper was written based on the publications on IS from 1989 to 2019 since its emergence. A systematic review of the key literature in IS was conducted to collect the secondary data. The ISI Web of Science (WoS) developed by Thomson Reuters Scientific is used in review as it has been recognised as mostly use tool to generate quantitative analysis for scientific research (Meho and Yang, 2007). The topic "Industrial Symbiosis" was then used to search the titles of articles published over the years. 841 of results were retrieved in WoS relating to the publications, exploring the topic of "Industrial Symbiosis". Further, the literature in conference papers and organisational reports relate to the IS development were also reviewed. In total, 32 key papers, in the field of IS referring to the concept, its design and development process, were selected.

Majority of the papers were selected from journal published literature, such as Journal of Industrial Ecology, Journal of Cleaner Production, Resources Conservation and Recycling and Sustainability, which is 78% from the total number of publications. Only 22% of literature is related to the conference papers and other institutional reports on IS initiatives across the globe. The majority of the papers were selected to review the conceptual consideration of the IS development, issues and the related case studies including China, Denmark, Netherlands, United States, Europe, New York and Australia to name a few. The selected articles were manually reviewed to identify the current status and the gaps in the process of IS development.

3. KEY LITERATURE FINDINGS

3.1 THE CONCEPT OF INDUSTRIAL SYMBIOSIS

IS is an approach to the apply IE principles (Milani *et al*., 2018). As scholars revealed, IS imitates the behaviour of natural eco systems in which waste of one firm become a resource for another (Grant *et al*., 2010). "IS engages the separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products" (Chertow, 2007, p.12) for mutually agreed economic and environmental paybacks (Christensen, 2006). ISs are industrial networks that cooperatively increase their use of resources among different industries for economic, environmental, and social benefits simultaneously, such as waste elimination, CO_2

savings, water savings, cost savings, creating and safeguarding jobs, name in few (Lieder and Rashid, 2016; Domenech, *et al*., 2019; Maqbool *et al*., 2019). IS grasps a high prospective to make a substantial impact to improve resource efficiency and innovation (Ghali and Frayret, 2019).

3.2 THE APPROACHES FOR DEVELOPING IS IN GLOBAL CONTEXT

A number of IS initiatives have been launched across the whole world since its benefits have been understood (European Commission, 2017; Sun *et al*., 2017; Tao *et al*., 2019). For example, the model of IS was first fully realized in the eco-industrial park at Kalundborg, Denmark (Chertow, 2000). Simultaneously, at least sixty state-level industrial parks have been established in China during last decade, which account for a large proportion of the world's industrial parks (Liu *et al*., 2018). Indeed, the IS networks in European countries have been impacted considerably on their environmental and economic development through water savings, reduction of raw material extraction and carbon emissions reductions. For instance, Scotland has experienced a 38,836.60t of GHG savings while Hungary has obtained 1876t GHG savings, 619t of material savings and 13,018m^3 of water savings during the period of 2007 to 2012 (Domenech *et al*., 2019).

According to IS theory and practice, IS networks can be emerged in different ways and are shown to follow significantly different developmental pathways (Tao *et al*., 2019).To differentiate IS from other types of exchanges, Chertow (2000) firstly introduced a "3-2 heuristic" as the minimum basis to develop the symbiotic relationships. According to this, at least three different firms have to be engaged in the process to exchange at least two types of resources. The initiation of the IS relationships was confronted by Boons *et al*. (2015) by introducing two new perspective of IS, such as, technical and organisational. As Boons *et al*. (2015) further stated, IS can be approached in three different ways from the technical perspective, such as process oriented, residue oriented and place-oriented IS. The process oriented IS considers the corporative network around the industry while the residual flow is the main concern in residue-oriented IS. In place oriented IS, the network is destined to a specific location. There are four different ways to implement IS under organisational perspective, namely anchor manufacturing, eco-cluster development, government planning and the business incubator (Boons *et al*., 2011).

In 2012, Chertow and Ehrenfeld (2012) introduced five new development options for IS, such as built and recruit model, planned eco-industrial park model (PEIP), self-organising symbiosis model (SOS), retrofit industrial park model (RIP) and the circular economy eco-industrial park model (CE-EIP). As Chertow and Ehrenfeld (2012) further stated, built and recruit model encourages the eco-industrial development. A main feature considered in PEIP model is locating the organisational entities based on their geographic proximity. The decisions made by the independent agents are considered in SOS model. RIP model has been introduced for industrial parks which were already existed in the industry (Wen *et al*., 2018). Indeed, CE-EIP model is a new concern towards developing more sophisticated symbiotic relationships. According to the study by Yuan *et al*. (2006), CE has been emerged in China in early 2009 and has been interacted with IS as a new occurrence in industry (Tao *et al*., 2019). Further, Tao *et al*. (2019) introduced four new IS models, such as newly planned model, retrofit model, speed-dating/ exogenous model and intrinsic/endogenous model. Further to authors, all four models foster the involvement of the government in IS planning and development. Furthermore, Domenech *et al*. (2019) identified three types of IS activities, namely self-organised activity, facilitated networks and planned networks in practice. As they further verified, an intermediary or a third party may coordinate the symbiotic activities in facilitated networks. The planned networks may take place as a result of a corporative plan in which the firms engaged in the network are sharing infrastructure, services and the coordination and promotion related liabilities of IS exchanges.

3.2.1 The Development Process of IS

The designing and planning of IS can be identified with respective to several stages. As outlined by Grant *et al*. (2010), five stages of any IS project lifecycle can be identified as synergy identification, symbiosis assessment, barrier removal, implementation and follow up (review and documentation). Further, National Industrial Symbiosis Programme in UK came up with six processes in IS implementation (National Industrial Symbiosis Programme [NISP], 2013 cited in Tao *et al*., 2019) as; building the IS network by recruiting new members and assessing the characteristics of the organisation (sector and business size, etc), availability of resources and locations, facilitating a platform (workshop) for the participants in selected firms to share information regarding the possible resource exchanges, identifying and mapping the possible synergetic opportunities among the firms, using a suitable data management tool (SYNERGie etc) to identify the benefits of the proposed exchanges and the ways to reduce cost through effective management of resources, introducing a central or an intermediate position to coordinate the network and verifying the output reports of facilitated synergies. Considering the existing stages in IS development, Tao *et al*. (2019) re-identified the five stages of IS development in their study as, awareness development, planning, negotiation, implementation and evaluation. Accordingly, the key stages of IS development can be determined as stated in Figure 1.

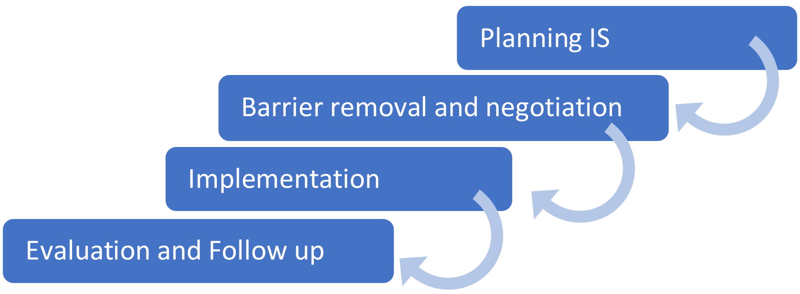

Figure 1: Key stages of IS development process

The stages of IS development process can be described as follows:

Phase 1: Planning IS

This phase includes the initial planning of IS. Conducting expert facilitated workshops, identifying the firms and their synergies, assessing and mapping the opportunities are included under this phase. Synergy identification and pre-assessment occur through three primary means, such as new process discovery, resource matching and relationship mimicking (Grant *et al*., 2010). Further, the economic gains and cost possibilities and the possibilities towards creating job opportunities of the activities will also be considered (Chertow and Lombardi, 2005).

Phase 2: Barrier removal and negotiation

After identifying the suitable partners for the relationship in IS network, negotiation is taken place to comply with the volume, quality, price and the supplying frequency of the resources (waste, energy etc). Further, introducing strategies to overcome the barriers in implementing IS activities is also considered at this stage. As Golev *et al*. (2015) identified, the barriers may include the unavailability of information, lack of commitment of partners, trust and coordination issues among the partners, regulatory, social and economic concerns.

Phase 3: Implementation

The decisions will be taken place to implement the identified synergies at this stage (Maqbool *et al*., 2019). The suitable approach to manage the symbiosis is also considered prior implementing the exchanges (Chertow and Ehrenfeld, 2012). Further, identifying and distributing the tasks and responsibilities among the firms also come under this phase. This stage is completely governed by the firms those who have engaged in the IS network (Grant *et al*., 2010).

Phase 4: Evaluation and follow up

This phase mainly includes two tasks, such as continuous monitoring of impact and disseminating the outcomes. This phase ensures the stability of the IS activities through continuous improvement. Further, communicating the results and outcomes of the implemented IS relationship is a major concern (Maqbool *et al*., 2019).

3.3 ISSUES IN EXISTING PROCESS

It is a well-known fact that many of the IS projects have resulted in failures without achieving the expected results. As Chertow (2007) identified, IS projects have been failed and discontinued in long term due to inefficiencies. While its numerous benefits motivate the formation and development of symbiotic relationships among the industries, the obstacles toward implementing synergies can also be observed in systems, which could undermine the expected collaborative gains (Golev *et al*., 2015).

As found by scholars, IS relationships can be failed even after reaching its planning stage (Chertow, 2007; Gibbs and Deutz, 2007). The shortcomings of the top-down approach in IS development has been attributed towards the failure of the majority of the cases (Desrochers, 2004). Furthermore, the unstable resource flow could also be resulted in long term inefficiencies (Chertow, 2007). The risk of interdependency on the industry partners and the authority of control over decisions can be influenced the stability of the resource flow. IS networks fundamentally exchange the resources, however, they could subside the stability of the resource flow due to the lack of quality, continuity, and quantity of flows and or could not achieve the expected efficiencies (Fichtner *et al*., 2005).

An investigation of eco-industrial parks in United States (30 parks) and in Europe (33 parks) made by Gibbs *et al*. (2005) have found that not all projects have been succeeded. Gibbs *et al*. (2005) recognised the difficulty in organising the stable IS relationships and the fewer number of initiatives for exchanging resources as the key issues. As they further stated, Brownsville Eco-Industrial Park, Texas, Brownsville Eco-Industrial Park, Texas and Plattsburgh Eco-Industrial Park, New York are the example projects which have been failed due to the deficiency in the process. Further, out of 15 IS projects in Londonderry, New Hampshire, and Cape Charles have been failed in long term even though they have been identified as the successful projects in early stages (Bakke, 2005 cited in Chertow, 2007).

Although there is a general recognition of the importance of initiating IS in achieving ecological and economic benefits until recently, there is neither a standardised mechanism for modelling the IS networks and their respective effect towards resource efficiency improvements (Zhang *et al*., 2015). Most of the case studies have been presented for quantifying the reduction of environmental impacts and the possible economic gains. However, such an approach of analysis does not provide any indication whether the project has been achieved the expected efficiency to which extent or not achieved. Hence, a measure of efficiency for IS networks is also lacking (Fraccascia *et al*., 2017), which manipulates for increasing the risk of the difficulty in achieving expected efficiencies. However, not having a standardised mechanism for optimising IS and for assuring it's expected returns in long term can be found in existing practice and related literature, which despites having a more robust model of IS (Chertow, 2007).

4. THE PROPOSED REDEVELOPMENT

The facts reviewed above foster the need of developing a systematic mechanism for optimising the IS. Despite much research in IS, the research gaps in IS development supporting the proposed redevelopment can be highlighted as follows;

- In most of the studies, the main focus has been given to prove the development of IS in respective countries through subjective evaluations. However, fewer studies were fund on assessing the issues of IS networks where many of IS projects have been failed and discontinued in long term.
- Since there is no prior evaluation for optimising the resource flow network and expected collaborative gains prior implementing the IS relationships, the fear of dependency on partners, risk of resource flow stability and the lack of quality, continuity, and quantity of flows have resulted escalating the failure rate of IS projects.
- Even though a broader and subjective consideration of IS networks has been adopted in previous research works, a standardised way to model the stable IS network and its resource flow to quantify their optimum returns and efficiencies remains experimental.

The proposed redevelopment for optimising resource flow efficiency of IS is presented in Figure 2.

As Figure 2 illustrates, the process begins with planning of IS which may occur through existing or planned business relationships of the firms. As identified in key literature, identifying possible synergies and resource matching may take place. The gathered inputs and output data and related resource links can be evaluated in the next step. Compared to the traditional top down approach, the second step will be formalised to evaluate the identified symbioses to make a decision of which IS model could give an optimum resource flow efficiency.

The development of this robust model may take three key steps. The first step will be to identify the standardised ways to determine functional characteristics of the IS network, and its effect on resource efficiency. Second step will be to investigate the various optimisation methods and their extent of application in industrial symbiosis context. Developing a model for optimising the resource flow efficiency of IS will be the third and the most important step of this research. Finally, the validity and the applicability of the developed model will be tested in both secondary data and a real industry scenario.

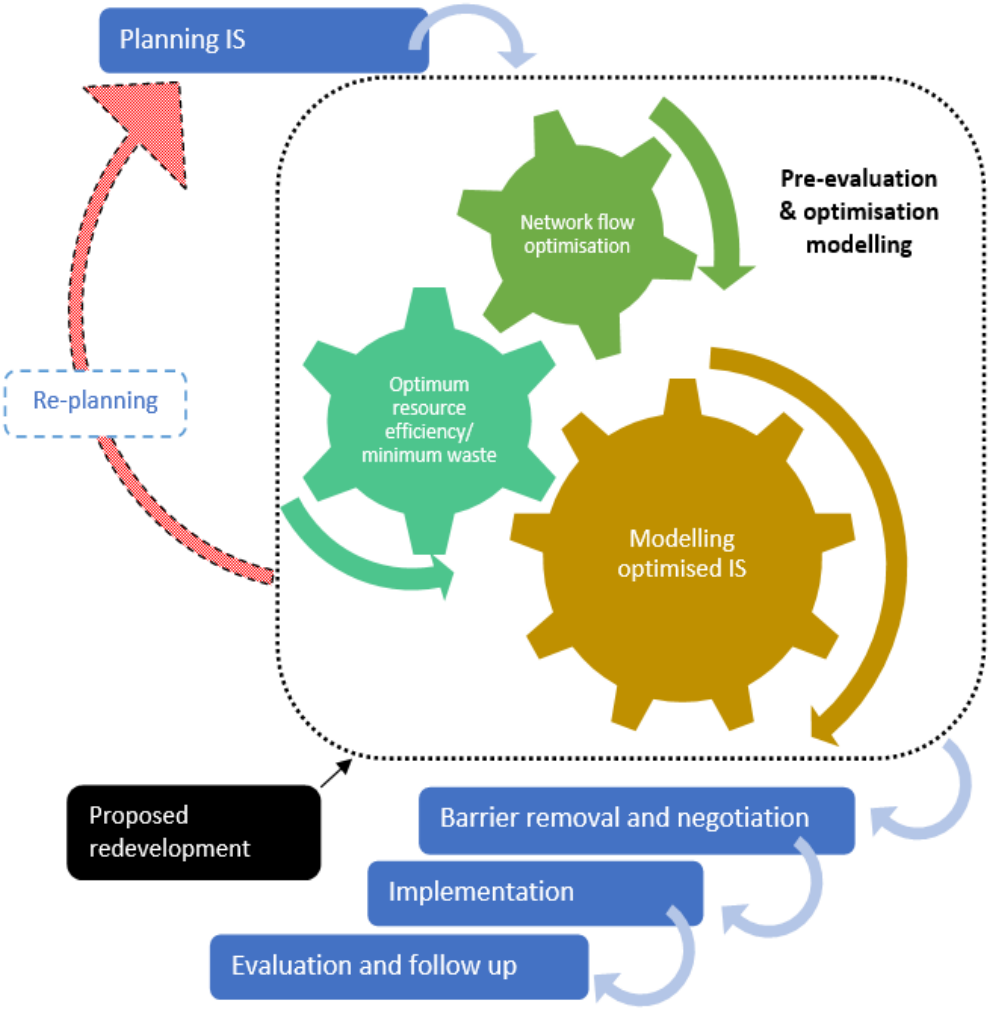

Figure 2: The proposed redevelopment

5. CONCLUSIONS AND THE WAY FORWARD

This paper provides an underpinned overview about the concept of IS, its development and the issues that have been arisen in the IS design and implementation process. Many of IS projects have been failed and discontinued in long term due to the issues in the existing process specially, less stability, lack of quality and continuity of the resource flow. However, there is no a standardised mechanism to evaluate the IS networks and expected collaborative gains. Thus, a prior evaluation for optimising the IS network and the resource flow before its implantation was identified as a timely need. Accordingly, the new phase of pre-evaluation for optimisation modelling was proposed adding into the development process of IS. The proposed redevelopment can be applied in any context to evaluate the identified synergies of IS prior its implementation thus, the re-planning is possible. The application of the proposed model may assist the industries to obtain a holistic idea about their engagement in IS which may reduce the interdependency risk of the IS partners. Further, the proposed model may result in high stability of the resource flow in which firms may maintain the required optimum resource flow efficiency by continuing the resource input and output flows in long term. This may also reduce the resource cost especially for raw material extraction, storage and disposal.

Since this is a part of a research for optimising the IS, this paper only conceptualise the proposed redevelopment. The next stage of the research will be intended to develop the proposed model for optimising the resource flow efficiency of IS.

6. REFERENCES

Boons, F., Spekkink, W., and Jiao, W., 2014. A process perspective on industrial symbiosis: Theory, methodology, and application. *Journal of Industrial Ecology*, *18*(3), pp.341-355.

Boons, F., Spekkink, W., and Mouzakitis, Y., 2011. The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review. *Journal of Cleaner Production*, *19*(9-10), pp.905-911.

Boons, F., Spekkink, W., Isenmann, R., Baas, L., Eklund, M. and Brullot, S., 2015. Comparing industrial symbiosis in Europe: Towards a conceptual framework and research methodology. In *International perspectives on industrial ecology*. Edward Elgar Publishing.

Chertow, M. and Ehrenfeld, J., 2012. Organizing self-organizing systems: Toward a theory of industrial symbiosis. *Journal of Industrial Ecology*, *16*(1), pp.13-27.

Chertow, M.R. and Lombardi, D.R., 2005. Quantifying economic and environmental benefits of co-located firms. *Environmental Science and Technology*, 39(17), pp.6535-6541.

Chertow, M.R., 2000. Industrial symbiosis: literature and taxonomy. *Annual Review of Energy and the Environment*, *25*(1), pp.313-337.

Chertow, M.R., 2007. Uncovering" industrial symbiosis. *Journal of Industrial Ecology*, *11*(1), 11-30.

Christensen, J., 2006. The History of the Industrial Symbiosis at Kalundborg, Danemark. In *Scientific Workshop 'Frontiers of Research in Industrial Ecology'*.

Desrochers, P., 2004. Industrial symbiosis: the case for market coordination. *Journal of Cleaner Production*, *12*(8-10), pp.1099-1110.

Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D. and Roman, L., 2019. Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, Conservation and Recycling*, *141*, pp.76-98.

European Commission, 2017. The role of waste-to-energy in the circular economy. In: *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*, 11.

Fichtner, W., Tietze-Stöckinger, I., Frank, M. and Rentz, O., 2005. Barriers of interorganisational environmental management: two case studies on industrial symbiosis. *Progress in Industrial Ecology, an International Journal*, *2*(1), pp.73-88.

Fraccascia, L., Albino, V. and Garavelli, C.A., 2017. Technical efficiency measures of industrial symbiosis networks using enterprise input-output analysis. *International Journal of Production Economics*, *183*, pp.273-286.

Frosch, R.A. and Gallopoulos, N.E., 1989. Strategies for manufacturing. *Scientific American*, *261*(3), pp.144-152.

Gertler, N., 1995. *Industry ecosystems: developing sustainable industrial structures* (Doctoral dissertation, Massachusetts Institute of Technology).

Ghali, M.R. and Frayret, J.M., 2019. Social semantic web framework for industrial synergies initiation. *Journal of Industrial Ecology*, *23*(3), pp.726-738.

Gibbs, D. and Deutz, P., 2007. Reflections on implementing industrial ecology through eco-industrial park development. *Journal of Cleaner Production*, *15*(17), pp.1683-1695.

Gibbs, D., Deutz, P. and Proctor, A., 2005. Industrial ecology and eco-industrial development: A potential paradigm for local and regional development?. *Regional Studies*, *39*(2), pp.171-183.

Golev, A., Corder, G.D. and Giurco, D.P., 2015. Barriers to industrial symbiosis: Insights from the use of a maturity grid. *Journal of Industrial Ecology*, *19*(1), pp.141-153.

Grant, G.B., Seager, T.P., Massard, G. and Nies, L., 2010. Information and communication technology for industrial symbiosis. *Journal of Industrial Ecology*, *14*(5), pp.740-753.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.H., Haberl, H. and Fischer-Kowalski, M., 2009. Growth in global materials use, GDP and population during the 20th century. *Ecological Economics*, *68*(10), pp.2696-2705.

Lieder, M., and Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production, 115*, pp.36-51.

Liu, Z., Adams, M., Cote, R.P., Geng, Y. and Li, Y., 2018. Comparative study on the pathways of industrial parks towards sustainable development between China and Canada. *Resources, Conservation and Recycling*, *128*, pp.417-425.

Maqbool, A., Mendez Alva, F. and Van Eetvelde, G., 2019. An assessment of European information technology tools to support industrial symbiosis. *Sustainability*, *11*(1), p.131.

Meho, L.I. and Yang, K., 2007. Impact of data sources on citation counts and rankings of LIS faculty: Web of Science versus Scopus and Google Scholar. *Journal of the American Society for Information Science and Technology*, 58(13), pp.2105-2125.

Milani, A., Schluter, L. and Gjerding, A. N., 2018. *An Ecosystem Analysis of Industrial Symbiosis Development in Aalborg*, Denmark, Department of Business and Management, Innovation, Knowledge and Entrepreneurial Dynamics, Aalborg University: Denmark.

Sun, L., Spekkink, W., Cuppen, E. and Korevaar, G., 2017. Coordination of industrial symbiosis through anchoring. *Sustainability*, *9*(4), p.549.

Tao, Y., Evans, S., Wen, Z. and Ma, M., 2019. The influence of policy on industrial symbiosis from the Firm's perspective: A framework. *Journal of Cleaner Production*, *213*, pp.1172-1187.

United Nations Environment Programme, 2009. *Global green new deal.* United Nations Environment Programme, New York, NY.

Wen, Z., Hu, Y., Lee, J.C.K., Luo, E., Li, H. and Ke, S., 2018. Approaches and policies for promoting industrial park recycling transformation (IPRT) in China: Practices and lessons. *Journal of Cleaner Production*, *172*, pp.1370-1380.

Yuan, Z., Bi, J. and Moriguichi, Y., 2006. The circular economy: A new development strategy in China. *Journal of Industrial Ecology*, *10*(1-2), pp.4-8.

Zhang, Y., Zheng, H., Chen, B., Su, M. and Liu, G., 2015. A review of industrial symbiosis research: theory and methodology. *Frontiers of Earth Science*, *9*(1), pp.91-104.

Wijerathne, M.D.I.R., Gunasekara, K.A. and Perera, B.A.K.S., 2019. Overcoming the challenges of sustainable development in Sri Lanka using lean construction principles. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 473-483. DOI: doi.org/10.31705/WCS.2019.47. Available at: https://2019.ciobwcs.com/papers

OVERCOMING THE CHALLENGES OF SUSTAINABLE DEVELOPMENT IN SRI LANKA USING LEAN CONSTRUCTION PRINCIPLES

M.D.I.R. Wijerathne[1], K.A. Gunasekara[2] and B.A.K.S. Perera[3]

ABSTRACT

Sustainability is gaining popularity in the construction industry because of the growing concern that the industry has on the serious negative impacts of construction activities on the environment. To achieve sustainable development through environmentally friendly practices, such as green building practices, construction waste management would be essential. However, the new construction philosophy lean, can be used to overcome the environmental challenges of sustainable development. Thus, the aim of this study was to investigate how the challenges of sustainable development could be overcome in Sri Lanka using the principles of lean construction. The study used a qualitative approach consisting of a literature review and 20 expert interviews. Interview findings were analyzed manually using content analysis. Specifying value and identifying the value stream were found to be the most suitable lean principles that can overcome the challenges of sustainable development. The research findings also reveal that there is an urgent requirement to practice lean principles in the construction industry in Sri Lanka.

Keywords: *Lean Construction Principles; Sustainability Challenges; Sustainable Development.*

1. INTRODUCTION

Sustainability enables the satisfaction of the needs of the current population to fulfil the needs of the future generations without any risks while protecting the environment (Wao *et al*., 2016). The move towards sustainability is a modern paradigm (Vanegas *et al*., 1996). By considering sustainable principles, significant value can be obtained, especially in the built environment (Andelina *et al*., 2015). Population growth; urbanization; global warming; high energy usage; high levels of soil, air and water pollution; fast waste generation; transportation; resource constraints etc., have to be considered when undertaking sustainable development (De Sherbinin *et al*., 2007).

During the past several decades, the quantity of waste produced during construction has increased considerably (Formoso *et al*., 2002). To monitor waste disposal, a wide range

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of measures, including the control of excess consumption of materials, have already been adopted (Formoso *et al*., 2002). For the sustainable development in the construction industry, the use of green building practices is essential to manage construction waste (Kamar *et al*., 2010).

To achieve sustainable development, construction industry also has to change its processes from linear to cyclic processes, increase the use of reused, renewed and recycled resources and decrease the consumption of energy and natural resources (Miyatake, 1996).

Koskela (1992), an inventor, introduced a new construction philosophy known as lean, to address the environmental issues faced by the construction industry in pursuing sustainable development. Lean principles provide gargantuan possibilities to improve the industry and help to solve industrial problems (Hallman, 2013). Lean construction principles are also believed to improve the construction industry as a whole (Egan, 1998; Howell and Ballard, 1998). Some argue that because of the specific characteristics of construction, lean principles as they are may not be applicable to the construction sector (Winch, 2003). Many researchers, however, have focused their attention on the lean construction concept, which is expected to minimize the waste in the construction industry (Lim, 2008; Lean Construction Institute, 2012). According to the Lean Construction Institute (2012), lean construction focuses on minimizing wastage using unique techniques, thereby enhancing the value of production. Hence, the main aim of lean construction can be considered as the development of the construction process by reducing the waste generated in construction while maximizing the value of the project. If as claimed by the Lean Construction Institute (2012), lean construction can maximize the value of a construction project, it will lead to cost savings, high quality end products and increased confidence in the safety and project sustainability on the part of construction laborers. According to Green and May (2005), lean is a socio-technical concept, valuable to the work culture of an organization. Therefore, it is important to study the interconnection between the sustainable challenges and lean concept. The aim of this research was, therefore, to identify the contribution made by lean construction principles towards meeting the challenges of sustainable development in Sri Lanka. The objectives of the research were to identify the principles of lean construction and the significant challenges of sustainable development, and the use of lean construction principles to overcome the identified challenges. While cost, performance and quality are the criteria traditionally used to assess building materials, products and systems, sustainability criteria relate to resource depletion, environmental degradation and a healthy environment (Kibert, 1994).

2. RESEARCH PROBLEM

Construction industry is a large-scale waste producer, which impacts heavily on the environment because of the large quantities of natural resources it consumes (Wu *et al*., 2014). Therefore, it needs to focus on sustainable construction. One possible approach to sustainable construction can be lean construction as it focuses on introducing social and environmental issues as new values to be achieved rather than on its mere accidental benefits to the environment (Nahmens and Ikuma, 2011). There is a research gap on the contribution made by lean construction principles to overcome the challenges of sustainable development in the construction sector of developing countries like Sri Lanka.

This subject, however, has already been studied in the context of developed countries like UK.

2.1 LEAN CONCEPT AND LEAN PRINCIPLES

Rachman and Ratnayake (2018) described the lean concept as an approach for performing activities more efficiently, i.e. with fewer resources (e.g. time, workforce, equipment and space). The lean concept has also been argued as a methodology that could enhance the business performance of the petroleum industry (Banawi *et al*., 2014). The basic concept behind lean is the elimination of waste. To eliminate waste, production systems in construction have to be designed to reduce the waste of resources, time, and effort and maximise the values (Arashpour and Arashpour, 2015). The lean concept essentially includes the development of a clear set of objectives for the delivery process of a project and the application of project control throughout the life cycle of the project, i.e., from its design to delivery (Meng, 2019). In the construction industry, the lean concept advocates the concurrent consideration of the development of production as well as construction process. Lean theory can be categorized into five principles (Aziz and Hafez, 2013) as summarized in Table 1.

Table 1: Categories of lean principles

Principle	How it is performed
Specifying value to the customer	By identifying the value of related activities to ensure the value of the final product
Identifying the value stream	By eliminating waste to remove all activities that will not add value to the final product
Making a continuous improvement	By ensuring an impeccable delivery to the users within the agreed time duration
Ensuring a continuous flow in the value chain and the process	By monitoring the whole supply chain
Having pull driven systems	By producing the exact needs of the customer and being ready for the changes wanted by the customer

There are eleven lean principles (Koskela, 1992): minimizing the share of non- value adding activities, increasing the output value through the proper consideration of the customer needs, reducing the variability, reducing the cycle times, simplifying by reducing the number of steps, parts and linkages, increasing the output elasticity, increasing the process transparency, focus controlling the complete process, building continuous improvement into the process, balancing the flow improvement with conversion improvement, and benchmarking.

2.2 NEED FOR LEAN CONSTRUCTION

A key part of the lean project delivery process is the elimination and reduction of waste, i.e., non-value adding activities (Abdelhamid and Salem, 2005). According to Thilakarathna and Senarathne (2012), in Sri Lanka, which is still a developing country, non-value adding activities (NVAA) are at a significant level of which most significant are the “defects” and “waiting”. By eliminating waste, lean construction assures the results of a construction project by managing its construction process and accomplishing its goals (Jamil and Fathi, 2016).

Construction industry, which lacks efficiency, faces numerous difficulties. Therefore, the industry can use lean construction to overcome a majority of its problems (Alinaitwe, 2009). In human resource management, the lean concept gives employees the opportunity to make informed choices about their workplace performance, nature of their contribution, resolution of self-issues and their job satisfaction (Wickramasinghe and Wickramasinghe, 2012). Furthermore, it enables the workers to enjoy enriched jobs, with autonomy to make decisions (Howell, 1999).

2.3 MAJOR CHALLENGES OF SUSTAINABILITY

The concept of sustainability originated during early human civilizations, such as South African Bushmen (Ding, 2008). Since then the concept has been adopted by many industries and today the society is encouraged to embrace sustainability in order to create a better world (Shen *et al*., 2011). Sustainable development is interrelated to economic growth and environment (Ding, 2008). In the construction industry, high performance and green / sustainable construction are often interchangeable. Yet, sustainable construction is most popular with regard to ecological, social, and economic problems of a building (Ding, 2008). To ensure sustainability, a "beneficial co-existence" is required to generate and sustain the environmental, social and economic conditions that allow people to live with nature, today as well as in the future. In the construction industry, sustainable objectives are considered at each stage of the building lifecycle. These sustainable objectives are often an encumbrance to the environment. However, it will not be possible to resolve environmental issues if poverty remains (Hart, 1997). The challenges faced by the different economic sectors of a country with regard to sustainability can be different. These challenges as identified by Hart (1997) are presented in Table 2.

Table 2: Major challenges to sustainability

	Developed economies	Emerging economies	Survival economies
Pollution	Greenhouse gases, toxic materials, polluted sites	Industrial emissions, polluted water, lack of sewage treatment	Dung and wood burning, lack of sanitation, ecosystem destruction due to development
Depletion	Material scarcity, insufficient reuse and recycling of the materials	Overuse of renewable resources, overuse of water for irrigation	Deforestation, overgrazing, soil loss
Poverty	Urban and minority unemployment	Urbanization, lack of skilled workers, income differences	Population growth, low status of women, dislocation

2.4 NEED FOR LEAN PRINCIPLES TO OVERCOME THE BARRIERS AND CHALLENGES OF SUSTAINABLE CONSTRUCTION

Institutional sustainability will be significant for an organization to achieve competitive success (Porter and Kramer 2006). However, the reason for maintaining institutional sustainability is usually based more on legal requirements, while cost of running a business is considered as a necessary evil to maintain legitimacy (Hart and Milstein, 2003). The main reason for applying lean in an organization is often an adverse incentive, such as a financial disaster (Womack and Jones, 1996). One main topic that is discussed even amidst environmental disasters is the integration of environmental, social and economic goals (Hargroves and Smith, 2005). Thus, it is important to disclose the positive side of sustainability when introducing lean management to businesses.

3. RESEARCH METHODOLOGY

The research question of this study was 'How to meet the challenges of sustainable development in Sri Lanka using the principles of lean construction'. According to Yin (2009), a research question starting with the word 'how' is more explanatory in nature and requires tracing operational links in a phenomenon which otherwise would not be achievable by depending only on frequencies. By using a qualitative approach in a research, the exploration and a better understanding of the complexity of a phenomenon will be possible (Williams, 2007). Thus, this research used a qualitative approach, which contained 15 semi structured interviews (using an interview guideline) conducted with professional experts, each of whom had more than 5 years of experience in working in the construction industry in the Western Province of Sri Lanka. Each of the face to face interviews lasted for 45-60 minutes. The data collected were analysed using manual content analysis.

4. RESEARCH FINDINGS

4.1 IDENTIFICATION OF THE CHALLENGES OF SUSTAINABLE DEVELOPMENT AND THE LEAN PRINCIPLES TO OVERCOME THEM

The challenges of sustainable development identified using the literature review was validated in the Sri Lankan context through the interviews. The interviewees were requested to remove, add to and modify the challenges identified from the literature to suit Sri Lanka. They were also requested to validate the lean principles identified from the literature by adding to, removing or changing them, based on their experience. They were thereafter requested to identify the lean principles that are suitable for overcoming the challenges of developing the three categories of sustainability: *economic, environmental and social sustainability.* They were also requested to describe the application of the lean principles to overcome each challenge.

4.2 LEAN PRINCIPLES THAT WILL OVERCOME THE CHALLENGES OF DEVELOPING ECONOMIC SUSTAINABILITY

The challenges of developing economic sustainability and their associated lean principles identified from the literature and validated through the interviews are summarised in Table 3.

Table 3: Lean principles that will overcome the challenges of developing economic sustainability

	Challenges for economic sustainability	**Lean principles**
1	Poor knowledge of sustainable design	Identifying the value stream, Specifying value, Perfection
2	Fear of increase in cost / price fluctuations	Pull driven system, Identifying the value stream, Continuous flow

	Challenges for economic sustainability	Lean principles
3	Poor workmanship during construction	Continuous flow, Perfection, Pull driven system, Specifying value
4	Mode of funding the project / Financing the project	Identifying the value stream, Perfection, Specifying value, Pull driven system
5	Unrealistic project duration	Continuous flow, Pull driven system, Identifying the value stream
6	Budget constraints	Specifying value, Identifying the value stream, Continuous flow
7	Lack of technical expertise in sustainable construction	Identifying the value stream, Perfection, Continuous flow
8	Greenhouse gases	Identifying the value stream, Perfection, Specifying value
9	Migration to cities	Perfection, Pull driven system, Specifying value
10	Lack of skilled workers	Specifying value, Identifying the value stream, Pull driven system
11	Income inequality	Perfection, Pull driven system, Continuous flow
12	Population growth	Identifying the value stream, Perfection, Specifying value

Several new lean principles were also identified by the interviewees: reducing the share of non-value adding activities, increasing the output value through systematically considering customer requirements, reducing variability and reducing cycle time. The interviewees also identified several new challenges of developing economic sustainability, such as payment problems faced in the construction industry, insufficient knowledge of project managers, low number of progress meetings, lack of equipment and machinery, financial issues and lack of competent people to implement the systems.

4.3 Lean Principles that can Overcome the Challenges of Environmental Sustainability

The challenges of developing environmental sustainability and the lean principles applicable to them that were identified from the literature and validated through the interviews are summarized in Table 4.

Table 4: Lean principles that will overcome the challenges of developing environmental sustainability

	Challenges of environmental sustainability	Lean principles
1	Lack of knowledge and non-availability of alternative sustainable materials	Identifying the value stream, Specifying value, Continuous flow
2	Poor working conditions in relation to safety	Pull driven system, Identifying the value stream, Continuous flow
3	Poor construction methods	Identifying the value stream, Pull driven system, Continuous flow

	Challenges of environmental sustainability	Lean principles
4	Lack of demand for sustainability in construction from the clients	Specifying value, Perfection, Identifying the value stream
5	Use of toxic materials	Specifying value, Perfection, Identifying the value stream
6	Contaminated sites	Specifying value, Identifying the value stream, Perfection
7	Industrial emissions	Specifying value, Identifying the value stream, Perfection
8	Contaminated water/ Contaminated water at the site	Identifying the value stream, Perfection, Specifying value
9	Dung and wood burning/ Increased pollution	Specifying value, Identifying the value stream, Perfection
10	Ecosystem destruction caused by development	Pull driven system, Perfection, Specifying value
11	Insufficient reuse and recycling of resources	Specifying value, Identifying the value stream, Perfection
12	Over exploitation of renewable resources	Perfection, Identifying the value stream, Pull driven system
13	Deforestation	Identifying the value stream, Pull driven system, Perfection
14	Overgrazing	Specifying value, Identifying the value stream, Perfection
15	Soil loss	Identifying the value stream, Pull driven system, Specifying value

The interviewees identified several new challenges of developing environmental sustainability, such as educating clients on sustainability methods and requesting them to implement them, failure to work closely with environmental authorities towards getting the approvals and absence of a proper market for sustainable operations.

4.4 LEAN PRINCIPLES THAT CAN OVERCOME THE CHALLENGES OF DEVELOPING SOCIAL SUSTAINABILITY

The challenges of developing social sustainability and the associated lean principles identified from the literature and validated through the interviews are summarised in Table 5.

Table 5: Lean principles that will overcome the challenges of developing social sustainability

	Challenges for social sustainability	Lean principles
1	Inadequate awareness and knowledge of the concept of sustainability and its benefits	Specifying value, Perfection, Continuous flow
2	Poor understanding of project objectives and requirements.	Specifying value, Continuous flow, Pull driven system

	Challenges for social sustainability	Lean principles
3	Lack of related legislation and government support	Specifying value, Continuous flow, Pull driven system
4	Incompetence of contractors/subcontractors	Pull driven system, Continuous flow, Specifying value
5	Unwillingness to adopt new construction methods	Specifying value, Identifying the value stream, Continuous flow, Pull driven system, Perfection
6	Economic, physical and social environment of the educational building project	Pull driven system, Perfection, Specifying value
7	Non availability of sewage treatment	Identifying the value stream, Perfection, Continuous flow, Specifying value, Pull driven system
8	Absence of sanitation	Continuous flow, Pull driven system, Perfection
9	Scarcity of materials	Identifying the value stream, Perfection, Specifying value
10	Overuse of water for irrigation	Identifying the value stream, Pull driven system, Perfection
11	Urban and minority unemployment	Pull driven system, Specifying value, Identifying the value stream
12	Low status of women	Perfection, Specifying value, Identifying the value stream

Some of the challenges faced in developing social sustainability, such as the non-availability of continuing professional development (CPD) programs for new graduates; little attention paid to the implementation of sustainable practices; non-availability of a proper market place for sustainable operations; education systems and cultural gaps; top management's perception of sustainability as being costly; conflicts with the government and organizational policies; and rules and regulations were identified through the interviews.

There are many ways of applying these lean principles to overcome the challenges of attaining sustainability identified through the interviews. The lean principles common to all three types of sustainability are imparting knowledge about the lean principles, educating the relevant personnel about sustainability, training of the relevant personnel, standardization of sustainable construction practices, government and foreign funding , realistic construction periods, accurate preliminary estimates, new R&D methods, green buildings, professional education systems, use of alternative methods, HSE (health, safety and environment) toolbox workshops and lean based safety applications, reviewing of the construction methodology to be used before commencing construction, legal enforcement through the state sector, adherence to ISO (International Organization for Standardization) standards, making clients aware about green-house education, life cycle analysis over construction and pre-qualifying the contractors based on CIDA (Construction Industry Development Authority) categorizations.

The research findings indicate that the lack of or inadequate knowledge of sustainability is a challenge common to all three types of sustainability. To overcome these challenges, practices such as conducting discussions to enlighten the relevant personnel about the related issues, educating all employees about issues related to sustainability and providing lean based higher education systems to the relevant professionals, conducting training and awareness programs to all employees, and explaining to the customers the benefits of sustainability can be adopted. Moreover, poor workmanship during construction, lack of technical expertise in sustainable construction, poor construction methods and the incompetence of contractors/subcontractors can be identified as the workmanship related challenges of economic, environmental and social sustainability. These challenges can be overcome by applying practices such as employing a qualified quality engineer, introducing lean practices to all employees, standardizing sustainable construction practices, developing training programs, educating clients on sustainability methods, providing education on sustainability, providing lean based education, reviewing construction methodology by the engineer or architect before commencing construction , introducing sustainability development to construction, providing lean/sustainable based professional development on construction, using easy construction methods, pre-qualifying contractors based on CIDA guidelines, standardizing the lean construction practices used by the contractors and standardizing the contractors based on the lean and sustainable practices they use.

5. CONCLUSIONS AND RECOMMENDATIONS

Lean construction is a continuous process of overcoming the challenges faced in attaining sustainability, which establishes value for the end-product in construction. Though the concept originated in the production sector, many researchers all over the world have proved its applicability to the construction industry. Although there are different interpretations of the lean principles, all of them are mainly based on five common principles. The study enabled to identify the lean principles that can overcome the challenges faced in developing economic, environment and social sustainability in Sri Lanka thereby achieving the aim of the research. In addition to the lean principles and challenges of sustainable development already mentioned in the literature, several new lean principles and challenges were identified from the interviews. There is an urgent need to use lean principles in construction projects in Sri Lanka. Moreover, although many professionals have heard about lean construction, they know very little about it.

This study covered several aspects of using lean principles in Sri Lanka to overcome the challenges of sustainable development. The following recommendations will help to implement lean construction principles within the Sri Lankan organizations to facilitate the attainment of sustainability by overcoming any challenges present.

- Educating all stakeholders in the construction industry about lean principles and getting them to practice the principles in their respective organizations
- Standardizing contractors and clients based on their use of lean principles for sustainable development

6. REFERENCES

Abdelhamid, T. and Salem, S., 2005. December. Lean construction: a new paradigm for managing construction projects. *In Proceedings of the International Workshop on Innovations in Materials and Design of Civil Infrastructure* (pp. 28-29).

Alinaitwe, H. M., 2009. Prioritising Lean construction barriers in Uganda's construction industry. *Journal of Construction in Developing Countries*, 14(1), pp.15-30.

Andelin, M., Karhu, J., and Junnila, S., 2015. Creating shared value in a construction project–a case study. *Procedia Economics and Finance*, 21, pp.446-453.

Arashpour, M. and Arashpour, M., 2015. Analysis of workflow variability and its impacts on productivity and performance in construction of multistory buildings. *Journal of Management in Engineering*, 31(6), p.04015006.

Aziz, R. F. and Hafez, S. M., 2013. Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal,* 52(4), pp.679-695.

Banawi, A. and Bilec, M.M., 2014. A framework to improve construction processes: Integrating Lean, Green and Six Sigma. *International Journal of Construction Management*, 14(1), pp.45-55

Ding, G.K., 2008. Sustainable construction-The role of environmental assessment tools. *Journal of Environmental Management*, *86*(3), pp.451-464.

De Sherbinin, A., Schiller, A., and Pulsipher, A., 2007. The vulnerability of global cities to climate hazards. *Environment and Urbanization*, 19(1), pp.39-64.

Egan, J., (1998). *Rethinking Construction: Report of the Construction Task Force*. London: HMSO.

Formoso, C.T., Soibelman, L., De Cesare, C. and Isatto, E.L., 2002. Material waste in building industry: main causes and prevention. *Journal of Construction Engineering and Management*, 128(4), pp.316-325.

Green, S. D. and May, S.S., 2005. Lean Construction: Arenas of Enactment, Models of Diffusion and the Meaning of 'Leanness'. *Building Research and Information*, 33(6), pp.498-511.

Hallman, M., 2013. *Implementing last planner on construction sites* (Doctoral dissertation, Chalmers University).

Hargroves, K. and Smith, M.H., 2005. *Natural advantage of nations*. Earthscan.

Hart, S.L., 1997. Beyond greening: strategies for a sustainable world. *Harvard business review*, *75*(1), pp.66-77.

Hart, S.L. and Milstein, M.B., 2003. Creating sustainable value. *Academy of Management Perspectives*, *17*(2), pp.56-67.

Howell, G.A., 1999, July. What is lean construction-1999. In *Proceedings IGLC* (Vol. 7, p. 1).

Howell, G. and Ballard, G., 1998. Implementing lean construction: understanding and action. *In Proceedings of the 6th Annual Conference of International Group for Lean Construction*.

Jamil, A. H., and Fathi, M. S., 2016. The Integration of Lean Construction and Sustainable Construction: A Stakeholder Perspective in Analyzing Sustainable Lean Construction Strategies in Malaysia. *Procedia Computer Science*, 100, pp.634-643.

Kamar, K.A.M., Hamid, Z.A., Ghani, M.K., Egbu, C. and Arif, M., 2010. Collaboration initiative on green construction and sustainability through industrialized buildings systems (IBS) in the Malaysian construction industry. *International Journal of Sustainable Construction Engineering and Technology*, 1(1), pp.119-127.

Kibert, C.J., 1994, November. Establishing principles and a model for sustainable construction, *Proceedings of the first international conference on sustainable construction* (pp. 6-9). Tampa Florida, November.

Koskela, L., 1992. *Application of the new production philosophy to construction*. California: Stanford University.

Lean Construction Institute, 2012. *What is lean construction?*. [Online]. Available from: http://www.leanconstruction.org [Accessed 14 January 2018].

Lim, V.A.J., 2008. *Lean construction: knowledge and barriers in implementing into Malaysia construction industry* (Doctoral dissertation, Universiti Teknologi Malaysia)

Meng, X., 2019. Lean management in the context of construction supply chains, *International Journal of Production Research,* pp.1-13.

Miyatake, Y., 1996. Technology development and sustainable construction, *Journal of Management in Engineering*, 12(4), pp.23–27.

Nahmens, I. and Ikuma, L. H., 2011. Effects of lean construction on sustainability of modular homebuilding, *Journal of Architectural Engineering*, *18*(2), pp.155-163.

Porter, M.E. and Kramer, M.R., 2006. The link between competitive advantage and corporate social responsibility. *Harvard Business Review*, *84*(12), pp.78-92.

Rachman, A., and Ratnayake, R. C., 2018. Social Network Analysis in Lean Thinking: A Method for Improving Information Flow in Technical Integrity Management System Development. In *2018 IEEE IEEM* (pp. 1293-1298).

Shen, L. Y., Ochoa, J. J., Shah, M. N., and Zhang, X., 2011. The application of urban sustainability indicators–A comparison between various practices. *Habitat International*, 35(1), pp.17-29.

Thilakarathne, N. and Senarathne, S., 2012. Literature review on lean implementation cases in the construction process. *In: FARU International Research Symposium, Sri Lanka,* University of Moratuwa, pp.147-162.

Vanegas, J. A., DuBose, J. R., and Pearce, A. R., 1995. Sustainable technologies for the building construction industry. *In: Symposium on Design for the Global Environment*, Atlanta, GA. November (pp. 2-3).

Wao, J. O., Ries, R., Flood, I., and Kibert, C., 2016. Refocusing value engineering for sustainable construction. *In: 52nd ASC Annual International Conference Proceedings* (pp. 13-16).

Wickramasinghe, D. and Wickramasinghe, V., 2012. Effects of perceived organisational support on participation in decision making, affective commitment and job satisfaction in lean production in Sri Lanka, *Journal of Manufacturing Technology Management*, *23*(2), pp.157-177.

Williams, C., 2007. Research methods. *Journal of Business and Economic Research*, *5*(3), pp.65-72.

Winch, G., 2003. Models of manufacturing and the construction process: the genesis of re-engineering construction. *Building Research and Information*, *31*(2), pp.107-118.

Womack, J. P. and Jones, D. T., 1996. *Lean Thinking*, Simon & Schuster, New York.

Wu, Z., Ann, T. W., Shen, L., and Liu, G., 2014. Quantifying construction and demolition waste: An analytical review. *Waste Management*, 34(9), pp.1683-1692.

Yin, R.K., 2009. *Case Study Research: Design and Methods*, 4th edn, Sage Publications, Thousand Oaks, California.

Jayalath, C. and Perera, B.A.K.S., 2019. Policy gaps that deter fostering sustainable construction in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 484-492. DOI: doi.org/10.31705/WCS.2019.48. Available at: https://2019.ciobwcs.com/papers

POLICY GAPS THAT DETER FOSTERING SUSTAINABLE CONSTRUCTION IN SRI LANKA

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ABSTRACT

One of the guiding principles used for structuring the policy of construction in Sri Lanka is to ensure achieving sustainable development. Though the construction practitioners in Sri Lanka are aware of sustainable construction practices, there is lack of verification as to enthusiasm of the state policy that has been extended to this noble cause. A desk review was carried out to demystify the existing policy directions. A comprehensive literature survey was carried out to identify the drivers and barriers of its implementation. A structured questionnaire survey was conducted among 100 individual practitioners to gauge their perception and experience. 80 responses were received, 62 were considered valid for analysis. Data collected were then analyzed using the relative importance index. It was revealed that the key driver is end user requirements and the crucial barrier is lack of policies. Only 3 out of 17 dimensions have been at least superficially earmarked within the policy framework. The study suggests that the uptake of enhanced policies would indeed help in fostering sustainability. The outcome will be valuable for the government officials to formulate a policy that truly promotes strategic direction. This is the first local research on identifying policy gaps related to the subject arena.

Keywords: *Barriers; Drivers; Policy Making; Sri Lanka; Sustainability.*

1. INTRODUCTION

In Sri Lanka, the guiding principles in structuring the policy of construction industry are to include combating environmental impacts and achieving sustainable development. The National Policy for Construction is formulated in terms of the provisions of Subsection 2 (1) of the Construction Industry Development Act No.33 of 2014. As stated, the aim of the construction policy is to create an efficient construction industry through regulation, standardization, capacity building and facilitation. A policy is deemed to be contextual and substantive. Context is all about barriers and drivers that affect the implementation of practices. Hence it is considered imperative to find out any policy dimensional gaps that eventually deter the sustainable practices and to highlight some promising ideas which could successfully fill those gaps. First, different definitions of sustainability are presented, and these aspirational standards are tested empirically as to their importance and compared with current policy goals. This is indeed a precursor to any policy revisit after 5 years of its introduction.

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The aim of this research is therefore to gauge the enthusiasm of the construction policy extended to the noble cause of sustainable construction. The objectives are to identify drivers, barriers, and policy gaps of sustainable construction.

2. DEMYSTIFYING SUSTAINABLE CONSTRUCTION

According to DuBose *et al*. (1997), "sustainability reconciles the pervasive human desire for a high quality of life with the realities of the global context. It calls for unique solutions for improving welfare that do not come at the cost of degrading the environment or impinging on the wellbeing of other people". Sustainable development was defined by the World Commission on Environment and Development (1987) as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Hill and Bowen (1987) identified four attributes of sustainability; social, economic, biophysical and technical. These are supplemented with a set of over-arching, process-oriented principles. Kibert (1994) finds sustainable construction as creating a healthy built environment using resource-efficient, ecologically based principles. According to Lawson (1992), sustainable construction includes 'cradle to grave' appraisal. Professional actors in the construction industry construct definitions of sustainable development to valorize their professional role (Abrahams, 2017). All stakeholders at all stages should commit to sustainability to enable change in perception to start with (Sfakianaki, 2015). The key factors that need to be considered include the release of conceptual guidelines and management regulations (Shi *et al*., 2012). This warrants a careful study on the drivers and barriers at the outset. Drivers are meant to be the various elements that trigger, sustain and expand the uptake of sustainable construction practices. On the other hand, "barriers" are the conditions that impede progress towards achieving a strategic business objective (Vandierendonck *et al*., 2010). However, there is ample requirement to apply these concepts in the local construction projects (Karunasena *et al*., 2016).

In a nutshell, sustainable development is a complex composite policy goal (Rydin *et al*., 2007). The way of positioning the construction sector into the global approach of sustainable development should be clarified and clearly claimed (Bourdeau, 1999). However, more holistic approaches are quite absent (Heijden and Bueren, 2013). A factor that may be hindering is the 'convoluted' nature of the policies (Warnock, 2007). Any national policy has to address this complex matrix. A policy offers a framework which is certainly useful for benchmarking. A policy provides a generic structure allowing flexibility (Presley and Meade, 2010). However, much of the research on technical and scientific knowledge has focused on the emergence of policy agendas (Rydin *et al*., 2007). The gap between policy intent and effective solutions remains difficult to close (Meacham, 2016). For effective policymaking, it is essential that these various paths (dimensions) be disentangled so that the policies may be targeted in a manner that induces a changed behaviour away from environmentally damaging inequitable growth (Robert and Herman, 1996).

3. DRIVERS AND BARRIERS

There are a number of challenges in introducing sustainable practices and certain enablers need adopting a more sustainable path (Plessis, 2007). Tables 1 and 2 depict the drivers and barriers of sustainable construction identified by past researchers, respectively.

Table 1: Drivers identified by past researchers

Drivers	Reference
Policy imposition Client requirements	Opoku and Ahmed (2014)
Green reputation Stakeholder influence Competitive advantage Legal requirement	Abrahams (2017)
Concession of tax Awareness on impacts	Roper and Beard (2006)
Monitoring system in place Certification program Accreditation scheme Regular audits	Bash and Haikines (2015)
Customer willingness to pay extra for green initiatives	Presley and Meade (2010)
Societal accountability Specific tender weightage on sustainable elements Technical knowhow	Majdalani *et al*. (2006)
Improved process flow and productivity	Rydin *et al*. (2007)
Improvement in environmental quality	Ogunbiyi *et al*. (2014)
Integration of principles of lean construction Energy conservation Improving indoor environmental quality Environmental/resource conservation Waste reduction	Mohamed *et al*. (2017) Meacham (2016) Ahn *et al*. (2013)

Table 2: Barriers identified by past researchers

Barriers	Reference
Lack of policy Lack of design itself Lack of codes	Opoku and Ahmed (2014)
Lack of public awareness Lack of demand Lack of strategic direction	Arif *et al*. (2013)
Low level of education and experience on sustainable construction Lack of demand for sustainable buildings Tendency to maintain current practices, and limited knowledge and skills of subcontractors	Ahn *et al*. (2013)
Wrong perceptions on capital costs	Susan and Eric (2014)
Lack of expertise Lack of database Resistance to change	Ahn *et al*. (2013)

Barriers	Reference
Lack of government support	
Lack of measurement tools	
Lack of incentives	
Lack of audits	
Higher investment costs	
Lack of cooperation	
Lack of technology	
Lack of training	
Increased capital costs	
Learning curve	Wyatt *et al*. (2000)
Attitudinal issues	Athapaththu and Karunasena (2018)
Lack of priority	
Lack of life cycle initiative	
More complex planning	
Building control systems	
Gaps in the legal framework	
Weak enforcement of prevailing rules	
Less institutional intervention	
Less commitment of key stakeholders	

4. RESEARCH METHODOLOGY

This study used a mixed approach where the validity and reliability of results are enhanced (Lund, 2012; Neuman, 2011). As the first step of the process, a desk review was carried out on the existing policy of construction in Sri Lanka to identify policy gaps if any. A literature survey was undertaken to identify drivers and barriers. An interview guideline was developed with the use of literature findings. A questionnaire was subsequently piloted on five (5) senior construction practitioners those who have more than 25 years working experience to establish the appropriateness of the questions and alleviate the inconsistencies if any. Some of the questions were amended to reflect the views of the pre-test respondents. A structured questionnaire involving closed-ended queries was subsequently disseminated among 100 construction practitioners in Sri Lanka using a stratified sampling method via online Google forms survey and 62 completed questionnaires were received with the rate of response of 62% (Table 3). The respondents were required to rank the extent to which each of the barriers and drivers do exist using a 5-point Likert scale. The degree of perception was taken on the Likert scale of 5 = strongly agree, 4 = agree, 3 = fairly agree (average), 2 = disagree, 1 = strongly disagree. RII (refer equation 01) was used for the analysis. RII aids in finding the contribution a particular variable makes to the prediction of a criterion variable both by itself and in combination with other predictor variables Johnson and LeBreton (2004). RII was calculated using equation (01).

$$RII = \frac{\Sigma W}{A \times N} \qquad (01)$$

Where: RII= Relative Importance Index; W= Weighting given to each factor by the respondents, A= Highest weight and N= Total number of respondents.

Table 3: Profile of the respondents

Designation of Respondents	Years of Experience							
	10 to 15		15 to 20		20 to 25		More than 25	
	Distributed	Received	Distributed	Received	Distributed	Received	Distributed	Received
Construction Manager	5	4	5	3	5	4	5	3
Site Manager	5	3	5	2	5	2	5	2
Project Manger	5	4	5	4	5	4	5	3
General Manager	5	2	5	2	5	3	5	3
Training experts in Construction Sector	5	3	5	4	5	4	5	3
Total Responses	*25*	*16*	*25*	*15*	*25*	*17*	*25*	*14*
Rate of Response				*62%*				

Findings of the empirical study were mapped with the literature findings and overlap factors were identified as 'crucial' in policy considerations.

5. FINDINGS AND DISCUSSION

5.1 POLICY REVIEW

A desk review was carried out to identify the policy actions and derivatives falling within the purview of sustainable construction. As such, the National Policy for Construction was formulated in terms of the provisions of Subsection 2 (1) of the Construction Industry Development Act No.33 of 2014. It was found that there are three key policy priorities namely, energy efficiency, disaster resilience and environment friendliness. Though the policy is silent on application on traditional knowledge, it must be noted that, the Construction Industry Development Act (CIDA), No. 33 of 2014 stipulates that in formulating the National Policy, emphasis shall be given to the involvement of professionals within the construction industry, including resource personnel in the field of traditional knowledge. The policy gaps are those silent in the various existing regulations (where the directives are not given as shown in Table 5). It does not broadly address any implementation mechanism either.

5.2 EMPIRICAL STUDY

A total of 80 responses were received and 62 were deemed to be valid for analysis after data screening, thus representing 62% response rate. 33% had never been engaged in sustainable construction projects. 45% reported that 1 out of 10 projects uses sustainable construction concepts whilst 22% reported that 1 out of 25 projects uses sustainable construction methods. Again, the majority had engaged in less than five such projects. It is observed that sustainable construction practices are not frequent. There are 10 key drivers and 14 barriers found in the empirical study. Tables 4 and 5 depict their overlap with the literature findings which indicates that these overlap factors are more imperative than non-overlap factors in drafting a policy.

Table 4: Empirical ranking of drivers and their overlap (O/L) with literature findings

Drivers	RII	O/L	Rank
Client requirements	0.79	X	1st
Stakeholders' influence	0.71	X	2nd
Cost efficiency	0.69		3rd
Competitive advantage	0.68	X	4th
Legislative provisions	0.67	X	5th
Awareness	0.67	X	5th
Clear and consistent guidelines	0.65	X	7th
Win more contracts to remain in business	0.64		8th
Financial incentives	0.60	X	9th
Company reputation and brand image	0.59		10th

Table 5: Empirical ranking of barriers and their overlap (O/L) with literature findings

Barriers	RII	O/L	Rank
Lack of polices	0.76	X	1st
Lack of codes	0.72	X	2nd
Lack of financial incentives	0.69	X	3rd
Lack of investment	0.68	X	4th
Initial cost	0.67	X	5th
Lack of client demand	0.66	X	6th
High cost of environmental service	0.66	X	6th
Insufficient research	0.64	X	8th
Lack of public awareness	0.64	X	8th
Competitive pressure	0.62	X	10th
Lack of database	0.62		10th
Lack of green products	0.60	X	12th
Lack of expertise	0.58		13th

With regard to barriers that inhibit the sustainable practices, respondents were asked to rank 14 items on a scale of 1 to 5 with one being the least significant factor and five being the most favoured factor. The analysis revealed that "lack of policies" was the first barrier. The lack of building codes was the next in line. It recorded a value of 0.72. This is followed by lack of investment with a value of 0.69. The least rank RII was the lack of lack of expertise. Further, the empirical ranking of drivers and barriers and their overlap with the literature findings highlight the priority of policy wise attention. Overlap is where the factors emphasized in both literature survey and empirical study.

Having identified that the lack of policies is the topmost barrier (Table 4), respondents were next asked to rank the various dimensions of sustainable construction drivers found in the empirical study. The most ranked dimension was "traditional knowledge". It recorded an RII value of 0.84. This was followed by "environmental friendliness" with an RII value of 0.81. Priority of projects was ranked again second with an RII value 0.81. The least ranked dimension was 'valuation of bonus' with an RII of 0.60. There are 17 dimensions ranked in the order of their relative importance so that the policy gaps with no directives become apparently plausible. The findings are illustrated in the Table 6.

Table 6: Ranking of policy dimensions

Dimension	Policy Profile	RII	Rank	Policy Directives
Traditional Knowledge	Foster culture in adapting TK	0.84	1st	CIDA Act, No. 33 of 2014, Article 2, Part 1
Environmental friendliness	Stimulate adoption of environmentally favourable construction practices	0.81	2nd	National Construction Policy, Sec 2.2, VI
Priority of projects	Take a scientific and apolitical approach	0.81	2nd	
Building adaptive reuse	Espouse means of BAR in respect of buildings nearing obsolesce	0.81	2nd	
Research	Establish centrally coordinated arm of research	0.76	5th	
Land use	Use non-arigable lands and harmonize land policy ensure complementarity	0.74	6th	
Low carbon initiatives	Encourage supply chain in carbon free materials and process selection	0.72	7th	
Deconstruction and recycling	Minimize the release of building debris to the environment	0.71	8th	
Solar energy	Explore market potentials	0.71	8th	
	Grant concessions	0.70	10th	
Green technology	Promote green in all design, construction and maintenance aspects	0.69	11th	
Procurement	Assign in tender evaluation equal weightage on the most environmentally favourable offer as same as the least cost and technically feasible offer	0.68	12th	
Green building indexing	Introduce green building index and indices along with the national green specification applicable for construction	0.68	12th	
Disaster resilience	Emphasize the use of building resilient concept and mainstream disaster risk reduction into construction practices and structures	0.68	12th	National Policy on Disaster Management, Sec 25.b/27.a
Sustainable Construction Index	Assess progress in sustainable construction. The result can help a nation to pinpoint areas needing improvement	0.67	15th	

Dimension	Policy Profile	RII	Rank	Policy Directives
Bid selection	Stipulate sustainable construction as a contractor selection criterion in bid documents	0.66	16th	
Mapping knowledge flows	Tacit knowledge can be transferred through strong ties in sparse networks	0.63	17th	
Valuation bonus/reduction	Assign a "valuation bonus" to a sustainable building or a "valuation	0.60	18th	

6. CONCLUSIONS

This study provided a number of dimensions that can guide policy formulation in Sri Lanka. Only 3 out of 17 dimensions have been superficially earmarked within the policy framework in Sri Lanka. They have been addressed in the legislation named CIDA Act, No. 33 of 2014. The National Construction Policy and the National Policy on Disaster Management refer to environmental friendliness and building resilience respectively. In a nutshell, the Government needs to focus on policy dimensions such as traditional knowledge to sustainable bid selection, deconstruction, adaptive reuse, reduction of taxes and levies, on sustainable products and low carbon initiatives. This being said, it is for certain that there is still no fully-fledged policies present. A policy gap analysis, like this, can be beneficial in long run as this research can help present the policies that may be necessary and efficient for the entire construction industry, that will otherwise deter the implementation of sustainable construction.

7. FURTHER RESEARCH

It is recommended that further studies be conducted using larger samples and also a probabilistic (random) sampling approach to validate the findings of this study so that the results can be generalized. It is also imperative to see how the various factors are related. Inferential statistical methods can be employed to determine whether there exists causal relationship between the various identified variables. For example, Analytic Hierarchy Process tools would help establish consistency of human perception and judgement. Such information will provide pertinent information on how to promote sustainable construction practices in Sri Lanka.

8. REFERENCES

Abrahams, G. 2017. Constructing definitions of sustainable development. *Smart and Sustainable Built Environment*, 6(1), pp.34-47.

Ahn, Y.H., Pearce, A.R., Wang, Y. and Wang G. 2013. Drivers and barriers of sustainable design and construction: The perception of green building experience. *International Journal of Sustainable Building Technology and Urban Development*, 4(1), pp.35-45.

Arif, M., Egbu, C., Haleem, A., Kulonda, D., and Khalfan, M. (2009). State of green construction in India: drivers and challenges. *Journal of Engineering, Design and Technology*, 7(2), pp.223-234.

Athapaththu, K.I. and Karunasena, G. 2018. Framework for sustainable construction practices in Sri Lanka. *Built Environment Project and Asset Management*, 8(1), pp.51-63.

Bash T. and Heikines K. 2015. Barriers and drivers for sustainable building. *Building Research & Information*, 39(3), pp.239-255.

Bourdeau, L. 1999. Sustainable development and the future of construction: a comparison of visions from various countries, *Building Research & Information*, 27(6), pp.354-366.

DuBose, J.R. and Pearce, A.R. 1997. The Natural Step as an assessment tool for the built environment. *Proceedings Second International Conference on Buildings and the Environment*, CSTB and CIB, June, pp.595-602.

Heijden, A. and Bueren, D. 2013, Sustainable Leadership, San Francisco, CA: Jossey- Bass

Hill, R. C., and Bowen, P. A., 1997. Sustainable construction: principles and a framework for attainment. *Construction Management and Economics,* 15(3), pp.223-239.

Johnson, J. W. and LeBreton, J. M. 2004. History and Use of Relative Importance Indices in Organizational Research*. Organizational Research Methods*, 7, pp.238-257.

Karunasena, G., Rathnayake, R.M.N.U. and Senarathne, D. 2016. Integrating sustainability concepts and value planning for sustainable construction. *Built Environment Project and Asset Management*, 6(2), pp.125 – 138.

Jian Zuo, Kunhui Ye, Martin Skitmore, Bo Xiong, Xiaolong Gan 2015 Why sustainable construction? Why not? An owner's perspective, *Habitat International,* pp.61-68.

Lawson, W. R. 1992. Capital energy costs of building and the recycling of building materials. *Proceedings of Construction Beyond 2000*, Espoo, Finland.

Lund, T. 2012. Combining qualitative and quantitative approaches: Some arguments for mixed methods research. *Scandinavian Journal of Educational Research*, 56(2), pp.155-165.

Majdalani, Z., Ajam M. and Mezher, T. 2006. Sustainability in the construction industry: A Lebanese case study. *Construction Innovation,* 6(1), pp.33-46.

Meacham, B.J., 2016. Sustainability and resiliency objectives in performance building regulations. *Building Research & Information*, *44*(5-6), pp.474-489.

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), pp.120-130.

Plessis, C.D. 2007. A strategic framework for sustainable construction in developing countries. *Construction Management and Economics*, 25(1), pp.67-76.

Presley, A. and Meade, L. 2010. Benchmarking for sustainability: An application to the sustainable construction industry. *Benchmarking: An International Journal*, 17(3), pp.435-451.

Neuman, W.L. 2011. *Social Research Methods: Qualitative and Quantitative Approaches*. 7th ed. Boston: Pearson.

Ogunbiyi, O., Goulding, J.S. and Oladapo, A. 2014. An empirical study of the impact of lean construction techniques on sustainable construction in the UK. *Construction Innovation*, 14(1), pp.88-107.

Roper, K.O. and Beard J.L. 2006. Justifying sustainable buildings: Championing green operations. *Journal of Corporate Real Estate*, 8(2), pp.91-103.

Rydin, Y., Amjad, U. and Whitaker, M. 2007. Environmentally Sustainable Construction: Knowledge and Learning in London Planning Departments*. Planning Theory & Practice*, 8(3), pp.363-380.

Sfakianaki, E. 2015. Resource-efficient construction: Rethinking construction towards sustainability. *World Journal of Science, Technology and Sustainable Development,* 12(3), pp.233-242.

Shi, Q., Zuo, J. and Zillante G. 2012. Exploring the management of sustainable construction at the programme level: A Chinese case study. *Construction Management and Economics,* 30(6), pp.425-440.

Vandierendonck, A., Liefooghe, B., and Verbruggen, F., Task switching: interplay of reconfiguration and interference control. *Psychological Bulletin*, 136(4), pp.601, 2010.

Warnock, C. 2007. Bringing existing buildings into the sustain-ability equation. New Zealand Sustainable Building Conference SB07. CIB, Auckland.

WCED. 1987. *Our common future.* New York, Oxford Univ. Press.

Wyatt, D.P., Sobotka, A. and Rogalska, M. 2000. Towards a sustainable practice. *Facilities*, 18(1/2), pp.76-82.

Rathnasinghe, A.P. and Kulatunga, U., 2019. Potential of using big data for disaster resilience: The case of Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 493-501. DOI: doi.org/10.31705/WCS.2019.49. Available at: https://2019.ciobwcs.com/papers

POTENTIAL OF USING BIG DATA FOR DISASTER RESILIENCE: THE CASE OF SRI LANKA

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ABSTRACT

The epoch of big data is evolving new possibilities for Disaster Management (DM). The concept of Big Data has been constantly scrutinised in terms of data creation, storage, retrieval, and analysis where professionals have identified its significance upon the volume, velocity and variety. Big Data provides the opportunity to gather more information in less time. Hence, analysis of Big Data can substantially enhance various disaster resilience activities such as issuing early warnings for evacuations; help emergency response personnel to identify areas that need urgent attention; coordination of disaster management activities; and to identify the most effective response methods for various situations. Therefore, Big Data is identified as a great catalyst for disaster response and, for better understanding of the damage situation and decision-making. Moreover, Big Data has the potential to improve disaster resilience by connecting people, processes, data and technology. However, it is essential to understand the type of Big Data that needs to be generated, to develop the data analysis as in necessary to help with real time responses, decision making and tracking of disaster victim. In order to accomplish the aim, a qualitative research approach was followed. This topical study marked the importance of big data in predicting human behavioral patterns during a disaster. Accordingly, the effective management of human and physical resources in habitual disaster territories was appraised through existing case studies in developed countries. Further, the research has successfully identified the challenges in employing Big Data upon its legal and technological barriers.

Keywords: *Big Data (BD); Disaster Management (DM); Disaster Resilience.*

1. INTRODUCTION

Ample natural and human induced disasters strike across the world frequently while mislaying thousands of lives and several more from their habitats and destroying vast amounts of properties (Altay and Green 2006; Galindo and Batta 2013). According to the World Disaster Report of 2015, "more than eight hundred thousand people are killed, and about two billion people were affected by six thousand natural and technological disasters around the world during the last decade" (Hamza, 2015, p.05). Therefore, the effective management of disasters can result in saving an uncountable number of human lives. Accordingly, the concept of DM is comprised of three segments: vigilance, reaction, and retrieval (National Academies Press, 2006). Thus, the assembling, archiving and analysis of disaster related data in a proficient manner is vital for an effective DM. Upon that view,

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the incorporation of BD can be identified as a major influence throughout all the stages of DM (Arslan *et al.*, 2017).

This paper comprehends the preliminary findings of the literature synthesis on how Big data has been incorporated into Disaster Resilience (DR) of Sri Lanka in relation with DR mechanisms introduced by the countries like Japan, Philippines and Indonesia. The main reason to incorporate the DR mechanisms from the aforementioned countries is the resemblance of disasters faced by those likeminded cultures to Sri Lanka (Kolb, 2013). Moreover, the legal issues related to Big data is a controversial fact among most DM forums. Consequently, this paper acknowledges the issues related to the end user's privacy and intellectual property rights in Big data application.

2. BACKGROUND

Before 2004, Sri Lanka had limited emergency warning mechanisms for natural disasters. However, following the Boxing day Tsunami, the number of data sets used to gather information on disasters has improved. These include satellite data; gauge data from rain, rivers, and reservoirs; information from the South Asian Disaster Knowledge Network, the Meteorology Department, the National Building Research Organisation; daily situation reports and improved hazard maps (Disaster Management Centre, 2013). Further, the 2004 Tsunami resulted in improving the mechanisms to issue early warnings. Currently, the use of SMS to communicate warnings on disasters is common in Sri Lanka. Mainly, the Disaster Management Centre (DMC) in Sri Lanka carries out such communications during disaster situations.

When a forthcoming disaster is being noted, DMC can declare any warnings through the communication mode of SMS without even consulting the service providers. Furthermore, the DMC also uses armed forces, the police and social aid networks like the Sri Lanka Red Cross Society to send out warnings in forms of sirens and loudspeakers (UNESCAP, 2009). In addition to the DMC, private television and radio organisations also use SMS in order to inform the public on disasters. Further, quick and constant updates on forthcoming disasters are also provided through television and radio as "Breaking News". Besides that, emergency warnings and updates on disasters are distributed via social media such as Facebook and Twitter. However, usage of social media is limited to the people living in urban areas and to the working community of Sri Lanka. Those who are in the rural areas and who work in agriculture rarely use social media. Further, government organisations such as the Department of Meteorology provide early warnings through their websites.

2.1 DATA MANNING AND RESPONDING UPON DISASTERS: EXISTING GAPS

The success of the early warnings issued through SMS, television and radio was demonstrated during April 2012 when over a million of people in the coastal area were evacuated following a Tsunami warning (Perera, 2012). Despite such successful evacuations and, millions in investments, there are gaps in DM of Sri Lanka in terms of collating the information gathered through various data sets and reaching the grass-root communities who live in rural areas. Further, inadequate national level policy to address data sharing for disaster management on emergency warnings, and the absence of institutionalised data sharing mechanisms among the Government and private organisations have been identified as sensible concerns to achieve effective DM (Disaster Management Centre, 2013). Therefore, the Disaster Management Centre has identified the need of integrating all disaster risk management data sharing producers and users into a single platform, promoting online data sharing among national to local and, regional to global level, and setting up an information management hub as the pathway to a future with effective disaster responses (Disaster Management Centre, 2013).

In Sri Lanka, due to the cultural and attitudinal reasons, most of the communities rely on Government based media. Therefore, the lack of trust to act upon SMS, especially if they are issued by private organisations is also evident. This mainly occurred when the severity of the disaster is not as significant as what has been mentioned in the SMS. Similar findings have been noted by the studies carried out in Bangladesh by Kulatunga *et al.* (2013).

Furthermore, the intervention of Sri Lankan service providers for a successful evacuation during disasters, and extraction of big data on human behavioural patterns during disasters to identify the evacuation pathways and communities with high risk are still in a primary stage. In contrast, countries like Japan use Big Data from service providers for instances such as to plan future responses of residents who are living in an area that has previously suffered from a disaster; records of important population subsets such as areas with elderly communities with infants and youth; to create new best-case scenarios in evacuation procedures for communities and government (Kolb, 2013).

3. RESEARCH METHOD

This paper intends to answer the research problem of "how the Big Data concepts and applications can be incorporated into the disaster resilience in Sri Lanka, and to identify the barriers to connect communities during disasters" through a qualitative research method. Thus, the qualitative research method is appraised as its ability to achieve an in-depth analysis on incipient and new concepts which are also consisted with a trivial literature supporting. Accordingly, this research is mainly focussed upon an in-depth investigation on literature sources about the incorporation of DM and Big data sources such as; DM protocols published by the Disaster Management Centre of Sri Lanka and the guidelines introduced by countries commonly affected by disaster such as; Japan and Indonesia. Moreover, authors of this article conveyed a considerable attention towards the case studies produced on the relevance of social media platforms and state strategies to collect disaster information in use of future disaster contexts. Consequently, the outcomes of the comprehensive literature analysis have been presented in the form of a conceptual model which is totally based on DM and Big data literature.

4. DISASTER MANAGEMENT

In compared to other management disciplines, the concept of DM has not yet been clearly defined or developed. Henstra and McBean (2005) elucidated on DM as a concept which embraces a range of principles and observations which are developed to avoid, manage and diminish the effect of a disaster. Furthermore, Park, Park and Kim (2019) defined DM as 'a process that includes activities before, during and after a hazard event that aim at preventing disasters, reducing their impacts and recovering from their losses'. However, many literature sources were in a common ideology related to the purpose of DM as to reduce probable fatalities, safeguard the immediate delivery of suitable backing to affected public and to achieve effective and speedy disaster recapture (Oloruntoba, Sridharan, and Davison, 2017).

4.1 PHASES OF DISASTER MANAGEMENT

Many authors identified mitigation, preparedness, response and recovery as the main phases of DM as identified in Table 1. However, these four factors have been identified in different criteria; Fajardo and Oppus (2010) recognised it in terms of a process, Henstra and McBean (2005) viewed them as theoretical essentials, and O'Brien *et al*. (2010) appraised these factors as a sequence.

Table 1: Key factors of disaster management

Classification	Content
Mitigation	• Comprises of recording the past risks, review and appraisal for declining future risks by means of spatial scheduling, mechanical actions, and public awareness
Preparedness	• Involves emergency planning and training, installation and operation of monitoring and forecasting warning systems
Response	• Response measures aim to maintain or re-establish public safety by search and rescue operations, and measures to provide for the basic humanitarian needs of the affected population
Recovery	• Includes rapid damage assessment as well as rehabilitation and reconstruction

Source: Park, Park and Kim (2019)

Although academic experts have expressed different views on the DM phases and their nature, it was their common doctrine that the involvement of the identified phases of DM will be identified according to the nature of the disaster (Park, Park and Kim, 2019). In other words, the degree of importance will not be the same in all four phases during a particular disaster.

4.2 DISASTER MANAGEMENT IN SRI LANKA

Sri Lanka has proven its ability to manage and reduce the effects of natural disasters from the times of its Kings. Accordingly, the ancient rulers introduced reservoirs with a bionetwork controlling method which prospered the country's agronomic culture for many spans (Ministry of Disaster Management, 2014). However, with the advancement of population and human activities, the Sri Lankan authorities are facing challenges related to the effective management and risk reduction of disasters.

The absence of vigilance of first-instance exposures to disasters on First-Aid, Cardiopulmonary Resuscitation (CPR) and the essentials of aged and incapacitated can be identified as one of the foremost loopholes in the DM of the Sri Lankan context (Disaster Management Centre, 2013). Additionally, Sri Lanka is identified to track down a worthy coverage in disaster related data on environment, demography, socio-economic factors, hydrology, soils, water, and climate change. However, effective DM in SL has been affected through poor arrangements to access information which is being composed by different organisations (Ministry of Disaster Management, 2014). Accordingly, this is the instance where the role of Big data takes a place in the DM practice of Sri Lanka so as to ensure the predictability of human behaviours related to disaster environments and effective decision making practise over a disaster.

5. A REVIEW OF BIG DATA USED IN DISASTER MANAGEMENT

As the occurrence of disasters exaggerate over the years, an anxiety has been developed among the people on how modern technology and innovations can be used to avoid, mitigate and manage disasters (Tan *et al*. 2016). Accordingly, this ideology was further acknowledged by Zheng *et al*. (2013, p. 451) while stating that "the techniques to efficiently discover, collect, organize, search, and disseminate real-time disaster information have become national priorities for efficient crisis management and disaster recovery tasks". It was further ascertained that the evolving technological revolutions comprising of social media, location-based systems, radio frequency identification, and big data analytics (BDA) are considered as influential gears that may support decision making and forecast throughout the DM phases (Akter and Wamba, 2017).

Upon this view, Mehrotra *et al*. (2013) promoted that the combination of Big data with DM would bring down a whole new generation of disaster response aspects as it has the prospect of mitigating the disaster effects by enabling access to critical immediate information. The role of Big data in respect of disaster management (DM) has been progressing (Akter and Wamba, 2017). However, previous studies have broadly conversed on reliability and application of sensible and up to date disaster information for DM and training circumstances (Velev and Zlateva, 2012). Accordingly, those studies have concluded on the effect of social media platforms in effective DM.

However, while going beyond the traditional aspect of Big data in DM, Wang *et al*. (2016) conducted a research on emergency communication systems for disasters, where he has drawn special attention towards Big data. According to him, Big data provides all possible data sets to understand the human behavioural patterns throughout the phases of DM while achieving the optimization of available resources during a disaster. Furthermore, Hristidis *et al*. (2010) conducted another study directed towards the effective utilization and improvement of data management to mitigate the severe disaster effects. His study highlighted the assortment, management, and presentation of real-time disaster related data throughout the DM process. Pu and Kitsuregawa (2013) acknowledged that Big data related to DM can be primarily obtained through dedicated sensor networks such as seismograph networks, remote sensing sensors

5.1 BIG DATA IN DISASTER PREPARATION

Pu and Kitsuregawa (2013) viewed this stage in the DM process as the most challenging due to the difficulty in predicting the possibilities in a multi-hazardous setup. Accordingly, they highlighted the need of highly accurate big data models to predict the uncountable number of variables and uncertainties.

Jongman *et al*. (2015) identified the Big data's contribution towards early detection of floods and its various parameters such as possible wave height, period, river's volume capacity to discharge the flood. Further to him, following parameters were obtained through the integration of many data sets from different bases where both isolated sensing data and social media platforms were identified to hold a major role in flood forecast and effect inquiry. Moreover, specifically to social media platforms, social media posts, keywords and hashtags empower relevant authorities to visualize and map locations related to disasters, which have played a vital role in actual flood disaster situations at Pakistan and Philippines (Velev and Zlateva, 2012).

5.2 BIG DATA IN DISASTER RESPONSE

During the DM phase of response, the top priority of relevant authorities should be to ensure the public safety through immediate evacuation and rescue operations. Accordingly, Pu and Kitsuregawa (2013) identified three aspects where Big data can be incorporated and used to improve disaster response. These three aspects are Big data's promising nature to obtain probable identification of critical disaster zones, real time situation study and to recognise the most proficient response from former disaster setups. With the ever increasing usage of smartphones, various data formats can be originated during the due course of a disaster. Rahman, Di and Zannat (2017) acknowledged on those data sets as influential data streams which enable an effective DM process through visualization and GIS mapping. Accordingly, it was reviewed that such data patterns may help in identifying the number of people in critical zones and their ability to self-evacuate or assist in vacating upon their age, medical records, and service provider details (Rahman, Di and Zannat, 2017).

Moreover, many researchers have expressed their viewpoint regarding advanced GPS systems used in software applications such as Google Maps and Find My IPhone. Accordingly, Jongman *et al*. (2015) revealed the GPS software's ability to provide general evacuation and safety advices which would be unique to a service user; upon user's immaturity or health conditions or incapacity. In view of that, Heinzelman and Waters (2010) revealed on the Haiti earthquake disaster in 2010, where more than 80,000 text messages were scrutinized by the authorities to detect people who required aid to evacuate. A similar technique was followed during the Nepal earthquake, where earthquake details were broadcasted through phone applications and Twitter (Bossu *et al*., 2015).

5.3 BIG DATA IN DISASTER RECOVERY

As the final phase of the DM process, disaster recovery is included with assessing the damages caused by disaster, forming decisions for future from the lessons learnt from the real-time disaster situation and research further to improve disaster resilience. Accordingly, many researches came up with technological innovations to assess the post disaster damages. For an example, Hong *et al*., (2015) executed parallel processing of Unmanned Aerial Vehicle (UAV) imagery to detect the damages of buildings caused from the Ya'an earthquake in China as three-dimensional models. Further to Hong *et al*., intervention of UAV as Big data helped to generate rapid information regarding the post disaster management. Moreover, Rahman, Di and Zannat (2017, p 05) discussed on Big data's role in disaster recovery period as "to enhance disaster management capacity for future events".

5.4 CHALLENGES LINKED WITH BIG DATA

The combination of Big data and DM is comparatively innovative to many administrative bodies in the world. Therefore, it is inevitably with rising challenges in incorporating Big data to disaster field where Big data's prospects has been ignored in real-time decision-making processes. Accordingly, with the high population and rapid increasing of disasters around the world, it is essential to implement much accurate forecasting and early warning systems which Big data has promised in providing (Rahman, Di and Zannat, 2017). Even though large amount of data sets are being produced during a disaster, not every such data set will not be the accurate one. Therefore, it is essential to implement the noise removal from these Big data, which is highly challengeable (Pu and Kitsuregawa, 2013). The language barrier is one severe challenge upon the Big data's approach towards DM. Because, most of these DM specifications are formed on contextual basis where the appropriate translations are to be done prior to the adoption in any country (Rahman, Di and Zannat, 2017).

Legal barriers upon Big data is a burning topic in the technological world which would also be applicable to the DM field as well. Accordingly, data privacy is a universally accepted right of people where many social data of people are being considered private. Therefore, it is a challenge beneath the DM professionals to decide whether the extraction of social media data, service provider data, data relating to family and health would be an intervention to the private autonomy of a person (Pagollo, 2017). Moreover, resilience of big data sets itself is a practical challenge to be considered where the demand for Big data sets would peculiarly increase during a disaster. Therefore, there should be alternative options to Big data because the accessibility to these data is highly vulnerable where the data itself can be easily damaged by the disaster (Rahman, Di and Zannat, 2017).

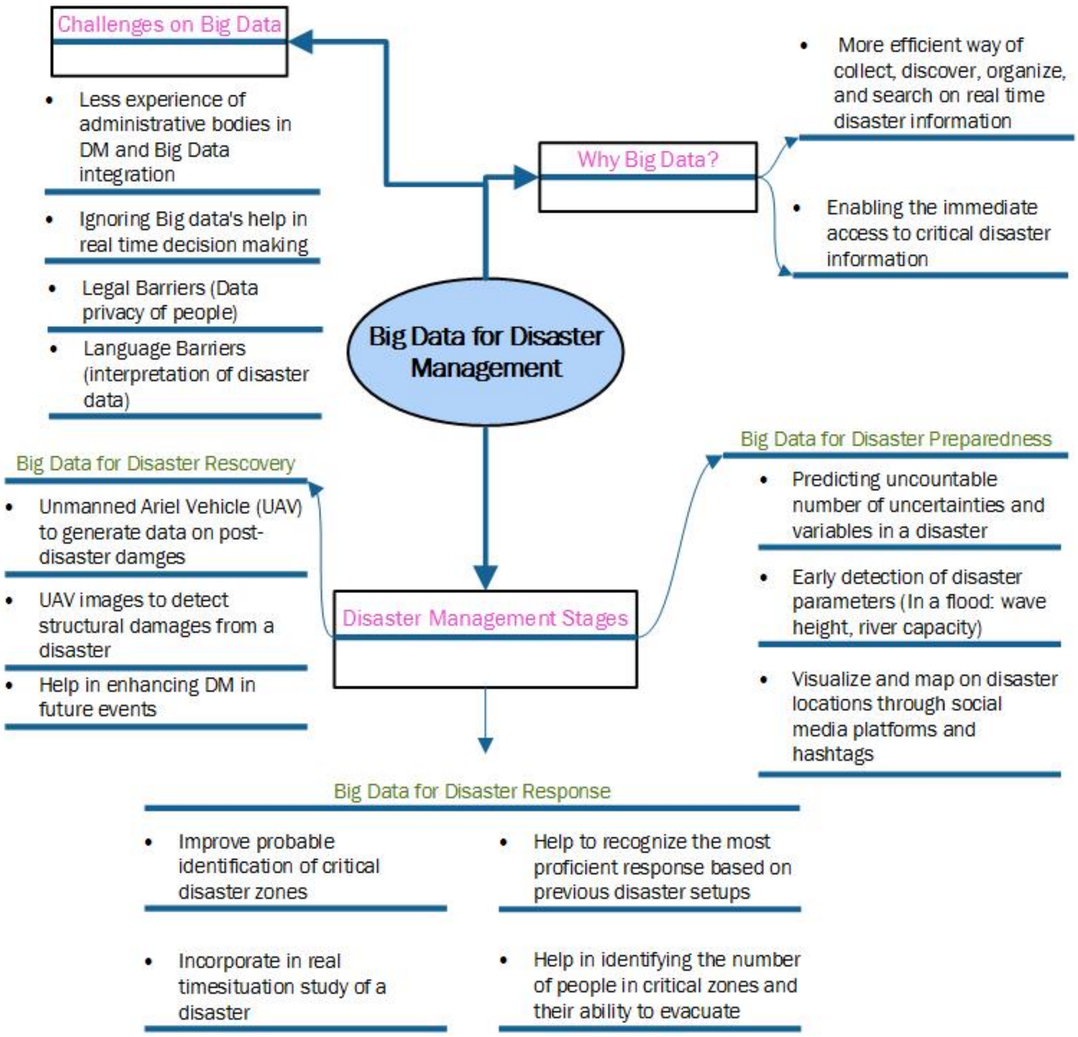

Figure 1: Conceptual model on big data and disaster management combination

6. CONCLUSIONS

It is evident through literature sources that Big data holds a vital role for an effective DM process. Large volume of data from different platforms such as; social media, sensor networks, and other sources have proved their expediency in DM through various real-world case studies. Moreover, the significant features of Big data have promised the administrators and the first responders in disasters to come up with accurate and definite decisions in mitigating the disastrous effects. Further, many sources have proved the existence of Big data in present natural disaster forecasting systems where the probability of a disaster will be measured in comparison to various parameters in a large volume of data set.

Moreover, data sets relating to human behaviours; crowdsourcing, cloud computing, and cyber layouts will help in extracting the required information for the DM. The Big data archive can be supportive for prototype improvement and authentication as to certify more effective DM. However, the integration of Big data and DM is yet a new topic for most of the administrative bodies where they have ignored the importance of Big data in most of their real-time decision making in a disaster. Further, the legality of incorporating human related data for government work is a burning issue in the legal field on the right to privacy. Therefore, most of the policy makers are obeying an indolent path towards such incorporation into the DM field. However, many of the real-world case studies have proven Big data's usefulness and ability to improve the accuracy of disaster prediction which makes its incorporation an inevitable fact.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

Akter, S. and Wamba, S., 2017. Big data and disaster management: a systematic review and agenda for future research. *Annals of Operations Research*, *86*, pp.1587-1592.

Altay, N., and Green, W. G., 2006. OR/MS research in disaster operations management. *European Journal of Operational Research*, *175*, pp.475–493.

Arslan, M., Roxin, A., Cruz, C. and Ginhac, D., 2017. A Review on Applications of Big Data for Disaster Management. In: *The 13th International Conference on SIGNAL IMAGE TECHNOLOGY & INTERNET BASED SYSTEMS* [online] Available at: https://hal.archives-ouvertes.fr/hal-01678238/document.

Bossu, R., Laurin, M., Mazet-Roux, G., Roussel, F., and Steed, R., 2015. The Importance of Smartphones as Public Earthquake-Information Tools and Tools for the Rapid Engagement with Eyewitnesses: *A Case Study of the 2015 Nepal Earthquake Sequence. Seismological Research Letters*, *86*, pp.1587–1592.

Disaster Management Centre (DMC), 2013. *Improving Disaster Data to Improve Resilience*. Expert Group Meeting with Japan. Colombo: Ministry of Disaster Management.

Fajardo, J.T.B. and Oppus, C.M., 2010. A mobile disaster management system using the android technology. *WSEAS Transactions on Communications*, *9*(6), pp.343-353.

Galindo, G. and Batta, R., 2013. Review of recent developments in OR/MS research in disaster operations management. *European Journal of Operational Research*, *230*, pp.201–211.

Hamza, M., 2015. *World Disasters Report 2015: Focus on local actors the key to humanitarian effectiveness.* International Federation of Red Cross and Red Crescent Societies.

Henstra, D. and McBean, G., 2005. Canadian disaster management policy*:* Moving toward a paradigm shift, *Canadian Public Policy/Analyse de Politiques*, 31(3), pp.303-318.

Heinzelman, J., and Waters, C., 2010. *Crowdsourcing crisis information in disaster-affected Haiti*. US Institute of Peace.

Hong, Z., Tong, X., Cao, W., Jiang, S., Chen, P. and Liu, S., 2015. Rapid three-dimensional detection approach for building damage due to earthquakes by the use of parallel processing of unmanned aerial vehicle imagery. *Journal of Applied Remote Sensing*, *9*(1), p.097292.

Hristidis, V., Chen, S. C., Li, T., Luis, S., and Deng, Y., 2010. Survey of data management and analysis in disaster situations. *The Journal of Systems and Software*, *83*, pp.1701–1714.

Jongman, B., Wagemaker, J., Romero, B.R., and de Perez, E.C., 2015. Early flood detection for rapid humanitarian response: harnessing near real-time satellite and Twitter signals. *ISPRS International Journal of Geo-Information 4*, pp.2246–2266.

Kolb, J., 2013. *The Big Data Revolution Kindle Edition*. Jason Kolb.

Kulatunga, U., Wedawatta, G., Amaratunga, D., and Shamsuzzoha, M., 2013. Disaster Risk and Community Vulnerability: the Case of Patuakhali, Bangladesh. In: *9th annual international conference of the international institute for infrastructure renewal and reconstruction*, 10 July 2013, University of Queensland. Australia.

Mehrotra, S., Qiu, X., Cao, Z., and Tate, A., 2013. Technological challenges in emergency response. *IEEE Intelligent Systems*, *4*, pp.5-8.

Ministry of Disaster Management, 2014. *Sri Lanka Comprehensive Disaster Management Programme (SLCDMP)*. Colombo: Ministry of Disaster Management.

National Academies Press, 2006. *Facing hazards and disasters*. Washington: Author.

O'Brien, G., O'Keefe, P., Gadema, Z. and Swords, J., 2010. Approaching disaster management through social learning. *Disaster Prevention and Management: An International Journal*, 19(4), pp.498-508.

Oloruntoba, R., Sridharan, R. and Davison, G., 2018. A proposed framework of key activities and processes in the preparedness and recovery phases of disaster management. *Disasters*, *42*(3), pp.541-570.

Pagallo, U., 2017. The Legal Challenges of Big Data. *European Data Protection Law Review*, 3(1), pp.36-46.

Park, J., Park, S. and Kim, K., 2019. Disaster management and land administration in South Korea: Earthquakes and the real estate market. *Land Use Policy*, 85, pp.52-62.

Perera, K., 2012. *Sri Lanka, the tsunami and the evolution of disaster response - Sri Lanka*. [online] ReliefWeb. Available at: https://reliefweb.int/report/sri-lanka/sri-lanka-tsunami-and-evolution-disaster-response [Accessed 18 Sep. 2019].

Pu, C. and Kitsuregawa, M., 2013. *Joint Workshop Report on Big Data and Disaster Management*. [online] Georgia Institute of Technology. Available at: https://grait-dm.gatech.edu/wp-content/uploads/2014/03/BigDataAndDisaster-v34.pdf [Accessed 1 Mar. 2019].

Rahman, S., Di, L. and Zannat, E., 2017. The role of big data in disaster management. In: *International Conference on Disaster Risk Mitigation*. [online] Available at: https://www.researchgate.net/publication/322265557 [Accessed 1 Apr. 2019].

Tan, X., Di, L., Deng, M., Huang, F., Ye, X., Sha, Z., Sun, Z., Gong, W., Shao, Y. and Huang, C., 2016. Agent-as-a-service-based geospatial service aggregation in the cloud: A case study of flood response. *Environmental modelling & software*, *84*, pp.210-225

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), 2009. *Tsunami Early Warning Systems in the Indian Ocean and Southeast Asia*. Report on Regional Unmet Needs. New York: Tsunami Regional Trust Fund, United Nations.

Velev, D. and Zlateva, P., 2012. Use of social media in natural disaster management. *International Proceedings of Economic Development and Research*, *39*, pp.41-45.

Wang, Y., Zhang, H., He, D., Guo, C., Zhu, W., and Yang, W., 2016. Function design and system architecture of disaster prevention and dispatch system in power system based on big data platform. *Dianwang Jishu/Power System Technology*, 40(10), pp.3213–3219.

Zheng, L., Shen, C., Tang, L., Zeng, C., Li, T., Luis, S. and Chen, S.C., 2013. Data mining meets the needs of disaster information management. *IEEE Transactions on Human-Machine Systems*, *43*(5), pp.451-464.

Ariyachandra, M.R.M.F., Samarakkody, A. and Perera, B.A.K.S., 2019. Real-virtual synchronisation: A review on the state-of-the-art geometric digital twinning of infrastructure. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 502-512. DOI: doi.org/10.31705/WCS.2019.50. Available at: https://2019.ciobwcs.com/papers

REAL-VIRTUAL SYNCHRONISATION: A REVIEW ON THE STATE-OF-THE-ART GEOMETRIC DIGITAL TWINNING OF INFRASTRUCTURE

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ABSTRACT

In the United Kingdom (UK), recent developments in the construction industry have increased the demand for digitised infrastructure, which facilitates the investigation of the as-is performance of assets. This establishes the need to create and maintain up-to-date digital copies of infrastructure assets, often labelled as Digital Twins. Digital twins are obtained by converting the unstructured data formats of the real-world assets, such as point clouds, into high-level digital representations. Yet, only few assets today have usable digital twins because of the high costs of the latter. This counteracts the benefits of the twins and reduces dramatically their true potential. Hence, there is a pressuring need to automate the process of creating digital twins. Geometric digital twin, the most basic form of the twin, contains only the geometry of the physical asset. This paper reviews the work done in computer vision, geometry processing, and civil engineering fields to determine the potential that exists for automatically producing geometric digital twins of infrastructure.

Keywords: *Geometric Digital Twin (GDT); Infrastructure; Point Cloud Data (PCD).*

1. INTRODUCTION

Digital twin (DT) emerged from the aerospace field and was initially defined by the National Aeronautics and Space Administration (NASA) as "an integrated multi-physics, multi-scale, probabilistic simulation of a vehicle or system that uses the best available physical models, sensor updates, fleet history, etc. to mirror the life of its flying twin" (Shafto *et al.*, 2010). It is expected to replicate its physical asset in a digital environment. However, the data and models held in it will relate only to their intended purpose (Boschert, Heinrich and Rosen, 2018). A digital twin of an infrastructure can learn and update itself continuously using multiple data sources to represent the near real-time status and working condition of the infrastructure (HM Government, 2013). It can be maintained throughout the whole life-cycle of the infrastructure and will be continuously accessible (Parrott and Lane, 2017). Hence it can provide an early insight into the risks posed to the infrastructure by climatic events, neighbourhood structures or aging (Koch *et al.*, 2014). According to Koch *et al.*, (2014), there can be three types of DT in the life-cycle of an infrastructure: (a) As-designed DT produced by the design team, (b) As-built

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DT produced by the main contractor and reflecting the state of the infrastructure at the time of its completion, and (c) As-Is DT produced by the infrastructure facilities management team by surveying the infrastructure regularly. DT hereinafter unless otherwise stated specifically refers to As-Is DT, generated for the existing infrastructure.

Most recently, the Heathrow airport terminal 2B project that experienced £10 million in savings and a reduction of 5 weeks in the schedule by digitising the project (Bower, 2014). The wider adoption of DTs by 2025 for the infrastructure is expected to provide 15-25% savings (Gerbert *et al.*, 2016; Barbosa *et al.*, 2017). However, West and Blackburn, (2017) claim that the generation of DTs of the existing infrastructure is highly discouraged today as the costs outweigh the benefits.

The aim of this paper is to investigate the state of the art in generating geometrically accurate models of existing infrastructure. The paper starts off by explaining the present status of digital twin generation. The subsequent sections provide a longitudinal literature review focuses on geometric modelling infrastructure. The paper finally concludes by deriving gaps in the knowledge and elaborating potential research contributions.

2. PRESENT STATUS OF DIGITAL TWIN GENERATION

Digital twinning is the mapping of a physical asset to a digital platform (Rossi, 2017). It can be continuously updated using data collected from sensors. The data so collected are first used to form a twin in an unstructured data format of the real-world asset, such as a point cloud data (PCD). It is a collection of XYZ coordinates of a three-dimensional (3D) coordinate system (Benli, 2015). This PCD, which is a low-level digital representation of the asset, then converted into a high-level digital representation, the DT, through a twinning phase, which structures the unstructured raw data.

Although many hardware solutions capable of collecting accurate geometrical data of infrastructure in the form of PCDs are already available, there are still only limited number of DTs of the existing infrastructure. The main reason is the difficulty experienced, even by skilled modellers, in manually generating at least a seemingly simple DT structure using PCDs. The Scan-to-BIM process (Tang *et al.*, 2010) of creating a DT involves four major steps: (1) raw image and/or PCD capture, (2) data preparation, (3) geometric modelling and (4) semantic enrichment of the model with additional information, such as topological relationships and material specifications. The 3rd step requires more than two thirds of the effort needed for generating the entire DT. Furthermore, the time required to manually create a DT from PCD using even the cutting-edge modelling software is almost 10 times more than that required to obtain the original point cloud (Trimble, 2017). Training of the modellers is also a necessity since DT generation is a highly domain-specific task; even proficient Computer Aided Design (CAD) professionals may not be adequately competent to manipulate modelling software without specialised training (McNell *et al.*, 2011). Generation of a DT from PCD incurs high costs, both fixed and variable. Fixed costs involve DT modelling software license fees, cost of hardware required for using the software, and cost of training of modellers. Variable costs are the fees spent on each individual modelling project, which relate to the total number of modelling hours and the hourly labour cost. If fixed costs and the hourly labour cost remain constant, the total cost of DT generation will depend on the total number of modelling hours. Thus, cost savings can be made by using automated solutions that will reduce the total modelling time.

The most advanced PCD-to-DT modelling software solutions are provided by major vendors, such as Autodesk, Bentley, Trimble, AVEVA and ClearEdge3D. According to Wang, Cho and Kim (2015) and Agapaki and Brilakis, (2018), although the currently available DT modelling commercial software can automate a large extent of the DT generation process, they are still far from being fully automatic. For commercial applications outside building and industrial environments, modellers have to first manually segment a PCD into subparts, and then manually fit the 3D shapes to the subparts. This demands a significant amount of time. PCDs has to be rotated repeatedly to get different views and identify the regions of interest using clipping polygons. The subsequent fitting of the accurate 3D shapes to the segmented sub-point-clusters is also challenging. Most software applications provide built-in shape libraries containing a few predefined and generic construction component primitives such as beams, walls and columns. However, the allowable primitives are also limited (Wang, Cho and Kim, 2015). Since infrastructure components usually have arbitrary shapes containing skews or imperfections, which cannot be simply fitted using idealised predefined shapes, modellers have to manually create an accurate solid form to fit each point cluster as none of the existing software packages available are capable of doing this automatically.

3. RESEARCH ON DIGITAL TWIN GENERATION

Automation of the modelling process can be divided into two parts: (1) object detection in PCD, and (2) 3D solid model fitting to point clusters.

3.1 OBJECT DETECTION IN PCD

Uijlings *et al.* (2012) define detection as the combination of clustering (from a PCD to point clusters) and classification (labelling the point clusters).

3.1.1 Bottom-up Approach

Bottom-up approach pieces together low-level primitive features like points to generate complex systems at successively higher levels until a top-level system is formed (Borenstein and Ullman, 2008). Its typical higher-level features are the surface normal (Sampath and Shan, 2010), meshes (Marton, Rusu and Beetz, 2009), surface planes/ patches (Zhang and Tang, 2015), non-uniform B-Spline surfaces (Dimitrov and Golparvar Fard, 2015; Dimitrov, Gu and Golparvar-Fard, 2016), and voxels (Vo *et al.*, 2015). There are three main methods used in this approach.

RANdom Sample Consensus (RANSAC) has essentially two steps repeated iteratively. Firstly, hypothetical shapes are generated by randomly selecting a minimal subset of points followed by estimating the fitting model parameter of the sample subset. Secondly, the remaining points are iteratively checked to determine whether they are consistent with the model instantiated by the estimated model parameters obtained from the first step. The shape model that possesses the largest percentage of points is then extracted. Tarsha-Kurdi, Landes and Grussenmeyer (2007) have proposed an extended RANSAC algorithm to extract roof planes from low density PCD having different complexities. Bosché (2012); Arikan *et al.* (2013) and Jung *et al.* (2014) have used RANSAC to detect planar surfaces such as walls, floors, ceilings etc. in PCD of buildings. Although this algorithm is found to be effective even in the presence of noise and outliers (Tarsha-Kurdi *et al.*, 2007), it has its own limitations as well. Firstly, since it is used to determine different planes from a single grouping, there can often be spurious-planes (i.e. planes overlapping multiple reference planes or a plane snatching points from its neighbouring planes), especially around boundaries (Yan *et al.*, 2012; Jung *et al.*, 2014). Secondly, it requires prior knowledge about the data, which is often not the case in practice. Hence RANSAC-based methods will perform well only in relatively simplified scenarios and thus will not be suitable for real infrastructure asset components whose as-weathered and as-damaged shapes would further increase the as-designed complexity.

Region Growing (RG) also has two main steps. It starts with a set of small iteratively merged areas by arbitrarily choosing initial seeds. Its second step adds in neighbouring points based on the similarity of the surface normal, curvature or co-planarity, until an edge is reached either when a non-surface point is detected or when the distance from the seed point exceeds a threshold. Xiao *et al.* (2013) have proposed two complementary plane segmentation algorithms: a sub-window-based RG algorithm for structured PCD, and a hybrid RG algorithm for unstructured PCD. On the other hand, Dimitrov and Golparvar Fard, (2015) have suggested an upgraded RG method through which the seed can be found adaptively. It can deal with curved surfaces within a large range of surface roughness. It excels when there are no substantive occlusions in the input PCD. Yet, this method over-segments objects when non-trivial occlusions are present. The persistent occlusions in real PCD were addressed by Xiong *et al.* (2013) through a learning-paradigm that can detect occluded planar surfaces and estimate their shapes in building PCD. This learning paradigm cannot be applied to infrastructure because occluded surfaces in infrastructure PCD do not follow a specific pattern unlike those in a building PCD. Assuming that there are many identical rectangular openings on a wall, it detects the rectangular-shaped openings, such as windows and doorways. Similarly, Laefer and Truong-hong (2017) have developed a kernel-density-estimation-based method for modelling steel members by simulating possible occlusions. The occluded regions in infrastructure PCD do not follow repetitive patterns. Most of those occlusions, being due to on-site vegetation and long-distance scanning, are in arbitrary locations and shapes, which cannot be tackled by any of the methods. Even though, RG-based methods have been proved to be efficient at object detection in PCD, they suffer from occlusion effects, and have boundary weaknesses, as a result of the inaccurate estimation of normals or curvatures of points near region boundaries. These limitations often require manual adjustment.

Hough-Transform (HT) maps every point in the dataset to a manifold in the parameter space containing many cells that act as accumulators with each of their points casting votes. Vosselman (2009) have employed HT-based methods to detect 3D roof planes in PCD. However, Tarsha-Kurdi, Landes and Grussenmeyer (2007) have reported that plane detection rates based on HT are lower than those using RANSAC. HT is not suitable for solving higher dimensional problems since, plane detection requires a 3D Hough parameter space while cylinder detection requires a 5D Hough parameter space. Shah (2006) suggested a two-stage approach to detect cylinders in PCD to reduce computational complexity and the number of dimensions. His method transforms 5D Hough space cylinder detection problems into 2D and 3D Hough space problems. Ahmed, Haas and Haas (2014) have employed HT to detect straight cylindrical pipes using thin slices resampled from PCD. HT, however, is a powerful tool for detecting simple geometric objects within noisy and cluttered PCD. Nevertheless, it is sensitive to parameter dimensions and thus cannot be applied to shapes that have too many parameters, since then it would result in a sparse, high-dimensional accumulator that is poor in performance and high in memory requirements (Hassanein *et al.*, 2015). Thus, HT is not being used for detecting infrastructure objects, which often contain skews and imperfections, because of the impossibility of describing such objects using generic shapes with limited parameters.

Hence the three main bottom-up methods RANSAC, RG, and HT, can be considered as being generally reliable for detecting generic 2D and 3D object shapes in the presence of noise and outliers. Nevertheless, their high computational requirements render them ineffective for detecting complex objects in real infrastructure PCDs, which usually contain complex geometries.

3.1.2 Top-down Detection

The top-down approach begins with a broad view of the picture and is broken subsequently into compositional sub-problems that are easier to solve (Kokkinos and Yuille, 2006). A pioneering study that used the top-down modelling approach is REFAB (Reverse Engineering FeAture-Based) (Thompson *et al.*, 1999), which uses geometric constraints, such as parallelism, concentricity, perpendicularity and symmetry, to convert points to mechanical solid models. Nüchter and Hertzberg (2008) have used a relationship reasoning network for semantic mapping. They used a set of pair-wise relationship rules such as parallel, equal height, above, under, and orthogonal to coarsely classify major planes (wall, ceiling, floor and door) in an indoor PCD. The method presented by Su, Bethel and Hu (2016) uses a set of connectivity criteria such as proximity, orientation, and curvature, to merge and label industrial components (pipe, vessels, and walls) across voxels. In contrast, Perez-Gallardo *et al.* (2017) have suggested a semantic model-based system to detect the four object classes (pipes, planes, elbows, and valves) in industrial environments using topological information while Laefer and Truong-hong (2017) have leveraged a steel standard library to identify and match the cross-sections of steel frames in PCD. Recent research has relied on As-Designed documents to present the top-down modelling approach, which can simplify PCD clustering and classification tasks (Liu, Eybpoosh and Akinci, 2012). It is because the information gleaned from prior data can shift the focus from detecting objects to matching between a PCD and the existing models (Bosché, 2010). Belsky *et al.* (2014) have encapsulated domain expert knowledge in the form of rule sets to infer and enrich semantics for a geometric building model.

However, all these methods have been tailored for buildings, indoor environments, and industrial objects and not for infrastructure settings, as the geometric properties of infrastructure components are quite different from those of the objects found in buildings. Also, there are either few or no As-Built or As-Is models for the existing infrastructure indicating that there is only little knowledge available about embedded objects in related PCDs. The following Figure 1 represents a framework which synthesizes all object detection methods used in the studies being presented.

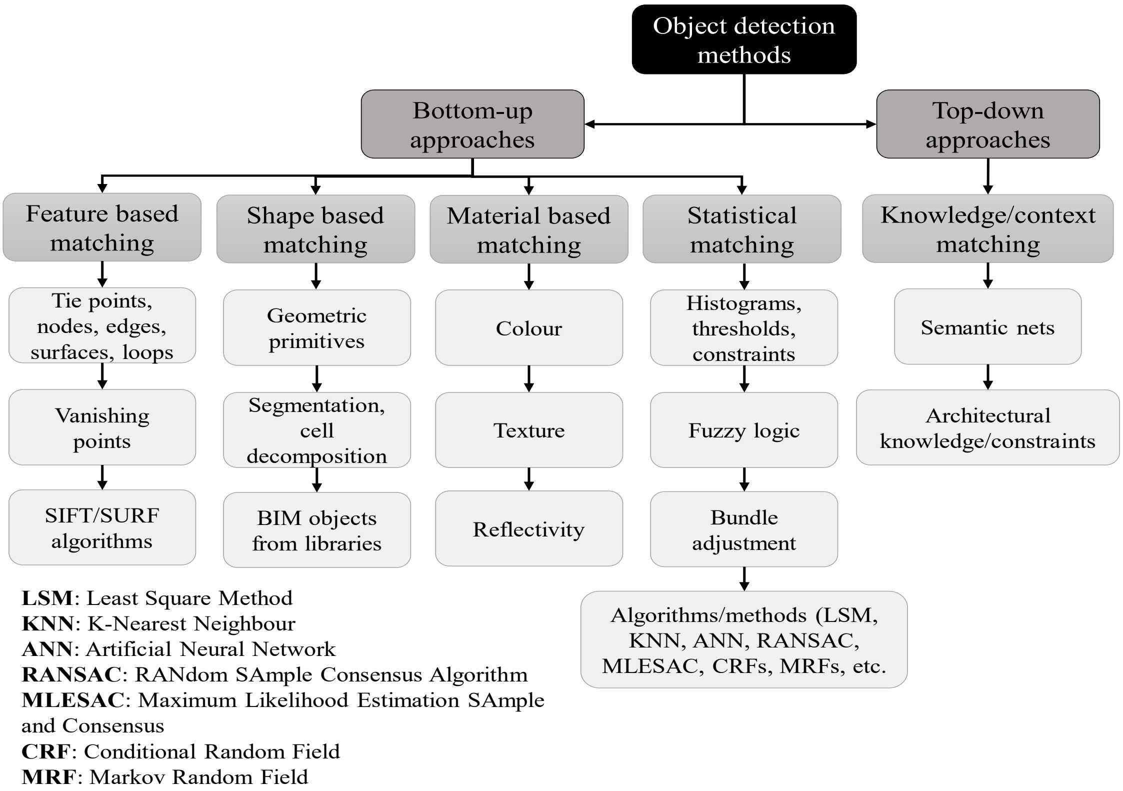

Figure 1: Object detection methods (Adopted from Volk, Stengel and Schultmann, 2014)

3.2 FITTING THE MODEL TO A POINT CLUSTER

Point cluster, which is the output of the object detection step, is a subpart of the PCD. Fitting a 3D solid model to a labelled point cluster will transform a point cluster of unordered spatial points into a structured, information-rich 3D representation. The choice of digital representation depends on; (1) the nature of the object being modelled, (2) modelling technique used, and (3) application scenario where the object is brought to life. Shape representation methods can be categorized into three groups.

Implicit representation is a solid modelling approach that represents 3D shapes using mathematical formulations, i.e., implicit functions. Using computer-aided geometric modelling, an arbitrary constructive solid can be defined as a single real-valued function (x,y,z)) of three variables with $f(x,y,z) \geq 0$ (Rvachev, 1982) and for the surface, (x,y,z) =0 (Ricci, 1973). Common implicit surface definitions include, but are not limited to, planes, spheres and ellipsoids. Implicit surfaces have difficulty in describing sharp features such as edges and vertices, although they are good at checking whether a point lies inside, outside, or on the surface (Song and Juttler, 2009). Since only a very limited number of primitives can be exactly represented by algebraic formulas, their usefulness is limited when modelling real-world 3D objects with non-idealised shapes, such as infrastructure components. In addition, infrastructure components contain defects that reduce further the effectiveness of the implicit representations.

Boundary representation (B-Rep) describes a shape using its boundary surfaces. The model formed using B-Rep is, therefore, an explicit representation, as the object is represented by a complicated data structure giving information about each of its vertices, edges, and loops and the way of joining them to form the object. The geometry of a vertex is given by its (x, y) coordinates. The edges are straight or curved lines. A face is represented by a description of its surface with algebraic or parametric forms. Kwon *et al.* (2004) assuming that a construction site consists of these primitives, have introduced a rapid and accurate local spatial modelling algorithm to fit sparse PCD to planes, cuboids, and cylinders in B-Rep. Valero and Cerrada (2012) have developed methods to yield B-Rep models for indoor planar objects such as walls, ceilings and floors with high precision.

Constructive solid geometry (CSG) is a high-level volumetric representation that works both as a shape representation and as a record of the way an object has been built up (Deng, Cheng and Anumba, 2016). The final shape of the object can be represented as a combination of a set of elementary solid primitives that follow a certain type of logic. The primitives can be cuboids, cylinders, spheres, cones etc. The methods proposed by Shah (2006) and Patil *et al.* (2017) can be used for modelling a cylindrical piping system using simple primitives. Alternatively, the random sampling method of Schnabel, Wahl and Klein (2007) can be used to automatically model objects composed of five basic shapes (planes, spheres, cylinders, cones, and tori), which can provide a representation consisting solely of shape proxies. Walsh *et al.* (2013) have developed a shape library containing a generic description of objects (i.e. cuboid, cylinder) to fit point clusters using surface fitting in the form of least squares. The reliability of the method is unclear as a quantitative assessment of the fitting performance is not given in the work. Xiao and Furukawa (2012) have introduced the inverse CSG algorithm to reconstruct large-scale indoor environments with a CSG representation consisting of volumetric primitives by imposing regularization constraints. It uses only cuboids as volumetric primitives considering that they are the most common shapes found in indoor walls. The expansion of the set of geometric primitive types would, however, be necessary as construction elements can contain other shapes.

4. GAPS IN KNOWLEDGE

The existing object detection methods used in DT-related work concentrate mostly on a low-level of primitive generation (Dimitrov, Gu and Golparvar-Fard, 2016), i.e. surface clustering from points. Only few methods enable the direct generation of labelled point clusters. Furthermore, the existing methods focus on generating either building or industry elements, which basically take generic shapes, such as cuboids and cylinders (Patil *et al.*, 2017), or standardized steel beams (Laefer and Truong-hong, 2017). These methods cannot be directly used to detect infrastructure components in PCD because idealised shapes are rare in real infrastructure elements. In addition, real PCD are noisy and imperfect and suffer from occlusions and sparseness. These factors render methods designed for synthetic data or simplified scenarios ineffective for infrastructure. The few DT related studies on the existing infrastructure, also have restrictive constraints; they take an idealised infrastructure solid model as the input to infer the semantic meaning of components train a classifier with generic shapes or test against a synthetic infrastructure point cloud (Zhang, Vela and Brilakis, 2014). These gaps in knowledge derives potential research contributions in the area such as;

1. Developing a method to automatically detect infrastructure structural components in PCDs – These structural components might include decks, beams for a bridge, rails, sleepers, track bed for a railway and so forth. The approach will differ with the non-idealised shape of the infrastructure component. In addition, this approach

can combine the strengths of the data-driven strategy scenarios with very high point densities and model-based strategy in scenarios with very low point densities.

2. Developing a method to automatically fit 3D solid models to the point clusters of infrastructure components – To tackle the need of the common format, the output 3D model shall compatible with many software available, such as Industry Foundation Class (IFC) format.
3. Leveraging a reasonable 3D model assessment metrics to assess the generated GDTs of infrastructure – This is necessary as the problem of evaluating the quality and degree of automation of a generated GDT compared to its PCD has yet to be studied in depth. This assessment must compatible with the end user requirements and the level of the detail expected from the resulting model.

5. SUMMARY AND DISCUSSIONS

The use of DTs for existing infrastructure is limited as the perceived benefits outweigh the cost of and the effort required for DT modelling. The average time required to manually create an infrastructure GDT from a PCD using cutting edge modelling software (i.e. Autodesk Revit 2016) is about 10 times more than the time required to obtain the PCD, as the current software packages are not fully automatic. This stresses the need for automating the PCD-to-GDT process.

The knowledge gaps in the DT generation of infrastructure were identified by thoroughly reviewing in two parts the past studies on the state-of-the-art DT technologies corresponding to the two major steps of the PCD-to-GDT process: object detection in PCDs, and model fitting to point clusters. The object detection methods presently available concentrate on clustering low-level primitives to constitute surfaces and deducing the semantic meaning of the elements using high-level knowledge. However, those methods cannot effectively tackle the persistent occlusions and the varying point density problems of real PCD. In addition, none of them can address the challenges of complex geometry and topology of real infrastructure. Moreover, the existing model fitting methods concentrate on fitting idealised primitives, such as cuboids and cylinders, to indoor planar and industrial elements.

Thus, none of the existing methods can be used for detecting infrastructure components in real PCD (non-perfect data), and for modelling components with complex geometries. The contributions made by this paper to knowledge highlight the knowledge gaps and potential research contributions mentioned in Section 4, which can be used in the future to identify potential research objectives and formulate research questions.

6. REFERENCES

Agapaki, E. and Brilakis, I., 2018, June. State-of-practice on as-is modelling of industrial facilities. In *Workshop of the European Group for Intelligent Computing in Engineering* (pp. 103-124). Springer, Cham.

Ahmed, M., Haas, C. T. and Haas, R., 2014. Automatic Detection of Cylindrical Objects in Built Facilities. *Journal of Computing in Civil Engineering*, 28(3), pp.1-11.

Arikan, M., Schwärzler, M., Flöry, S., Wimmer, M. and Maierhofer, S., 2013. O-snap: Optimization-based snapping for modeling architecture. *ACM Transactions on Graphics (TOG)*, *32*(1), p.6.

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M.J., Sridhar, M., Parsons, M., Bertram, N. and Brown, S., 2017. *Reinventing construction: A route to higher productivity.* McKinsey Global Institute.

Belsky, M., Eastman, C., Sacks, R., Venugopal, M., Aram, S. and Yang, D., 2014. Interoperability for precast concrete building models. *PCI Journal*, *59*(2).

Benli, G., 2015. *Handbook of Research on Emerging Digital Tools for Architectural Surveying , Modeling , and Representation*. IGI Global.

Borenstein, E. and Ullman, S., 2008. Combined top-down/bottom-up segmentation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *30*(12), pp.2109-2125.

Bosché, F., 2010. Automated recognition of 3D CAD model objects in laser scans and calculation of as-built dimensions for dimensional compliance control in construction. *Advanced Engineering Informatics*, 24(1), pp. 107-118.

Bosché, F., 2012. Plane-based registration of construction laser scans with 3D/4D building models. *Advanced Engineering Informatics*, 26(1), pp.90–102.

Boschert, S., Heinrich, C. and Rosen, R., 2018. Next Generation Digital Twin., *Proceedings of TMCE 2018*, (May), pp. 209–218. Available at: https://www.researchgate.net/publication/325119950_Next_Generation_Digital_Twin.

Bower, D., 2014. *Heathrow T2: The Queen's terminal – A lesson in value and sustainability*.

Deng, Y., Cheng, J. C. P. and Anumba, C., 2016. Mapping between BIM and 3D GIS in different levels of detail using schema mediation and instance comparison. *Automation in Construction*, 67, pp.1-21.

Dimitrov, A. and Golparvar Fard, M., 2015. Segmentation of building point cloud models including detailed architectural/structural features and MEP systems. *Automation in Construction,* 51(C), pp.32-45.

Dimitrov, A., Gu, R. and Golparvar-Fard, M., 2016. Non-Uniform B-Spline Surface Fitting from Unordered 3D Point Clouds for As-Built Modeling. *Computer-Aided Civil and Infrastructure Engineering*, 31(7), pp.483-498.

Gerbert, P., Castagnino, S., Rothballer, C., Renz, A., Filitz, R., 2016. *Digital in Engineering and Construction. The Transformative Power of Building Information Modeling*. The Boston Consulting Group. Available at http://futureofconstruction.org/content/uploads/2016/09/BCGDigital-in-Engineering-and-Construction-Mar-2016.pdf

Hassanein, A.S., Mohammad, S., Sameer, M. and Ragab, M.E., 2015. A Survey on Hough Transform, Theory, Techniques and Applications. *IJCSI International Journal of Computer Science I*, 12(2).

HM Government, 2013. *Construction 2025: Industrial Strategy: Government and Industry in Partnership.*

Jung, J., Hong, S., Jeong, S., Kim, S., Cho, H., Hong, S. and Heo, J., 2014. Productive modeling for development of as-built BIM of existing indoor structures. *Automation in Construction*, *42*, pp.68-77.

Klasing, K., Althoff, D., Wollherr, D. and Buss, M., 2009, May. Comparison of surface normal estimation methods for range sensing applications. In *2009 IEEE International Conference on Robotics and Automation* (pp. 3206-3211). IEEE.

Koch, C., Paal, S.G., Rashidi, A., Zhu, Z., König, M. and Brilakis, I., 2014. Achievements and challenges in machine vision-based inspection of large concrete structures. *Advances in Structural Engineering*, *17*(3), pp.303-318.

Kokkinos, I., Maragos, P. and Yuille, A., 2006, June. Bottom-up & top-down object detection using primal sketch features and graphical models. In *2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'06)* (Vol. 2, pp. 1893-1900). IEEE.

Kwon, S.W., Bosche, F., Kim, C., Haas, C.T. and Liapi, K.A., 2004. Fitting range data to primitives for rapid local 3D modeling using sparse range point clouds. *Automation in Construction*, *13*(1), pp.67-81.

Laefer, D.F. and Truong-Hong, L., 2017. Toward automatic generation of 3D steel structures for building information modelling. *Automation in Construction*, *74*, pp.66-77.

Liu, X., Eybpoosh, M. and Akinci, B., 2012. Developing as-built building information model using construction process history captured by a laser scanner and a camera. In *Construction Research Congress 2012: Construction Challenges in a Flat World* (pp. 1232-1241).

Marton, Z. C., Rusu, R. B. and Beetz, M., 2009. On Fast Surface Reconstruction Methods for Large and Noisy Point Clouds. In *IEEE International Conference on Robotics and Automation*, pp.3218-3223.

McNell, D. Allison, H., and Black, W., 2011. Building Information Modeling [Online] Available at: www.infocomm.org/cps/rde/xbcr/infocomm.Brochure_BIM.pdf

Nüchter, A. and Hertzberg, J., 2008. Towards semantic maps for mobile robots. *Robotics and Autonomous Systems*, *56*(11), pp.915-926.

Parrott, A. and Warshaw, L., 2017. Industry 4.0 and the digital twin. In *Deloitte University Press* (pp.1-17).

Patil, A.K., Holi, P., Lee, S.K. and Chai, Y.H., 2017. An adaptive approach for the reconstruction and modeling of as-built 3D pipelines from point clouds. *Automation in Construction*, *75*, pp.65-78.

Perez-Gallardo, Y., Cuadrado, J.L.L., Crespo, Á.G. and de Jesús, C.G., 2017. GEODIM: a semantic model-based system for 3D recognition of industrial scenes. In *Current Trends on Knowledge-Based Systems* (pp. 137-159). Springer, Cham.

Ricci, A., 1973. A constructive geometry for computer graphics. *The Computer Journal*, 16(2), pp.157-160.

Rossi, B., 2017. *Digital twinning explained*. Available at: https://www.raconteur.net/business-innovation/digital-twinning-explained.

Rvachev, V. L., 1982. *Theory of R-functions and some applications*. Naukova Dumka, Kiev.

Sampath, A. and Shan, J., 2009. Segmentation and reconstruction of polyhedral building roofs from aerial lidar point clouds. *IEEE Transactions on Geoscience and Remote Sensing*, *48*(3), pp.1554-1567.

Schnabel, R., Wahl, R. and Klein, R., 2007, June. Efficient RANSAC for point-cloud shape detection. In *Computer graphics forum* (Vol. 26, No. 2, pp. 214-226). Oxford, UK: Blackwell Publishing Ltd.

Shafto, M., Conroy, M., Doyle, R. and Glaessgen, E., 2010. *DRAFT Modeling, Simulation, information Technology & Processing Roadmap, Technology Area*. Available at: http://www.nasa.gov/pdf/501321main_TA11-MSITP-DRAFT-Nov2010-A1.pdf.

Shah, T. R., 2006. Automatic Reconstruction of Industrial Installations Using Point Clouds and Images, *Publications on Geodesy 62 NCG*, (May).

Song, X. and Juttler, B., 2009. Modeling and 3D Object Reconstruction by Implicitly Defined Surfaces with Sharp Features. *Computers & Graphics*, 33(3), pp.321-330.

Su, Y., Bethel, J. and Hu, S., 2016. Octree-based segmentation for terrestrial LiDAR point cloud data in industrial applications. *ISPRS Journal of Photogrammetry and Remote Sensing*, 113, pp.59-61.

Tang, P., Huber, D., Akinci, B., Lipman, R. and Lytle, A., 2010. Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Automation in Construction*, *19*(7), pp.829-843.

Tarsha-Kurdi, F., Landes, T., Grussenmeyer, P. and Koehl, M., 2007, September. Model-driven and data-driven approaches using LIDAR data: Analysis and comparison. In *ISPRS Workshop, Photogrammetric Image Analysis (PIA07)* (pp. 87-92).

Tarsha-Kurdi, F., Landes, T. and Grussenmeyer, P., 2007. Hough-transform and extended ransac algorithms for automatic detection of 3D building roof planes from lidar data', *IAPRS*, XXXVI(1), pp. 407-412.

Thompson, W.B., Owen, J.C., Germain, H.D.S., Stark, S.R. and Henderson, T.C., 1999. Feature-based reverse engineering of mechanical parts. *IEEE Transactions on Robotics and Automation*, *15*(1), pp.57-66.

Trimble, 2017. *Creating a 3D CAD Model From a laser Scanned Point Cloud (Overview)*.

Uijlings, J.R., Van De Sande, K.E., Gevers, T. and Smeulders, A.W., 2013. Selective search for object recognition. *International Journal of Computer Vision*, *104*(2), pp.154-171.

Valero, E. and Cerrada, C., 2012. Automatic Method for Building Indoor Boundary Models from Dense Point Clouds Collected by Laser Scanners, *Sensors*, 12, pp.16099-16115.

Vo, A.V., Truong-Hong, L., Laefer, D.F. and Bertolotto, M., 2015. Octree-based region growing for point cloud segmentation. *ISPRS Journal of Photogrammetry and Remote Sensing*, *104*, pp.88-100.

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

Vosselman, G., 2009. Advanced point cloud processing. In *Photogrammetric Week'09* (pp. 137-146). Wichmann.

Walsh, S.B., Borello, D.J., Guldur, B. and Hajjar, J.F., 2013. Data processing of point clouds for object detection for structural engineering applications. *Computer‐Aided Civil and Infrastructure Engineering*, *28*(7), pp.495-508.

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

West, T. D. and Blackburn, M., 2017. Is Digital Thread / Digital Twin Affordable ? A Systemic Assessment of the Cost of DoD's Latest Manhattan Project. *Procedia Computer Science,* 114, pp.47-56.

Xiao, J., Zhang, J., Adler, B., Zhang, H. and Zhang, J., 2013. Three-dimensional point cloud plane segmentation in both structured and unstructured environments. *Robotics and Autonomous Systems*, *61*(12), pp.1641-1652.

Xiao, J. and Furukawa, Y., 2012. Reconstructing the World's Museums. *International Journal of Computer Vision*, 110(3), pp.668-681.

Xiong, X., Adan, A., Akinci, B. and Huber, D., 2013. Automatic creation of semantically rich 3D building models from laser scanner data. *Automation in Construction*, *31*, pp.325-337.

Yan, J., Jiang, W. and Shan, J., 2012. Quality analysis on ransac-based roof facets extraction from airborne lidar data. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 1*, pp.367-372.

Yue, K., Huber, D., Akinci, B. and Krishnamurti, R., 2006, June. The ASDMCon project: The challenge of detecting defects on construction sites. In *Third International Symposium on 3D Data Processing, Visualization, and Transmission (3DPVT'06)* (pp.1048-1055). IEEE.

Zhang, C. and Tang, P., 2015. Visual complexity analysis of sparse imageries for automatic laser scan planning in dynamic environments. In *Computing in Civil Engineering 2015* (pp. 271-279).

Zhang, G., Vela, P. A. and Brilakis, I., 2014. Computing in Civil and Building Engineering, *The Sixth Annual International Conference on Computing in Civil and Building Engineering*, pp.455–462.

Herath, A.G.T.L., Mallawaarachchi, H. and Rathnayake, R.M.D.I.M., 2019. Service consistency improvement of facilities management service providing organisations in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 513-523. DOI: doi.org/10.31705/WCS.2019.51. Available at: https://2019.ciobwcs.com/papers

SERVICE CONSISTENCY IMPROVEMENT OF FACILITIES MANAGEMENT SERVICE PROVIDING ORGANISATIONS IN SRI LANKA

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ABSTRACT

Service consistency acts as a key media to achieve sameness and fairness in service delivery. Service consistency is vital to attraction of new customers, enhanced corporate image, reduced costs, and increased business performance. Nonetheless, struggle in developing and applying measurements for service quality can be commonly identified with service consistency failure situations. Hence, to better manage changes as well as to overcome such issues, organization should adopt a proper methodology to improve service consistency for Facilities Management (FM). Thus, this study aims to improve the service consistency of FM service proving organizations in Sri Lanka. Case study method was adopted in qualitative phenomenon. Under the case study method, three cases (FM service providing organisations) were studied. Twelve (12) semi-structured interviews were conducted among the FM related professionals in the selected cases to collect the data. Case study data were analysed by using the content analysis and cross-case analysis techniques. Direct interaction with customers, complain handling procedures, conduct skill development programmes, collect customers feedback and recruit experienced professionals were identified as some of the existing strategies used for service consistency. Different customer expectations, employee turnover, communication errors and lack of customer experience about FM services were revealed as major issues for service consistency. Accordingly, the suggestions, including sharing information with each employee, improving decision making skills, developing customer care strategies and implementing better recruitment system, were proposed to overcome the identified issues of service consistency in FM service providing organisations in Sri Lanka.

Keywords: *Facilities Management; Service Consistency; Service Provider; Strategies; Sri Lanka.*

1. INTRODUCTION

Facilities Management (FM) is the practice of sustaining quality working environment and providing delivering and quality support service to meet core objectives of the organization at best cost (Amaratunga *et al*., 2000). Domingo (2003), stated, service consistency implies achieving sameness, uniformity and fairness in delivery of all the service regarding the correct place, occasion, time and service providers. However, there

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was an argument that FM is an all-encompassing non-core activity, which needs to be changed in the face of sourcing decisions. There is a clear gap in the literature that mainly considered FM as non-core and focused mainly on cost and efficiency drivers of sourcing decisions (Natukunda *et al*., 2013). Hence, considering the consistency of the service provided by those FM organizations is unseen (Hui *et al*., 2013). Even though FM had been increasingly accepted in the boardrooms of these commercial organizations, little has been studied the service consistency (Hui *et al*., 2013). Service recovery is the strategy for enhancing service consistency of FM services in order to implement customer satisfaction and customer perceptions of service quality. Han *et al*. (2007) mentioned that there are different standards for ensuring service quality of FM services (Han *et al*., 2007) however a little consideration has been given yet on service consistency. Similarly, in Sri Lanka, no guidelines for FM service consistency have been introduced (Weerasiri, 2015). Hence, the aim of this research is to improve the service consistency of FM service providing organizations through 3 key objectives; (1) To identify existing guidelines available for FM service consistency, (2) To investigate the service consistency issues in existing practice and (3) To propose strategies to enhance the service consistency of FM service providing organisations.

2. LITERATURE REVIEW

2.1 IMPORTANCE OF SERVICE CONSISTENCY FOR FM

Service consistency in business is a key performance indicator in customer experience, which is not well known but important (Watier, 2018). Service consistency is achieving sameness, uniformity and fairness in the delivery or execution of all the service attributes, regardless of time, place, occasion, and service provider (Domingo, 2003). Service quality and service consistency has become a significant differentiator and the most powerful competitive weapon which many leading service providing organizations (Wong and Sohal, 2003). Similarly, FM service providers are concerned with managing the multi-disciplinary activities to optimize their impact on people and the workplace and giving its customers value for money (Goyal and Michael, 2007). FM should be strategically planned, aligned to business needs and demonstrate contribution to achieving business objectives (Kaya *et al*., 2004).

2.2 STRATEGIES AND GUIDELINES AVAILABLE FOR IMPROVING SERVICE CONSISTENCY OF FM

As Han *et al*. (2007) mentioned, there are different standards such as International Standards Organisation (ISO) 9000, ISO 9001, ISO 9003, ISO 9004, ISO 41000 and ISO 41001for ensuring service quality of FM services. ISO 9001 and ISO 9004 form a consistent pair of standards on quality management. ISO 9001 aims to give quality assurance of product to enhance customer satisfaction while ISO 9004 is for a broader perspective of quality management system to give guidance for performance improvement in local organizations (Fonseca, 2014). Examining the key literature reveals the choice of service consistence improvement can be reflected in four primary themes, such as culture-based, design-based, variation-based, and failure-based improvement (Hartline *et al*., 2000). Cultural-based improvement is improving service culture through a focus on individual and group psychology (Schneider, 1986). Design-based Improvement is derived a service concept, a strategy for delivering on the key points of this strategy is developed, and the strategy ultimately dictates the design of the service delivery system. Further, variation-based improvement builds on the success of statistical process control (SPC) in manufacturing, as people attempted to apply SPC to services. Where meaningful numerical data can be obtained, the approach has shown its expected success. Krehbiel (1994) applied SPC, which track service quality issues to a service setting evaluating two process designs to determine which provides the more consistent service in terms of time spent in the system. Failure-based Improvement could be identified as a service quality improvement tool; a service guarantee is best seen as a means of generating reliable data about important service failures (La and Kandampully, 2004).

2.3 SERVICE CONSISTENCY OF FACILITIES MANAGEMENT IN SRI LANKA

Sri Lanka has been recognized as one of the service sectors driven economies in the region. As per the statistics published in the Press Note of Department of Census and Statistics of Sri Lanka in 2015, service sector has contributed to highest share of 56.3% to the Gross Domestic Product (Dissanayake and Ismail, 2012). Hence, drawing attention to service sector in Sri Lanka is very important. Among the other industries, FM has gaining recognition in managing the building facilities (Weerasiri, 2015). Further, FM service consistency is the main focused strategy for implementing ISO 41001 for FM service providing organizations in Sri Lanka. Thus, it is important to explore the current setting of service quality of FM service providers in order to introduce an effective service consistency guideline under the ISO 41001. Thus, this research investigates the existing service consistency related strategies, issues of FM and strategies to overcome the identified issues under four key headings: cultural- based, design-based, failure-based and variation-based improvements. The next section explains the research methodology adopted to ascertain the research outcomes.

3. RESEARCH METHODOLOGY

The research was designed to achieve objectives mentioned at section 1. Literature review was conducted on the major areas of FM, service consistency, quality and related strategies. Case study method was adopted in qualitative phenomenon because the research problem requires an in-depth investigation. Under the case study method, three cases were studied by adopting the multiple cases study design. Three FM service providing organisations in Sri Lanka were selected as the suitable cases (refer Table 1). The unit of analysis of this research is FM service providing organisation. According to Dawson (2002), semi-structured interview is the most common type of interview used in qualitative researches. Thus, altogether twelve (12) semi-structured interviews were conducted among the FM service related professionals in the selected cases (see Table 1). Case study data were analysed by using the content analysis technique. Since this is a multiple case study research design, cross-case analysis was conducted to identify interrelationships and differences between each case.

Table 1: The profile of interviewees

Case	Description	Respondent	Designation	Years of Experience
Case A	Cleaning and janitorial services, landscaping services, building	A1	Facility Executive	10 years
		A2	General Manager	5 years
		A3	Facility Executive	7 years

Case	Description	Respondent	Designation	Years of Experience
	maintenance services, pest control services and hygiene management services	A4	Administrative Officer	8 years
Case B	Mechanical, electrical, plumbing, civil services and FM consultancy services	B1	Operation and Facilities Manager	6 years
		B2	Operation Executive	11 years
		B3	Managing Director	9 years
		B4	General Manager	6 years
Case C	Buying and selling property and property management	C1	Facilities Manager	4 years
		C2	General Manager	10 years
		C3	Facilities Manager	4 years
		C4	Mechanical Engineer	9 years

4. RESEARCH FINDINGS AND ANALYSIS

As this research aimed, the existing strategies and related issues of FM service providing organisations are presented relating to four (04) broader headings, such as culture-based, design-based, variation-based, and failure-based improvement. Moreover, the probable strategies were proposed to enhance the service consistency of FM in Sri Lanka.

4.1 CULTURE–BASED IMPROVEMENTS

4.1.1 Existing Strategies

As the existing strategies for enhancing service consistency, 'continuing a customer-based service culture' and 'fulfilling client's requirements correctly' were identified. Facility Executive of case A stated that, *"there is a customer-based service culture and the organization always tries to satisfy the customers"*. As further verified by Operation Executive of case B, *"motivating the employees in the organization to take customer-centric approach to satisfy customers while performing their regular duties and activities"* was identified as another strategy. Facilities Manager of case C stated that, "*there is a strong customer focused service culture and the employees are focused on listening, serving and satisfying customer*". Accordingly, continuing customer-based service culture', having a direct communication with customers, complain handling, conducting awareness programs and conferences and fulfilling client's requirements correctly are the key existing strategies to improve service consistency of FM service providing organizations.

4.1.2 Issues

Majority the respondents have specified that 'the different working environments' as a main issue under culture-based improvement. Further, 'failure in customer relationships' is another major issue for the enhancement of service consistency. This was confirmed by Administrative Officer of case A as *"failures in customer relationships can be happened and poor customer relationships will result in devastating outcomes including customer loss and company misdirection"*. Further, General Manager of case B emphasized that, *"need a proper management to handle customers considering their* *expectation".* Mechanical Engineer of case C explained that, "*faults in managing customer relationships is the common issue for every service provider in the industry".* Accordingly, different working environment, different customer expectations, different behaviour of employees and failures in customer relationships are the key issues recognised.

4.1.3 Proposed Strategies

Majority of the respondents have agreed that 'educating employees' as a main strategy for cultural-based improvement. Administrative Officer of case A stated that, *"need to employ new personnel that fit to the service culture and training and education are vital to developing a superior service culture*". On the other hand, 'conducting the training and development programs' is identified as the second most relevant strategy for cultural-based improvement with the aim of making modifications to the service consistency of FM service. Operation and Facilities Manager of case B suggested that, "*training and development is the best method to resolve those issues".* Hence, educating the employees and conducting training and development programs are the key strategies proposed for improving the service consistency.

The summary of the cross-case analysis findings for cultural-based improvements is illustrated in Table 2.

Table 2: The summary of key findings for culture-based improvements

Culture-based Improvements		
Existing strategies	**Issues**	**Proposed strategies**
Continuing customer-based service culture	Different customer expectations	Conducting the training and development programs
Directing communication with customers	Different working environment	Educating the employees
Fulfilling client's requirements correctly	Different behaviour of employees	
Complain handling	Failures in customer relationships	
Conducting awareness programs and conferences		

4.2 DESIGN-BASED IMPROVEMENTS

4.2.1 Existing Strategies

'Expand team work activities', 'conduct training programs' and 'better supervision' are the existing strategies, which were mainly identified in design- based improvement. 'Better supervision' has been mentioned as a trigger for existing strategy by majority of the respondents. For instance, General Manager of case B stated that, *"awareness programs are conducted to identify customers' expectations and direct communication with the customers is very essential to build better customers relationship".* Hence, better supervision, understanding the service delivery objectives clearly, continuing team work activities, conducting workshops and conferences, providing customer focused service, managing employee behaviour and resources and conducting training programs are identified as the existing strategies.

4.2.2 Issues

Majority the respondents have highlighted that 'employee turnover' could highly affect the design-based improvement. Accordingly, this issue was highlighted by 5 out of the 12 respondents. Interviewee C1 supported to the fact by stating "*More absenteeism and high levels of turnover can happen due to low morale of the employees. These issues are costly for the company*". 'Different customer expectations' and 'employee faults' were insisted by majority of the respondents. General Manager of case B stated that, *"poor planning causes delays in service delivery and different customers' expectations and their expectations are higher than the service that the company is provided"*. Further, Mechanical Engineer of case C highlighted that, *"different customer expectations and need for fully understanding the expected service",* as another issue in the existing practice. Accordingly, employee turnover, different customer expectations and employee faults are the key issues under this category.

4.2.3 Proposed Strategies

Majority of the respondents have proposed that 'introducing a schedule to recruit new employees' and 'implementing quality framework for new recruitment system' as the new suggestions. As they further stated, the company team should be actively involved in the new process to resolve new employee issues time to time. Facilities Manager of case C suggested that, *"proper planning to recruit employees to the company and motivate and encourage the employees by rewarding them"*. Conversely, 'developing proper plans for service delivery' and 'enhancing communication skills' were recognised as the other suggestions. Accordingly, 'implementing and scheduling quality recruitment system', 'developing proper plans for service delivery' and 'enhancing communication skills' are suggested as new strategies for enhancing service consistency. The summary of the cross-case analysis findings for design-based improvement is illustrated in Table 3.

Table 3: The summary of key findings for design-based improvements

Design-based Improvements		
Existing strategies	**Issues**	**Proposed strategies**
Understanding service delivery objectives clearly	Different customer expectations	Implementing and scheduling quality recruitment system
Continuing team work activities	Employee turnover	Developing proper plans for service delivery
Conducting training programs	Employee faults	Enhancing the quality of training
Conducting workshops and conferences		
Providing customer focused service		
Better supervision		
Managing employee behavior and resources		

4.3 VARIATION-BASED IMPROVEMENTS

4.3.1 Existing Strategies

From the case study findings, 'conducting training and development programs' was identified as one of strategies existed. Facilities Manager of case C mentioned that, "*leadership of the company must keep employees in alignment with the vision as individuals and as teams and training and development programs are the best therapy to change behaviour of the employees"*. 'Adopting experience of the professionals' is another strategy for variation-based improvement. General Manager of case C stated that, *"it is good to recognize the need for a service culture change. But the collaborators should not expect immediate results. It takes long period to generate results on current changes. The company might be able to move through the changed process few years later"*. Accordingly, 'conducting training and development programs', 'implement quality of the service delivery', 'conduct skill development programs' and 'adopt experience of the professionals' are the key suggestions for the improvement of service consistency.

4.3.2 Issues

From the case study findings, altogether eight related issues were identified in variation-based improvement. The main issue encountered by variation-based improvement is 'lack of experienced employees. Further, Facilities Manager of case C stated that, *"lack of understanding about customer satisfaction" as one of the issues"*. 'Need more time to train employees' and 'lack of strong relationship with clients' were other issues, which hinder the variation-based improvement. Further, Operation and Facilities Manager of case B stated that, *"trained employees can perform the activities well, but the problem is that the training and development programs take more time to train the employees. This issue directly affects consistency of FM services"*. Accordingly, 'lack of experienced employees', 'need more time to train employees' and 'lack of strong relationship with clients' are the key issues which affect for the improvement of service consistency.

4.3.3 Proposed Strategies

'Enhance communications skills' is identified as an important strategy for variation-based improvement. This was further confirmed by Interviewee A1, *"Encourage employees to enhance communication skills and share information with each employee can improve the experience of the employees"*. Further, 'share information with each employee' and 'educate the employees' are the second most suggested strategies for variation-based improvement. 'Educating the employee' was further confirmed by Managing Director of case B by stating *"appropriate training plans should be developed by the management and educate the employees by selecting the best training method"*. Accordingly, 'enhance communications skills', 'share information with each employee', 'improve decision making skills' and 'educate the employees' are the key suggested strategies for enhancement of service consistency.

The summary of the cross-case analysis findings for variation-based improvement is illustrated in Table 4.

Table 4: The summary of key findings for variation-based improvements

Variation-based Improvements		
Existing strategies	**Issues**	**Proposed strategies**
Conduct training and development programs	Lack of experienced employees	Enhance communication skills
Adopt experience of the professionals	Need more time to train employees	Share information with each employee
Implement quality of the service delivery	Lack of strong relationship with clients	Educate the employees
Conduct skill development programs		Improve decision making skills

4.4 FAILURE-BASED IMPROVEMENTS

4.4.1 Existing Strategies

'Better customer interaction' is one of existing strategies, which was identified in failure-based improvement. Facility Executive of case A stated that, *"the organization can change the service according to the customer requirements and better customer interaction can provide better communication"*. Further, 'direct interaction with the customer' and 'providing customer focused service' are another strategy for service consistency under failure-based improvement. Hence, better customer interaction, direct interaction with the customer, providing branded service to the customers, collecting customer feedbacks and 'providing customer focused service are the existing strategies.

4.4.2 Issues

Among the issues identified under failure-based improvement, 'communication errors', 'lack of awareness of customers' and 'lack of customer experience about FM services' are the most specified issues by the respondents of all three cases. 'Lack of awareness of customers' was confirmed by Managing Director of case B by mentioning, "*sometimes the customers are not aware about the company policy and procedure and they are expecting more than from the service which company provides therefore it might be a challenge of satisfying all the expectations of the customer"*. Hence, 'lack of awareness of customers' is another major issue for the improvement of service consistency. Thus, 'communication errors', 'lack of awareness of customers', 'lack of customer experience about FM service' are the key issues for the improvement of service consistency.

4.4.3 Proposed Strategies

As per the case responses, various strategies were proposed. Facilities Manager of case C suggested that*, "creating customer focused mind-sets is the best solution to enhance the service consistency"*. These assertions confirm that 'developing customer care strategy' is the major suggested strategy for better improvement of service consistency. Further, 'improving communication skills' is another most important strategy for failure-based improvement.

The summary of the cross-case analysis findings for failure-based improvement is illustrated in Table 5.

Table 5: The summary of key findings for failure-based improvement

Failure-based Improvements		
Existing strategies	**Issues**	**Proposed strategies**
Better customer interaction	Communication errors	Improving communication skills
Direct interaction with customers	Lack of awareness of customers	Developing customer care strategies
Providing branded service to the customers	Lack of customer experience about FM service	
Providing customer focused service		
Collecting customer feedbacks		

Accordingly, the key research question of "how service consistency could be enhanced, which is applied in FM service providing organizations in Sri Lanka?" was fulfilled.

Hence, 'continuing customer-based service culture' and 'fulfilling client's requirement correctly' were the most common strategies used for cultural-based improvement and 'continuing team work' and 'conducting training programs' are the most common existing strategies which were related to design based improvement. Similar strategy was found by Scheidt and Chung (2018), the study identified customer interaction can be improved through training programmes and individual education. Further, State Government of Victoria (2017) stated that delivering customers' promise as a key strategy for service consistency. Accordingly, 'conducting training and development programs' was the most common strategy for variation-based improvement and 'better customer interaction' was the most common strategy for failure-based improvement. Further, it has been realized that, there are minor differences in the strategies being performed by the FM service providers in Sri Lanka due to their lack of homogenous characteristics. Most common related issue for cultural-based improvement was identified as 'different working environment'. 'Employee turnover' was the most common issue for design-based improvement of service consistency. Hence as the strategies, 'educating the employees' for cultural-based improvement and 'implementing and 'scheduling better recruitment system' for design-based improvement, 'enhancing communication skills' for variation-based improvement and 'developing customer care strategies' for failure-based improvement were recognised and proposed.

5. CONCLUSIONS

This study presents the existing strategies, related issues and suggestions to overcome the issues, which were related to the improvement of service consistency of FM service providing organizations in Sri Lanka under four broader headings of cultural-based improvement, design-based improvement, variation-based improvement and failure-based improvement. Strategies to deal with each issue faced by FM service providers were also identified from the case studies findings. 'Continuing customer-based service culture' and 'fulfilling client's requirement correctly' were the most common strategies used for cultural-based improvement and 'continue team work' and 'conduct training programs' are the most common existing strategies which were related to design based improvement. 'Conducting training and development programs' was the most common strategy for variation-based improvement and 'better customer interaction' was the most common strategy for failure-based improvement. Further, it has been realised that, there are minor differences in the strategies being performed by the FM service providers in Sri Lanka due to their lack of homogenous characteristics. Most common related issue for cultural-based improvement was identified as 'different working environment'. 'Employee turnover' was the most common issue for design-based improvement. Hence, the proposed strategies will create a major contribution by facilitating an approach for improving the service consistency in company processes. Further, this study increases the present level of importance associated with the effective management of FM. Indeed, FM industry practitioners could ensure their consistency in service delivery success via following the accurately identified service consistency practices.

6. REFERENCES

Amaratunga, D. and Baldry, D., 2000. Assessment of facilities management performance in higher education properties. *Facilities*, 18(7/8), pp.293-301.

Dawson, C., 2002. *Practical research method*. United Kingdom: How to Books Ltd.

Dissanayake, D.M.R. and Ismail, N., 2015. Relationship between celebrity endorsement and brand attitude: With reference to financial services sector brands in Sri Lanka. In: *Proceedings of 6th International Conference on Business and Information (ICBH),* pp. 472-487.

Domingo, R., 2003. Consistency in service quality [online]. Available from: http://www.rtdonline.com/BMA/CSM/9.html [Accessed 01 June 2019].

Fonseca, L., 2014. ISO 9001: 2015 Revision. In: *1st ICEQM-International Conference on Quality Engineering and Management,* Portugal: Guimaraes.

Goyal, S. and Pitt, M., 2007. Determining the role of innovation management in facilities management. *Facilities*, 25(1/2), pp.48-60.

Han, S.B., Chen, S.K. and Ebrahimpour, M., 2007. The impact of ISO 9000 on TQM and business performance. *The Journal of Business and Economic Studies*, 13(2), p.1.

Hartline, M.D. and Ferrell, O.C., 1996. The management of customer-contact service employees: an empirical investigation. *Journal of Marketing*, 60(4), pp.52-70.

Hui, E.C., Zhang, P.H. and Zheng, X., 2013. Facilities management service and customer satisfaction in shopping mall sector. *Facilities,* 31(5/6), pp.194-207.

Kaya, S., Heywood, C.A., Arge, K., Brawn, G. and Alexander, K., 2005. Raising facilities management's profile in organisations: developing a world-class framework. *Journal of Facilities Management,* 3(1), pp.65-82.

Krehbiel, T., 1994. Quality Service and the Taguchi Philosophy. *Mid-American Journal of Business*, 9(1), pp.7-15.

La, K.V. and Kandampully, J., 2004. Market oriented learning and customer value enhancement through service recovery management. *Managing Service Quality: An International Journal*, 14(5), pp.390-401.

Natukunda, C.M., Pitt, M. and Nabil, A., 2013. Understanding the outsourcing of facilities management services in Uganda. *Journal of Corporate Real Estate*, 15(2), pp.150-158.

Scheidt, S. and Chung, Q.B., 2018. Making a case for speech analytics to improve customer service quality: Vision, implementation, and evaluation. *International Journal of Information Management*, 45, pp.223-232.

Schneider, B., 1986. *Creativity in Services Marketing: What's New, What Works, and What's Developing.* Chicago: American Marketing Association.

State Government of Victoria, 2017. Keep customers with customer service excellence [online]. Business Victoria. Available from: http://www.business.vic.gov.au/marketing-and-sales/increasing-sales-through-marketing/customer-service-excellence [Accessed 15 May 2019].

Watier, C., 2018. When stability goes hand-in-hand with profitability [online]. Available from: https://www.lanla.com/en/publications/consistency-business-stability-goes-hand-hand-profitability/ [Accessed 15 February 2019].

Weerasiri, R.A.S., 2015. A Study on Service Quality and Customer Satisfaction of Supermarkets in Sri Lanka. *Sri Lanka Journal of Marketing,* 1(2), pp.36-46.

Wong, A. and Sohal, A., 2003. Service quality and customer loyalty perspectives on two levels of retail relationships. *Journal of Services Marketing,* 17(5), pp.495-513.

Jayawardhana, S.K.G.U.K., Hadiwattage, C. and Mahinkanda, M.M.M.P., 2019. Significance of construction technology knowledge for quantity surveyors in expressway construction projects. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 524-534. DOI: doi.org/10.31705/WCS.2019.52. Available at: https://2019.ciobwcs.com/papers

SIGNIFICANCE OF CONSTRUCTION TECHNOLOGY KNOWLEDGE FOR QUANTITY SURVEYORS IN EXPRESSWAY CONSTRUCTION PROJECTS

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ABSTRACT

The degree of social responsibility of professionals towards public projects are naturally high. Recently, in Sri Lankan context, expressway construction is becoming one of the major public project types. Due to that, the responsibility of professionals towards a successful expressway construction seems very high. Among professionals, Quantity Surveyor (QS) is a significant team member in any kind of construction project in terms of managing cost and time aspects. Being highly technical and complex, expressway QSs essentially need a significant level of construction technology knowledge to perform the duties and responsibilities. Therefore, the research was focused on investigating the significance of expressway construction technology knowledge for QS practitioners. The scope of the research was narrowed down to Sri Lankan expressway projects. A comprehensive literature review was carried out to identify the duties and responsibilities of QSs in expressway project stages. The research methodology was mixed approached comprising a questionnaire survey and s expert interviews round. Quantitative data analysis was carried out using RII method and qualitative data subjected to content analysis. The research concludes feasibility stage as the most technical knowledge sensitive stage of an expressway construction project with respect to the QS's role. Further, QSs with less experience make projects vulnerable for more cost and time issues due to lack of technical knowledge and such scenarios may add black marks to the role of the QS in big picture, therefore it is essential for the QSs to keep updated with the changing construction technologies.

Keywords: *Construction Industry; Expressway Construction; Quantity Surveyor; Sri Lanka; Technological Knowledge.*

1. INTRODUCTION

The construction industry has a significant cultural, environmental, social and economic impact on the country (Loosemore *et al*., 2018). Technical knowledge of the professionals and workers are valuable assets to any construction organisation (Mohamed and AbouRizk, 2005). Hence, the project team should have a sound level of construction technology knowledge to carry out projects with the use of advanced technologies. Expressway construction is more complex and highly technological than other

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constructions (Wu *et al*., 2005). Therefore, the cost management of expressway projects is significant. Among project team members QS is important in such cost aspects which means for value addition for expressway construction. As advisers, QSs estimate and monitor construction costs, from the feasibility stage of a project to the completion of the construction period (Australian Institute of Quantity Surveyors [AIQS], 1998). Being highly technical and complex, expressway QSs required a significant level of construction technology knowledge to perform their duties and responsibilities. AIQS (1998) has identified knowledge of construction technology as a core competency for QS professionals. Further, AIQS (1998) explained that a QS professional, it is compulsory to acquire knowledge of different construction processes, technologies related to construction processes, construction activities, sequencing of activities, erection techniques of plant and equipment, principles of site surveys, interpretation of building plans, construction codes and regulations, source and use of construction materials including testing and assessing techniques. Since QS is involved in almost all the phases of a construction project, he/she needs different levels of construction-related knowledge at different stages of a construction project. Further, it may valid depending upon the QSs role in contractor related and consultant related responsibilities. But in each project stages needs a different level of technical knowledge to perform the role of QS. Due to that, it is necessary to investigate the extent and level of technical knowledge required for QSs in assisting cost management expressway construction projects at different project stages.

2. LITERATURE SYNTHESIS

2.1 EXPRESSWAY CONSTRUCTION AS A HIGHLY TECHNICAL PROJECT TYPE

Expressway construction is a complex project type (Zheng and Chen, 2012). Further, the authors stated that the project programmes subject to heavy changes due to this complexity. There are many types and numbers of activities involved in expressway construction (Arditi and Bentotage, 1996). For instance, when constructing, mechanical and blasting methods are usually utilised, this will cause greater risks. Expressway disciplines consist of various number of technical activities and materials included items such as geometrics and alignment, landscape ecology, earthworks, pavement, retaining walls, slope protection, sound insulation, transportation facilities, drainage, bridges, tunnels, electrical, mechanical, lighting and maintenance (Rooshdi *et al*., 2014. There is a possibility of being highly technical; the given budget would not be adequate, because quantities of work are not exactly known until the project is completed (Pewdum *et al*., 2009). Further, it was found that there are factors, which heavily affect to the final budget: traffic volume, topography, weather conditions, evaluating date, contract duration, construction budget, percent of as planned completion, and percent of actual completion, while four (04) factors: work starting date, evaluating date, contract duration, percent of as planned completion, and percent of actual completion are greatly affecting to project duration. Pewdum *et al*. (2009) further founded that estimation of the road construction cost to be considered with project physical features such as; type of project, project scope, forecasting final budget, construction year, seasons, construction site, project period, project distance, number of lanes, number of streams cutting across the roads, and condition of soil at construction sites. Accordingly, these findings reveal that expressway construction is a highly technical discipline and less knowledgeability on technical aspects may cause adverse cost overruns of the projects.

2.2 STAGES OF EXPRESSWAY CONSTRUCTION PROJECTS

All construction projects pass through a set of common work stages consisting of inception, feasibility, scheme design, detail design, contract formation, construction, and commissioning. Although there may be changes to the sequence and importance of these stages, their identification helps in making judgements about organisational structure on construction projects (Hughes, 1991). In expressway construction various authors have identified different number of project stages for an expressway construction project and few are in the common practice yet. The expressway construction stages in terms of similarities with RIBA plan of work stages are tabulated in Table 1. According to the duties carried out in expressway project in its stages as mentioned by University of Brighton (2016), the comparison with RIBA stages was associated.

Table 1: RIBA Plan of Work vs. expressway construction work stages

RIBA Work Stage	Core Objectives of Stage of Work	Expressway Work Stages
Strategic Definition	Identify client's business requirements and client's strategic brief and other key project requirements	Feasibility study
Preparation and Brief	Develop objectives of the project, including quality objectives and outcomes of the project, sustainability achievements and budget of the project, other parameters or constraints and develop first project brief. undertaking feasibility studies and reviewing site conditions	
Concept Design	Prepare concept design, inclusive of outline proposals for structural design, outline specifications and basic costing information along with relevant projects strategies in accordance with programme for design. Agree or reject alterations to brief and issue final project brief	Preliminary engineering Plan
Developed Design	Prepare developed design including coordinated and updated proposals for structural design, outline specifications, cost information, and project strategies in accordance with design programme	Final engineering Plan
Technical Design	Prepare technical design in accordance with Design Responsibility Matrix and project strategies to include all architectural, structural specialist subcontractor design and specifications, in accordance with programme of design	Construction Plan
Construction	Offsite manufacturing and onsite Construction in accordance with construction programme and resolving queries of design from the site as they arise	Construction
Handover and Close Out	Handover of the facility and conclusion of contract	Closeout
In Use	Undertake in use facility in accordance with the schedule of facility	Maintenance and Upkeep

(Sources: Falls *et al*., 2010; Finnish Transport Agency, 2010; University of Brighton, 2016)

Although RIBA Plan of Work deals with building construction, it seems that stages in an expressway construction project also can be compared with it. In Table 1, it has been indicated that even though the terms and phrases used in RIBA Plan of Work are different (e.g. Technical design – the 5th stage of RIBA plan, which is called as construction plan in expressway construction stages; yet similar in terms of the activity), the duties carried out in parallel stages of an expressway construction are similar. It can be concluded that despite the project (building or infrastructure) the key duties remain as it is in almost all the novel construction project.

2.3 TECHNICAL KNOWLEDGE REQUIRED DUTIES AND RESPONSIBILITIES OF A QS IN DIFFERENT PROJECT STAGES

The activities identified by Herman (2016) in each phase can be mapped with the stages (up to the construction) identified by Falls *et al*. (2010); Finnish Transport Agency (2010) and University of Brighton (2016) as indicated in Table 2.

Table 2: Mapping expressway project stages defined by various authors

Project Stages: Identified by Falls *et al.* (2010); Finnish Transport Agency (2010) and University of Brighton (2016)	**Project Stages: Identified by Herman (2016)**
Feasibility study	Feasibility stage
Preliminary engineering Plan	Preliminary design and environment review
Final engineering Plan Construction Plan	Final design and right-of-way acquisition
Construction	Post contract stage/ Contraction

According to Herman (2016) and Mbachu (2015), the roles of QSs can be seen in five (05) different stages of construction development as shown in Table 3.

Table 3: Summary of construction technology-related duties and responsibilities of QS

Project stage	**Duty/Responsibility**
Feasibility stage	• Assess transportation purpose and need with the project team • Gain approval • Preparation of cost analysis • Preparation of estimates from sketch to detailed design • Preparation of cost plan • Financial feasibility studies including economic • Value management/ engineering • Preparation of cost-in-use/ life-cycle costing • Preparation of turnover, profit/loss forecast, and cash-flow projections • Cost checking during the development design • Contractual and tendering arrangements (early advice)

Project stage	Duty/Responsibility
Preliminary design and environment review	• Consider alignment issues and required lanes • Identify alternatives, including not building the project, to minimise potential harm to the environment and historic sites • Select preferred alternative • Preparation of specification and schedule of rates. • Value management including comparative design economics • Identify project cost, level of service, and construction location with the project team • Prepare a preliminary design of the expressway according to cost aspects • Early-stage comparative cost planning • Detailed compilation and analysis of unit rates/ preliminaries • To check and report the cost of design solutions as they are established or refined by the engineers • As changes are introduced into the project, to estimate the cost effectiveness of the change and to report
Final design and right-of-way acquisition	• Finalise design plans with the project team • Appraise utilities and affected citizens before construction, if necessary • Finalise project cost estimates • Taking off from detail design • Advising on the cost of design options • Analysis and scheduling of work • Measuring work to define rules • Preparing cost estimates • Prepare a financial appraisal
Post contract stage/ Contraction	• Advertise and evaluate bids; award contracts • Preparation of contract documents for main contract sub-contracts or contracts of supply including rationalisation of contract rates. • Evaluating bids • Begin construction • Application of cost control during the progress of the works. • Site surveys and measurement and attendance at site meetings • Monitoring of proposed construction methods, sequences, and those actually required and reporting thereon. • Variations and change proposals • Value Management (VM)/ Engineering (VE) including preparation of cost/benefit reports upon alternative construction methods • The report, evaluating and negotiating on contractual and extra-contractual issues • Analysis of contract pricing relative to cost recording methods. • Preparation and/or interpretation of cost/value and other reconciliation statements for management purposes • Annual budget advice on the construction • Accept delivery

Project stage	Duty/Responsibility
Construction management and resource procurement stage	• Planning and programming of construction activities • Site planning • Liaison with employer, consultants, statutory and service authorities. • Resource determination, scheduling, and purchasing. • Procurement of labour, plant, and materials. • Negotiation with and management of sub-contractors and suppliers

Sources: Mbachu (2015); Herman (2016)

Technology, common sense and common knowledge regarding technical aspects of the project is highly appreciated in the role of QSs (Lau, 2013). QSs seek to minimise the costs of a project and enhance value for money, while still achieving the required standards and quality (Olubunmi *et al.*, 2014). As Cunningham (2015) mentioned, the professional services carried out by QSs have traditionally included the planning of costs, management of projects from start to completion together with risk analysis and assessment.

3. RESEARCH METHODOLOGY

The research question is "What is the extent and level of technical knowledge required by QS in assisting cost management in expressway construction projects at different project stages?". Initially, a comprehensive literature survey was carried out by referring books, journals and other publications to identify technical aspect and QSs technology knowledge requirement in the expressway construction industry. The research further used a mixed research approach in achieving the research objectives comprising a questionnaire survey and expert interviews.

The purpose of the questionnaire survey was to identify the level of QSs competency requirement for technical activities in highway construction. The questionnaire consisted of two sections. The first section was to determine the technological activities, which has the most impact on the QSs role. Purpose of the second section of the questionnaire was to rate the competency level of QSs towards each technical activity. The questions were prepared with the findings of the literature review which highlighted the key duties and responsibilities of a QS in project phases (Table 2). The questionnaires used Likert scale (1-5) and multiple-choice (listed alternative answers) as well. Relative Importance Index (RII) method used to analyse data collected from the Questionnaire Survey. The composition of respondents according to their designation is given in Table 4.

The respondents were selected based on their experience in expressway construction. The sample consisted of different layers and designations of QSs who obtained exposure in Sri Lankan expressway construction projects. The major reason for selecting only the QSs as the sample, since the research focused on QSs' knowledge on expressway construction.

The expert interviews were used to gather views on the causes for lack of technical knowledge, challenges faced by the QSs due to lack of technical knowledge, and the probable strategies to overcome such challenges.

Table 4: Profile of respondents in questionnaire survey

Designation	Questionnaire Distributed	Number of Respondents	Response rate
Joint Venture (JV) QS	2	2	100%
Project QS (PQS)	10	9	90%
Senior QS (SQS)	3	3	100%
Consultant QS (CQS)	2	2	100%
QS	16	14	87.5%
Assistant QS	12	10	83.33%

4. RESEARCH FINDINGS

According to the results of research findings, it has been highlighted that 85% of the respondents have accepted expressway construction technologies as more complicated and significant than building construction technologies. In the Sri Lankan context, this indication is fare because the expressway construction is new to the country. Building construction has now become very much familiar with the industry practitioners including QSs. Taking everything into account it can be concluded as per findings that, expressway construction technologies as more complex than building construction technologies.

4.1 SIGNIFICANCE OF KNOWLEDGE REQUIRED BY QUANTITY SURVEYORS TO PERFORM TECHNOLOGICAL TASKS

It is important to identify the most significant, expressway construction technical knowledge highly needed project phases as per responses for the questionnaire. It indicates the overall ranking of the main project stages in expressway construction. According to the technical knowledge requirement following is the ranking of expressway construction stages as per the significance.

Rank 1: Feasibility Stage
Rank 2: Post contract stage/construction stage
Rank 3: Final design and right-of-way acquisition stage
Rank 4: Preliminary design and environment review stage
Rank 5: Accepting project delivery in aspects of cost and time stage

These findings indicate the most technical knowledge required stage when performing tasks in an expressway construction project by QSs is feasibility stage. The least technical knowledge required stage is accepting the project delivery stage. According to the results of the analysis, the top most technology-related knowledge areas identification criteria needed to establish. According to the RII values, if taken the cut off margin as the first quadrant, it selects only a single activity. If second quadrant considered, 23 tasks select as most significant duties. Due to that, first half of the second quadrant (which has RII value more than 85%) taken as the cut off margin for a task to become a significant duty among the list of all the construction technology required duties in an expressway construction. It shortlists the significant tasks as in Table 5.

Table 5: Most technical knowledge required duties or responsibilities of an expressway QS

Duty/responsibility	RII %	Rank
Preparation of cost analysis	90%	1
Variations and change proposals	88.5%	2
Application of cost control during the progress of the works	87.5%	3
Preparation of turnover, profit/loss forecast, and cash-flow projections	87%	4
Measuring work to define rules	87%	4
The report, evaluating and negotiating on contractual and extra-contractual issues	87%	4
Advising on the cost of design options	86.5%	7
Preparing cost estimates	86%	8
Value management/ engineering	85.5%	9
Contractual and tendering arrangements (early advice)	85.5%	9

Among ten most important construction technology-related tasks, four of them were in feasibility stage. The other thing is the topmost factor is also one of feasibility stage tasks. This indicates that the most technical knowledge required in an expressway construction is in initial stages. Without construction technology knowledge QS is unable to perform his/her tasks even at feasibility stage.

However, these significant tasks not indicate that the balance tasks are insignificant. As per the survey conclusion, it summarises that all identified task in the literature is essential to perform duties of QS in each project stages in different knowledge levels.

4.2 CHALLENGES DUE TO POOR TECHNOLOGY KNOWLEDGE OF QSS AND STRATEGIES TO OVERCOME THEM

As a key finding of the expert interviews, it was indicated that, if there is a poor technological background relevant to expressway construction by QS personally or their representative organisations, there can be many issues. Those underlying causes for lacking technical knowledge of QSs in expressway construction are listed below.

- Less experience in road construction
- Difficulty to find QSs with a proper level of technical knowledge
- Lacking educational syllabus coverage regarding expressway construction for QSs
- Less collaboration within the project team
- Fewer expressway projects available in the local context

Considering all the expert views, it can be concluded that there are challenges faced by QS personally or their representing organisations if there is a poor technological background relevant to expressway construction by QSs as listed below.

- Failure to evaluate different technical design options in terms of cost and time
- The hidden role of QSs and the advice given by the QSs might get rejected
- A disgrace to the profession and representing organisation
- Failures to the role of QS within the project team
- Inability to evaluate claims and variations
- Difficulties of reading construction drawings

- Increased risk of cost overruns and time overruns
- Inability to identify risks

From the expert interviews, the suggested strategies to overcome from challenges caused by the lack of construction technology are as follows.

- Educate on technology continuously (CPDs, Syllabus revisions)
- Analyse the case properly
- Improve the presentation system
- Well conversion with project documents
- Share knowledge among the team
- Self-learning from reading materials
- Good communication with other team members
- The assistance provides by experienced QSs
- Peer learning
- Developing competencies over application of the knowledge

5. CONCLUSIONS

It was identified that, when performing the role of QS, the knowledge regarding construction technology as essential. Even though as QSs it has been established that construction technology is a key competency of professional previous studies has not focused especially on expressway construction technologies despite playing this knowledge a major role in terms of cost impacts in the project. However, the required technology to perform knowledge level for each duty/ responsibility of QS in different stages of an expressway construction project varies. The primary focus of this study was to investigate the significance of technical knowledge for QS in assisting cost management in Expressway construction projects in Sri Lanka as a means of achieving successful project outcomes.

Mainly the technical aspect of expressway construction highlights its complexity compared to building construction. Being highly technical, from the initial stages of the project, the technical nature of stages can be seen. For completing a new major expressway project takes a number of years due to many tasks, requirements, approvals, and stakeholders. The expressway project stages are different from building project stages. Hence, RIBA Plan of Work is unable to apply for expressway construction and a different number of stages were defined. However, it can be mapped to expressway project stages with RIBA Plan of Work. The stages consist of feasibility stage, preliminary design and environmental review stage, final design and right of way stage, construction stage and resource management stage. The technical activities in each stage are different from one another.

There are criticisms of expressway projects due to not achieving project goals properly. Project delivery is not within a reasonable amount of time and finally, costs are not in line with the budgets. There is a possible contribution from QS towards avoiding criticisms. Hence, performing duties well in the project is required by expressway QSs. The role of QS in stages of expressway construction to be highlighted in terms of technology requirement.

For almost all the activities performed by QS, in each stage of an expressway construction, the technical knowledge is a must. According to the findings, the highest technical incentive required activities were preparation of cost analysis, variations and change proposals and application of cost control during the progress of the works. Highly technical knowledge required stage. With that, ranking stages as per level of technical knowledge need are; Feasibility Stage, Post contract stage/construction stage, Final design and right-of-way acquisition stage, Preliminary design and environment review and Accepting project delivery (in aspects of cost and time) in order. As per the requirement, QS should have relevant level of knowledge on construction activities when performing QS duties.

Due to lack of technical knowledge for such complex technological project, the challenges faced were identified as; the inability of paraphrasing design options in terms of cost and time, incapacity to convince the project team regarding cost, time and quality aspects and incompetence to identify risks. Apart from that disgrace to the profession and representing organisation, fails within the project team, inability to evaluate claims and variations, inability to read construction drawings, cost overrun and time overrun is the rest of challenges face due to lack of technological knowledge.

The key reasons for lack of technical knowledge for QSs were; less experience in road construction, difficulty to find QSs with proper knowledge, no syllabus regarding expressway construction for QSs, less collaboration in between the project team a and finally fewer expressway projects available in local context. As a major reason, Sri Lanka is still new to expressway construction. With regard to that the opportunities created for involving as an expressway construction was less. The solutions for this issue needed for overcoming from the undelaying causes.

In terms of contribution to the industry through this research, it is apparent that since this research have identified the priority of stages of the expressway construction project in terms of construction technology requirement for QSs. Based on that QSs can pay required level of attention for technological aspect when performing tasks at each project stage. Also the study identified that QSs should have sound technical knowledge on expressway construction technologies to perform assigned duties. Therefore, the study recommends the governing bodies to conduct CPDs for highway construction technologies due to still it is new to Sri Lanka. Finally, the study investigated the strategies to overcome challenges, which have been created based on QSs lack of technical knowledge, in the practical aspect also. If practitioners faced with similar challenges as identified in the research can follow the proposed strategies.

However, this research paves the way for future research directions such as;

- Since the current study was limited to QSs construction knowledge area and generalised it. Further research can be carried out for consultant QSs and contractor QSs separately
- QSs' construction technology knowledge required to perform tasks in feasibility stage of construction projects

6. REFERENCES

Arditi, D. and Bentotage, S. N., 1996. System for Scheduling Highway Construction Projects. *Computer-Aided Civil and Infrastructure Engineering,* 11(2), pp.123-139.

Australian Institute of Quantity Surveyors [AIQS], 1998. *Competency standards for Quantity Surveyors Construction Economists and Cost Engineers,* Sydney: AIQS.

Cunningham, T., 2015. *Cost Control during the Pre-Contract Stage of a Building Project-An Introduction.* Report prepared for Dublin Institute of Technology.

Falls, T., Thomasen, J., Clinckett, J., Molyneux, D., Youmans , A., Fillingham, C. and Lesurf, C., 2010. *A Guide to Project Closeout Procedures,* Ontario: Ontario General Contractors Association and Ontario Association of Architects.

Finnish Transport Agency, 2010. *Road Planning Process.* [Online] Available at: https://www.liikennevirasto.fi/web/en/ [Accessed 31 January 2018].

Herman, S., 2016. *The Motivation of Quantity Surveyors in the Malaysian Construction Industry for Improved Job Performance.* Salford: The University of Salford.

Hughes, W., 1991. Modelling the construction projects using plans of work. In: *Proceedings of International Conference CIB W65*, Dubrovnik, Yugoslavia, pp. 81-86.

Lau, E., 2013. *An Investigation of the Role of QS in Infrastructure Projects,* City University of Hong Kong.

Loosemore, M., Lim, B. T. H., Ling, F. Y. Y. and Zeng, H. Y., 2018. A comparison of corporate social responsibility practices in the Singapore, Australia and New Zealand construction industries. *Journal of Cleaner Production,* pp.140-150.

Mbachu, J., 2015. Quantity Surveyors' Role in the Delivery of Construction Projects: A Review. *Quantity Surveyors (NZIQS)*, *25*.

Mohamed, Y. and AbouRizk, S., 2005. Technical Knowledge Consolidation using Theory of Inventive Problem Solving. *Journal of Construction Engineering and Management,* 131(9), pp.993-1002.

Olubunmi, O.A., Timothy, I.O., Alabi, A.O. and Israel, O.T., 2014. Competitive strategies of selected quantity surveying firms in Nigeria. *International Journal of Management, Information Technology and Engineering*, *2*(11), pp.1-18.

Pewdum, W., Rujirayanyong, T. and Sooksatra, V., 2009. Forecasting final budget and duration of highway construction projects. *Engineering, Construction and Architectural Management,* 16(6), pp.544-557.

Ritchie, J., Nicholls, C. and Ormston, R., 2014. *Qualitative Research Practice.* 2nd ed. London: Sage Publications.

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

University of Brighton, 2016. *Project Workstages and Procedures Checklist.* [Online] Available at: https://staff.brighton.ac.uk/efm/Public_Docs/pm_framework_03_08_15.pdf [Accessed 31 January 2018].

Wu, C. H., Hsieh, T. and Cheng, W.l., 2005. Statistical analysis of causes for design change in highway construction on Taiwan. *International Journal of Project Management,* 23(7), pp.554-563.

Zheng, S. and Chen, J., 2012. The Study of The Core Concept of Safety Culture in Highway Engineering Construction Projects. *Systems Engineering Procedia,* 4, pp.460-467.

Kumarasiri, D.M.G.B.T. and Dissanayake, D.M.P.P., 2019. Stakeholders' involvement in successful implementation of waste to energy projects: Case studies in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 535-546. DOI: doi.org/10.31705/WCS.2019.53. Available at: https://2019.ciobwcs.com/papers

STAKEHOLDERS' INVOLVEMENT IN SUCCESSFUL IMPLEMENTATION OF WASTE TO ENERGY PROJECTS: CASE STUDIES IN SRI LANKA

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ABSTRACT

Same as to many countries, Sri Lanka is also facing a waste crisis due to the issues in municipal solid waste management. As a solution, Waste to Energy (WtE) concept was aroused, which transforms waste to energy in the form of electricity. Although it was a successful strategy for many of the countries, in Sri Lanka, most of the instances, WtE projects were resulted in failures due to issues provoke in the implementation. Poor stakeholder management has been one of the key contributing issues behind these failures. Hence, there is a timely need of identifying key stakeholders and their role to pledge project success. Despite the abundance of research on WtE projects, a gap in literature could be identified, when it comes to exploring stakeholders' involvement in successful implementation of WtE projects in Sri Lanka. Thus, this study is aimed at bridging this knowledge gap. A qualitative research approach with two case studies were used in this study. A total of 12 interviews were conducted and collected data were analysed using content analysis. The empirical findings revealed that government, community, central environmental authority, engineering procurement and construction contractors, municipal council and central electricity board are the most influential stakeholders involved in the implementation of WtE projects. Although their level of contribution is varied to each other, all stakeholders along with their interests and involvement collectively thrive to assure the successful implementation of WtE projects in Sri Lanka. The knowledge generated through this research can be used by respective industry practitioners in Sri Lanka in implementing future WtE projects successfully.

Keywords: *Implementation Process; Municipal Solid Waste Management (MSWM); Stakeholders; Waste to Energy (WtE).*

1. INTRODUCTION

Due to the rapid growth in the population, booms in the economy, rapid urbanisation, and the rise in the consumer choices, the Municipal Solid Waste (MSW) generated in mass levels in almost all the countries in the world (Palanivel and Sulaiman, 2014). It was estimated that the current global MSW generation levels are nearly 1.3 billion tonnes per annum and expected that, it will be increased up to 2.2 billion tonnes annually at the end of the year 2025 (Hoornweg and Bhada, 2012). Concequently, MSW generation has led to different adverse environmental impacts, public health risks (Ramachandra *et al.*

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2018). Ogawa (2000) reported, this is due to the low and irregular collection coverage, crude open dumping, no water and air pollution control in burning waste and handling of informal scavenging activities. Compared to developed countries, developing countries have to respond to these new challenges, and in recent times, WtE has been increasingly viewed as a solution to the problems derived from rising waste quantities in expanding cities as well as rapidly growing energy demand (Kothari *et al*. 2010; Energy Information Administration, 2017). However, WtE can never resolve the problem alone, but rather requirements to be entrenched in an integrated solid waste management system that relates to the specific local conditions with regards to waste composition, environmental challenges, informal sector, resource prices, financing, and other aspects.

There are certain key stakeholders that appear throughout the implementation of WtE projects (Contreras *et al*. 2008). Identification of such stakeholders, their interests and role in a WtE project is vital to assure the project success (Soltani *et al*. 2015). These stakeholders must be involved openly and actively (The World Bank, 1999), and should be consulted throughout the project phases. In Sri Lanka, although six (6) projects are being proposed to implement locally, only two of them have been implemented yet, two projects were failed already and implementation of rest of the projects have been adjourned (Priyalal, 2017). It has been discovered that poor stakeholder management has been one of the key contributing issues behind the failure of WtE projects in Sri Lanka. In this context, a timely need has been emerged in identifying the key stakeholders who are involved in implementation of WtE projects and their role to pledge project success. Despite the abundance of research on solid waste management, the stakeholders' involvement in successful implementation of WtE projects in Sri Lanka has not being researched yet. Thus, having identified the knowledge gap, this paper aimed to investigate the key stakeholders and their involvement stakeholders' in different phases WtE projects to ensure the success of upcoming projects.

2. LITERATURE REVIEW

Following sub sections explore the relevant literature in the research arena with major focus on the concept of WtE and its applicability and stakeholders involved in successful implementation of WtE projects.

2.1 THE CONCEPT OF WTE AND ITS APPLICABILITY

WtE technology can be defined as a process of recovering energy from waste by treating them, in the form of electricity, transport fuels or heat (Keunecke, 2016; Breeze, 2018). Moreover, a study conducted in China emphasised that WtE is the generation of energy from the waste directly through the methods of combustion such as gasification, incineration and pyrolysis or the production of hydrogen, methane and some other synthetic fuels through anaerobic digestion or through mechanical biological treatment methods, landfill gas utilization and bio refineries (Moya *et al*. 2017). According to Themelis and Ulloa (2007), by the year of 2013, the global market of WtE was valued about US dollars 25.32 billion and energy through thermal conversion technologies lead the global market which accounted as 88.2% of the total revenue of WtE market in 2013. Further, Schiffer *et al*. (2016) explained that Europe has the most demanding and sophisticated market for the WtE, which is 47.6% of the total WtE market. WtE market of China has the fastest growth rate and it was expected that it will be doubled its capacity of WtE within the period of 2011-2025. Moreover, they identified that among WtE treatment technologies, biological treatment is having the most potential growth rate which will be commercially viable. As the regional perspective Asia -Pacific will remark the highest growth rate (Schiffer *et al.* 2016). Developed countries such as Sweden, Germany, Netherlands, United Kingdom, Denmark etc. have already implemented WtE plants (Rawlins *et al.* 2014). Similarly, it is estimated that about 130 million tonnes of MSW are combusted annually in over 600 WtE facilities worldwide (Themelis and Ulloa, 2007). Benefits that can be gained from WtE plants includes reduction of waste volume, reduction of land demand compared to landfilling options, reduction of environmental and social externalities attributed to waste disposal and creation of job opportunities (Rawlins *et al.* 2014). Sri Lanka is also currently looking forward to use WtE technologies. The recent study by Priyalal (2017) identified six (6) mega WtE projects, which were proposed for supplying electricity to the grid. According to the researcher, two (02) of them have been implemented using the WtE methods such as incineration, gasification and anaerobic digestion. Not only these WtE methods, but also Sri Lanka has the capacity to use other latest methods such as pyrolysis, plasma technology as revealed by Priyalal (2017).

2.2 STAKEHOLDERS INVOLVED IN SUCCESSFUL IMPLEMENTATION OF WTE PROJECTS

Stakeholders are any individual or any group of people who are having a high impact to an organisation who can affect or affected by the achievement of organisations goals and objectives (Li *et al*. 2013). Hence, for the WtE projects, the involvement of stakeholders could affect critically since they are playing an important role in the design, implementation, and promotion of WtE projects (Contreras *et al.* 2008). Table 1 summarises the different types of stakeholders who are involved in a WtE project and their role in the project. This was based on the previous studies, which have been conducted by many researchers in the same area.

Table 1: Summary of stakeholder involvement

Stakeholder	Role/Interests
Regulatory stakeholders *(Government/ Municipalities)*	Have the centralised power for selection of MSWM strategies and implementing them The Municipalities are sentient of human health dangers and environmental impacts associated with WtE projects They have the direct control to decide whether the project will proceed or not, they have the power to see whether the project is in accordance with the pre-stated requirements
Industrial Experts *(Research institutions)*	Working with the government to undertake studies on WtE Have widespread of information on WtE technologies They focused on the vulnerable population needs and communicate them to wider audience which includes policy makers, managers and planners
Community and other Influencing Stakeholders *(Residents living near to the site, and media)*	Cannot directly influence to the project but can be indirectly influenced to it. If the media leads towards the opposition, it will be difficult to get a positive attitude from the population.

Stakeholder	Role/Interests
	They can be influenced to the WtE project by source reduction and cooperating with civil bodies in the identification of the site for the WtE facilities
	Concern about the project due to the impacts that could be occurs such as noise, visual, traffic, etc. causing terminations, delays and change of project
Private organisations	Searching and implementing appropriate actions to establish WtE plants, they are providing required funds
	WtE projects are PPP (Private- Public partnerships) projects by which Government is providing funds and private companies are engaged in construction and implementation of the project
Environmental regulators	Establishing environmental standards and regulations, monitoring and implementation Interested in the project to have a reduced environmental impact of waste management.
Collection and transportation companies	Interested towards the WtE projects to maintain or enlarge the business and there will be new requirements for sorting methods, containers, and transportation vehicles if there are WtE facilities
Energy producers	Imply oppositions to purchase of energy from external producers
	Barriers to sell energy at local electricity rates

However, when it comes to Sri Lankan context, involvement of such stakeholders, their role in WtE Projects have not been discussed in literature yet. Thus, in bridging this knowledge gap, this paper intends to discuss the role of stakeholders in the WtE projects throughout its project phases. The next section discussed the research process adopted in bridging this knowledge gap.

3. RESEARCH METHODOLOGY

Yin (2014) suggested that a research approach has to be selected based on the type of research question, the extent of control an investigator has over actual behavioural events, and the degree of focus on contemporary or historical events. Since, this study followed an in-depth investigation on contemporary phenomenon (i.e. investigating stakeholders' involvement in successful implementation of WtE project) within its real-world context, with a 'how' type of research question (i.e. how could different types of stakeholders be involved in a WtE project?), case study research strategy could be justified. Currently, only two mega projects have been initiated and implemented in Sri Lanka. Therefore, both projects were selected as the cases considering 'stakeholders in a WtE mega project' as the unit of analysis. Both cases are similar in context, expecting literal replications. Table 2 gives a brief description of the selected two (02) cases.

A total of 12 interviews were conducted from both cases. Table 3 provides the profile of interviewees.

Further, both within-case analysis and cross-case analysis were done using code-based content analysis during the data analysis process. A pattern-matching (Yin, 2014) effort is presented in the discussion in Section 5 for theoretical generalisation purposes.

Table 2: Description of two cases

Criteria	Case A	Case B
Project Commencement date	August 2017	October 2017
Project End Date	August 2039	October 2039
Type of WtE technique adapted	Moving grate incineration	Hybrid plant – Anaerobic digestion mass burn incineration/
Approximate amount of MSW utilized	800 tons per day	Anaerobic digestion - 120 tons per day and Mass burn incineration – 500 tons per day
Approximate units of electricity generated	10 MW	12MW
Project cost	1300 million	1400 million
Status	Work in progress	Work in progress

Table 3: The profile of interviewees

Case	Designation	Role
Case A	Managing Director	Oversee the overall activities of the project
	Deputy Project Director	Oversee the overall activities of the project
	Assistant manager -renewable energy	Responsible for obtaining necessary approvals
	Site Director	Responsible for the activities within the project site
	Project Director	Oversee the overall activities of the project
Case B	Chief Technical officer	Oversee the technical aspects of the project
	Chief commercial officer	Oversee the financial aspects of the project
	Manager – Regulatory compliance and local affairs	Responsible for obtaining necessary approvals
	Director (renewable energy) – Sustainable Energy Authority	Responsible for sustainable energy management projects
	Project Consultant – Mega Polis	Provides required project consultation
	Assistant Director (Waste Management)- CEA (	Responsible for the waste management projects
	Director – Waste Management Authority	Responsible for the implementation of waste management projects

4. CASE STUDY FINDINGS

It became apparent from the case study findings that both cases have been following almost similar implementation process, which includes five phases such as 'Planning and feasibility (P&F) phase (Phase I)', 'design phase (Phase II)', 'Construction phase (Phase III)', 'Commissioning phase (Phase IV) and finally 'Operation and maintenance (O&M) phase (Phase V). The case study findings on stakeholders' involvement in WtE projects were discussed under each phase, which will be the basis for following discussion.

4.1 STAKEHOLDER INVOLVEMENT IN PLANNING AND FEASIBILITY PHASE

This stage mainly deals with preparing project proposals and conducting project feasibility in terms of technical, environmental, economic, social, and legal. As revealed from both cases, Government, CEA, community, CEB, MC, funding organisations (i.e. financial institutes) are the key stakeholders who are generally engage in this phase. Because, these stakeholders could either be influential for the termination or continuation of WtE projects. Same as to them, project developer being the private party plays a major role in the project by handling entire implementation process. Although community belongs to the external stakeholder category, their influence on the success of the project is significant. For example, Project Director of Case A mentioned that, "*earlier there were proposals for WtE plants but most of them were stopped from the beginning itself due to public protests as they are unaware about the real benefits of such WtE plants"*. As mentioned in above, both CEB and MC significantly influence to the success of the project because, the project will be succeeded only if CEB agrees to purchase generated electricity from WtE plant on a pre agreed unit price, and MCs' agrees to supply waste. Currently, both projects are typically large investments, which have been funded by project developer with the support of both local and financial institutes (refer Table 4). In addition, research organisations, civil contractors, Sri Lanka Land Development Corporation (SLRRDC), Urban Development Authority (UDA) and sustainable energy authority are the rest of the stakeholders who are involved in this phase (refer Table 4). These findings corroborated among both cases.

Table 4: Summary on responses on stakeholder involvement in planning and feasibility phase

Stakeholder	Involvement/Interest
Project Developer	Cross-sectoral coordination (completing mandatory requirements as requested by the government)
	Invest money for the project
CEA	Consider about the environmental feasibility of the project
	Provide environmental policies and standards
Research institutes	Conducting feasibility studies on available technologies
	Conducting Environmental impact assessments
	Guidance with elongated view of allocating resources
	Assessing the economic feasibility of the project
Community	Concern about the impact to them by this project
Funding organisations	Providing necessary funds/loans for the project implementation
	Feasibility of the project before the commencement
CEB	Deciding the price, which they are purchasing a unit of electricity
	Provides the PPA (Power Purchase Agreement)
Municipal Council (MC)	Interested about the effectivity of the project
	Provides waste supply agreement which is mandatory for the project commencement.
SLLRDC and UDA	Provides required land for the project implementation
Sustainable Energy Authority	Considers WtE as a sustainable energy supplier

Stakeholder	Involvement/Interest
Government (Ministry of Megapolis)	Implement legislations Concern about the health of public and environmental endangers Provide infrastructural inputs and services Interest about the benefits (sustainable energy generation, solution for waste crisis)

4.2 STAKEHOLDER INVOLVEMENT IN DESIGNING PHASE

In this phase, the entire project will be designed including the basic design and detailed design with the layouts of the plant and civil works construction plan. The EPC contractor is identified as the main internal stakeholder. It became evident from the case study findings that EPC is a team, which consists of specialists in the fields of Engineering, Procurement and Construction. The team was outsourced by the project developer in both cases. The main role of EPC contracting team is, providing of WtE technology to the project and expert knowledge on the design reviews. This was further explained by Chief Technical Officer of Case B as, "*although our organisation has initiated the project, we do not have enough expertise knowledge and technology to continue the project, therefore, we have to take necessary support from the technology providers who have that specialised knowledge*." In addition, there are other few stakeholders who are involved in the design stage as presented in Table 5. These stakeholders are common to both cases. Both cases have been getting the support from research institutions like universities in reviewing the design.

Table 5: Summary on responses on stakeholder involvement in design phase

Stakeholder	Involvement/Interest
Project developer	Expect a successful design
EPC contractor	Provides the technical and constructions specifications of the plant
Research institutes	Provides consultation on technical drawings and specifications
CEA	Requires that design criterions in accordance with CEA regulations

4.3 STAKEHOLDER INVOLVEMENT IN CONSTRUCTION PHASE

In the construction phase, civil constructions and setting of the plant and machineries are the main activities identified through case study findings. As apparent from case study findings, both cases are still in the construction stage and have not started the WtE processes yet. In this phase, as revealed from both cases, EPC contractor, civil-contractor and project developer, government, CEA and community are the key stakeholders (refer Table 6). Same as to the design stage, EPC contractor is one of the key stakeholders involved in this stage too in addition to sub-contractors. At this stage, EPC contractor is responsible for the technical installations and provision of supervision for all the construction works while civil contractors play a major role in the construction works of the workshop structure. All the construction works have been monitored by the government to ensure that construction works are in accordance with building codes, relevant policies, and other relevant government regulations. Apart from those, the involvement of other stakeholders in this phase are summarised in Table 6.

Table 6: Summary of responses on stakeholder involvement in construction phase

Stakeholder	Involvement/Interest
Project Developer	Concern whether the construction works are according the schedule and payments are done by them
Civil-Contractor	Construction of the project (civil works)
EPC Contractor	Erection of machinery and equipment
Government	Monitoring the construction works to make sure that it is in accordance with the government requirements
CEA	Monitoring and enforcement of environmental standards and regulations related to construction
Community	Concern about the noise, dust and vibration traffic due to vehicles

4.4 STAKEHOLDER INVOLVEMENT IN COMMISSIONING PHASE

Although, two cases are still in the construction phase, in general practice, there are two types of commissions (i.e. cold commissioning and hot commissioning) in a WtE project as explained by all respondents. Although the activities to be done in each commissioning are common to both cases, duration of the commissioning period is different when comparing both cases. In Case A, the commissioning period of the plant will be 02 months and for Case B, it will be 04 months. Initially, the cold commissioning is done by operating the plant without MSW to make sure that systems of the plant are connected and working properly. Subsequently, the hot commissioning will be done using MSW as the fuel source without unit synchronizing but as a trail operation.

Same as to both design and construction stages, EPC contractor is the dominant stakeholder in this phase, because, all the responsibilities of both cold and hot commissioning are vested with EPC contactor. Although government has not played a direct role in this phase, they have been vigilant on commissioning activities to ensure that the project is success or not (refer Table 7).

Table 7: Summary of responses on stakeholder involvement in commissioning phase

Stakeholder	Involvement/Interest
Project Developer	Concern about the functionality of the project
EPC Contractor	Make sure that the plant is according to the design
Government	Concern about the functionality of the plant

4.5 STAKEHOLDER INVOLVEMENT IN O&M PHASE

Since both cases have not moved to this phase yet, practices done in this stage are identified from opinions of relevant stakeholders. As revealed from empirical research findings, O&M stage includes all the activities from the supply of MSW to the plant and to the final activity of transmitting the generated energy to the grid. Moreover, it is mandatory to perform routine check-ups and scheduled maintenance. Project developer, plant operators, O&M contractors, community, CEA, CEB, government, and MC are the stakeholders involved in this phase (refer Table 8).

Table 8: Summary of responses on stakeholder involvement in O&M phase

Stakeholder	Involvement/Interest
Project Developer	Functionality and the profitability of the project
Plant Operators	Health and safety of workers while working in the site
	Engage with the operations of the plant
O&M Contractors	Handling O&M activities of the plant
CEA	Concern about health risks and environmental problems
	Monitoring and enforcement of environmental standards and regulations
CEB	Continuous supply of electricity to the grid
Government	Concern about whether the plant is operating within the agreed conditions
	Concern about health risks and environmental problems
Municipal Council	To supply of waste to the plant continuously
Community	Interested of such projects because of the creation of job opportunities
	Expecting the success of the project as a solution to the prevailing waste crisis
	Concern about health risks
	Source segregation should be done by the community

In this phase, electricity is generated and transmitted to the grid. According to the respondents, the community who live around the project are benefited in this stage through by jobs, which have been created in relation to O&M works. Similarly, the rest of the whole community is also benefited through getting an effective solution to the prevailing waste crisis and it will exclude environmental externalities ensues from current MSWM practices, i.e. bad odour from landfills. Therefore, the community is attentive towards the effective and efficient operations of the plant. CEA is also playing a major role in the O&M phase of a WtE project. This was explained by Assistant Manager - renewable energy of Case A in detail manner as, "*incineration of waste in mass scale would cause environmental endangers, hence it is mandatory to adhere to the regulations and standards of CEA on noise levels, emissions, leachate, fly ash and bottom ash productions"*. In addition, responsibilities on occupational health and safety are mainly vested with plant operators in this stage. In ensuring such responsibilities, plant operators are closely working with O&M contractor. As per empirical research findings, being responsible on all O&M maintenance activities, O&M contractors are more dominant in this stage. As explained by the Managing Director of Case A, all such responsibilities are falls on them, once the agreement is signed with the project developer. Same as those stakeholders, involvement of the CEB and MC cannot be neglected in this stage. Respondents from both cases highlighted this fact. This is because, CEB is being the main electricity buyer of both projects (i.e. case A and case B), electricity will be purchased as agreed in PPA while MCs' will provide segregated MSW and they should exclude the pre-agreed waste like e-waste, hazardous waste. In this context, both projects will be continued only if CEB purchase electricity and MCs' supply MSW to the plant.

5. DISCUSSION

A significant success factor for the implementation of any project is its stakeholders (refer Section 2), which was evident through empirical research findings as well (refer Section 4). Thus, it is vital to identify the relevant stakeholders and their involvement towards the project. Table 9 depicts the stakeholders' involvement in each phase, which was based on both literature and case study findings.

Table 9: Stakeholder involvement in implementation of WtE projects: At a glance

Stakeholder	**Project phases involved in**				
	Phase I	**Phase II**	**Phase III**	**Phase IV**	**Phase V**
Project Developer	■	■	■	■	■
EPC Contractor		■	■	■	
Government* (Ministry of Megapolis)	■		■	■	■
Community (Public, media)*	■		■		■
Research Institutes*	■	■			
CEB*	■				■
CEA*	■	■	■		■
Funding Organisations (Financial institutions)*	■				
Municipal Council (MC)	■				■
SLLRDC and UDA	■				
Sustainable Energy authority	■				
Plant Operators					■
O&M Contractors					■
Civil Contractor			■		

Phase I: Planning and feasibility phase
Phase II: Design phase
Phase III: Construction phase
Phase IV: Commissioning phase
Phase V: O&M phase

Note: *Findings identified from both literature review and case study findings. Other findings are identified only from cases.

By reviewing the existing literature, seven (07) key stakeholders were identified such as government, industrial experts, community, private organisations, environmental regulators, collection and transportation companies and energy producers (refer Section 2.2). These literature findings were in general and not specific to the Sri Lankan context. However, these stakeholders are almost similar to the Sri Lankan context as well according to case study findings (refer Section 4). Case study findings further disclosed eleven (11) additional important stakeholders, such as Project Developer, CEB, EPC contractor, O&M contractor, civil-contractor, plant operators, MC, funding organisations, SLLRDC, UDA and sustainable energy authority (refer Section 4). These stakeholders are more dominant throughout the lifecycle of a WtE project. However, their involvement has not been discussed in the literature yet. It was acknowledged that only CEB is playing the role of energy producer, which was identified through the literature (The World Bank 1999; Soltani *et al*. 2015) and project developer being the private organisation who is handling the project. Moreover, the study done by Soltani *et al*. (2015), identified government and municipalities as one stakeholder, since both parties having interconnections to each other. However, case study findings were contrasted to the study by Soltani *et al.* (2015), wherein Sri Lankan context they were identified as two separate stakeholders. Although, the World Bank (1999) identified collection and transportation companies as one of the key stakeholders in a WtE project, it was not the same when it comes to the Sri Lankan context. This is because, currently, in Sri Lanka, collection of MSW are done by the municipalities itself. Further, although existing literature has not been stressed the necessity of partaking of an EPC contractor yet, the involvement of same stakeholder has made a significant impact to the Sri Lankan WtE projects as per empirical research findings. This is because, Sri Lanka being a developing country, currently lacks with required expertise technical knowledge on WtE projects. The existing situation has created the need for outsourcing EPC service from overseas. Same as to researchers such as Joseph (2006); Collaborative Working Group (2016); Pandey *et al*. (2016), case study findings too disclosed the influence of community on the successful implementation of a WtE project, because their perceptions towards the project are indirectly causing the project success or failure.

6. CONCLUSIONS

So far in Sri Lanka, only two WtE projects have been implemented and four projects were adjourned due to many issues arose. As identified, one of the main reasons for failures of these projects was the lesser understanding of the involvement of stakeholders in terms of their roles, which they need to perform when carrying out the project. Thus, this research intended to investigate the stakeholders' involvement in the successful implementation of WtE projects in Sri Lankan context. The study disclosed fourteen (14) stakeholders who are involved throughout the whole lifecycle of a WtE project together to make the project a success. Among them, community, CEA, CEB, government, municipal council, project developers and EPC contractors are identified as the most imperative stakeholders throughout the WtE implementation process in Sri Lankan context with the nature of their unique role. Understanding of the role of these stakeholders will enable the future WtE industry of Sri Lanka to coordinate them properly by saving project time and cost. Overall, the knowledge generated through this research can be used by respective industry practitioners in Sri Lanka in implementing future WtE projects successfully.

7. REFERENCES

Breeze, P., 2018. The Economics of Energy from Waste. *Energy from Waste*, pp.83-87.

Collaborative Working Group., 2016. *Waste to Energy Rapid Assessment Tool.* St. Gallen: Swiss Resource Center and Consultancies for Development

Contreras, F., Hanaki , K., Aramaki, T. and Connors, S., 2008. Application of analytical hierarchy process to analyze stakeholders' preferences for municipal solid waste management plans, Boston, USA. *Resources, Conservation and Recycling, 52*, pp.979–991.

Energy Information Administration [online] *Waste-to-Energy (Municipal Solid Waste) - Energy Explained, Your Guide to Understanding Energy*. Available from: Eia.gov:

https://www.eia.gov/energyexplained/index.cfm/data/index.cfm?page=biomass_waste_to_energy [Accessed 11th January 2017).

Hoornweg, D. and Bhada, P., 2012. *What a Waste: A Global Review of Solid Waste Management.* Washington: Urban Development & Local Government Unit - World Bank

Joseph, K., 2006. Stakeholder participation for sustainable waste management. *Habitat International, 30*, pp.863–871.

Keunecke, M., 2016. Energy from waste -Improvements in energy efficiency. *Waste Management, 54*, pp.1-2.

Kothari, R., Tyagi, V., and Pathak, A. 2010. Waste-to-energy: A way from renewable energy sources to sustainable development. *Renewable and Sustainable Energy Reviews, 14*(9), pp.3164-3170.

Li, T., Ng, S. and Skitmore, M. 2013. Evaluating stakeholder satisfaction during public participation in major infrastructure and construction projects. *Automation in Construction, 29*, pp.123–135.

Moya, D., Aldás, C., López, G. and Kaparaju, P., 2017. Municipal solid waste as a valuable renewable energy resource: a worldwide opportunity of energy recovery by using Waste-To-Energy Technologies. *Energy Procedia, 134*, pp.286-295.

Ogawa, H., 2000. Sustainable solid waste management in developing countries. *7th ISWA International Congress and Exhibition.* Kuala Lumpur, Malaysia: World Health Organization.

Ouda, O. and Cekirge, H., 2013. Roadmap for Development of Waste-to Energy Facility in Saudi Arabia. *American Journal of Environmental Engineering, 3*(6), pp.267-272.

Palanivel , T. M. and Sulaiman, H., 2014. Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman. *APCBEE Procedia*, pp.96-102.

Pandey, B., Vyas, S., Pandey, M. and Gaur, A., 2016. MSW to energy conversion methodology as physical, thermal, and biological methods. *Current Science Perspectives, 2*(2), pp.39-44.

Priyalal, G., 2017. *Energy Generation Using MSW: Case of Waste to Energy Mega Projects in Sri Lanka*. (pp. 1-91). Colombo: University of Moratuwa

Ramachandra, T., Bharath, H., Kulkarni, G. and Han, S., 2018. Municipal solid waste: Generation, composition and GHG emissions in Bangalore, India. *Renewable and Sustainable Energy Reviews, 82*, pp.1122-1136.

Rawlins, J., Beyer, J., Lampreia , J. and Tumiwa , F., 2014. *Waste to energy in Indonesia [online].* London: Carbon Trust., Available on: https://www.carbontrust.com/media/512147/ctc831-waste-to-energy-in-indonesia.pdf [Acessed 18th November 2017].

Schiffer, H.-W., Westhuizen, Z., Radu, C., Ibeanu , N., Marshall , J., Hoornweg , D., Itodo, I., 2016. *World Energy Resources Waste to Energy.* World Energy Council.

Soltani, A., Hewage, K., Reza, B. and Sadiq, R., 2015. Multiple stakeholders in multi-criteria decision-making in the context of MSW Management: A review. *Waste Management, 35*, pp.318-328.

The World Bank., 1999. *Technical Guidance Report: Municipal Solid Waste Incineration.* Washington, DC: The International Bank for Reconstruction and Development

Themelis, N. and Ulloa, P., 2007. Methane generation in landfills. *Renewable Energy, 32*, pp.1243–1257.

Yin, R., 2014. *Case Study Research: Design and Methods,* 5th ed. Thousand Oaks, CA: SAGE International Publications

Rubasinghe, K., Disaratne, V. and Mahinkanda, M.M.M.P., 2019. Suitability of traditional procurement system for green buildings in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 547 -555. DOI: doi.org/10.31705/WCS.2019.54. Available at: https://2019.ciobwcs.com/papers

SUITABILITY OF TRADITIONAL PROCUREMENT SYSTEM FOR GREEN BUILDINGS IN SRI LANKA

Kasuni Rubasinghe[1], Vijitha Disaratne[2] and M.M.M.P. Mahinkanda[3]

ABSTRACT

Green building construction is a momentous process of sustainability. It signifies the environmental credibility of sustainable. Further, it addresses the energy performance, overall cost of the construction product and conservation of natural resources. Therefore, green building concept has foremost influence on construction industry. Yet, it has core barriers in cost, knowledge, risk and government factors when involve the green construction to construction industry. Hence, procurement system can involve in reducing those barriers. Green procurement signifies both product and process of the construction. Concerning the process base, there are different procurement systems involved in different countries which depend on internal and external factors. There is high involvement in design and build procurement system worldwide which include Sri Lankan context as well. The status of applying traditional procurement system in green construction is significantly high even though it is not considered as highest. Therefore, it has high involvement on addressing the barriers through critical factors of traditional procurement system. It was carried out nine expert survey with qualitative analysis in order to identify involvement of traditional procurement system to green building construction. Accordingly, it focused on the critical factors of traditional procurement system specifically cost, time, complexity, client's involvement, project characteristics and technology. These success factors addressed the barriers which raised through high cost, lack of knowledge, risk and other influences of green building construction. Finally, this research subsidizes to knowledge, green procurement system provides the benefits to increment of green building construction in Sri Lanka.

Keywords: *Green Building Construction; Green Procurement; Procurement; Sustainability; Traditional Procurement System.*

1. INTRODUCTION

According to Low *et al*., (2014) "the greening buildings have become one of the most effective strategies for sustainable development"(Pg. 414). Author Liu *et al*., (2012) "Efforts on green buildings have generally focused on energy efficiency, conservation of natural resources, new environmentally friendly building materials and also revolutionary changes in concepts of design, procurement and management processes to bring about greater reduction in overall environmental impact of buildings" (p. 51).

Selecting a suitable procurement system is a major function that has to be adopted in building construction (Chan *et al.,* 2001). Procurement has become important to a project

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in overall quality in economics, social and environmental aspects (Oyegoke, *et al.,* 2009). There are common factors which affect to procurement system such as economic, legal, political, technology, client resources, project characteristics, variation, cost issues and time (Davis, *et al.,* 2008).

"Green procurement is the purchase of product or services which minimize or provide positive environmental impact." (Wong *et al*., 2016). Yet, this research identified the involvement of procurement systems to green building construction with emphasizing the status of traditional procurement system, addressing the barriers of green buildings construction and overcome them with success factors and identify the critical factors of traditional procurement systems which can address the barriers occur in green building implementation. According to literature findings, it is confirmed that many researchers have conducted research regarding green buildings and procurement, yet researches regarding green procurement system are done in less numbers. There are several researched has been carried out for overall green procurement system. Conversely, the depth study on traditional procurement system involvement on Green building has not been covered which identified as problem statement in this research. Hence, the aim of this research is to investigate the applicability of traditional procurement system to the procurement of green buildings in Sri Lanka.

2. LITERATURE REVIEW

2.1 SUSTAINABLE CONSTRUCTION AND ENVIRONMENTAL SUSTAINABILITY

Sustainable construction helps the building industry to achieve development by resolving the issues of environmental, cultural and socio-economic. In addition to that with proper management of all the features, the sustainable construction seeks to reduce the additional cost of all designing, constructing, operating and overall cost welfare (Shafii, *et al*., 2006). The environmental sustainability ensures that the environment and humans are interacting naturally (Bombugala and Atputharajah, 2010). The authors Hwang and Leong (2013) also proved the status by stating that "the term green building is defined as an environmentally sustainable building which is constructed with minimal environmental impacts" (p.312).

2.2 GREEN BUILDING IN CONSTRUCTION

According to Seyis and Ergen (2017) green building is high performance buildings that are designed and constructed in resource efficient manner to preserve energy, water, material and land through application environmental principals. It categorized under six (6) main parts as shown in Figure 1.

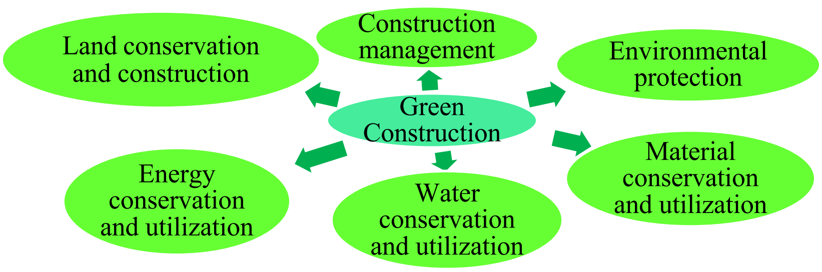

Figure 1: Green construction categorization (Source: Adapted from Shi, et al., 2013)

2.3 PRACTICES IN GREEN BUILDINGS

The employers make effort for pursuing the green building in order to enhance the building performance (Hettige, *et al*., 2016). Due to the significance of the green building, it has increased the popularity among architectural, engineering and construction industry in different countries as well (Li, *et al*., 2018).

2.4 MOTIVATING FACTORS OF ADOPTING GREEN BUILDINGS

There are several benefits can be gain through green buildings which are also categorized as economic, social and environment benefits (Waidyasekara and Fernando, 2012). As examples lowering energy, water wastewater costs. As social example expand market for environmentally preferable and as for environmental negative impact and mitigate carbon emission (Thatcher and Milner, 2016).

2.5 BARRIERS IN IMPLEMENTING GREEN BUILDING TECHNOLOGY

There are several barriers identified when implementing green technology. As the main barriers which directly influence when implementing the green building technology there are six barriers identified as shown in Figure 2.

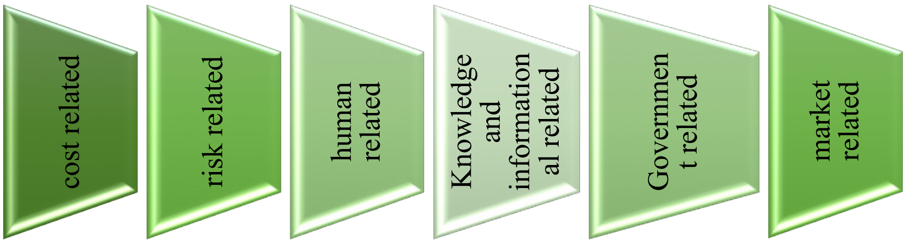

Figure 2: Barriers in implementing green building technology (Source: Adapted from Chan et al., 2018; Sim and Putuhena, 2015)

2.6 PROCUREMENT IN CONSTRUCTION

Procurement in construction is the process of contributing employers' satisfaction through the suitable process of designing and constructing. Rwelamila (2010) also defines procurement as distributing responsibilities among stakeholders and organization with defining relationship of project elements of construction project.

There are four (4) types of procurement system as in, separated, intergrated, management oriented and collaborative.

Table 1: Classification of types of procurement system

Ref	Separated	Integrated	Management Oriented	Collaborative
R1	Traditional, Lump sum, Cost reimbursement Provisional quantities	Design and build (D&B) Novation, Package deal/ Turnkey Contractors design and construct	Design and manage Management contracting Construction management	-
R2	Lump Sum Measure and Pay Prime cost	D&B, Package Deal Turnkey, Develop and Construct	Construction Management Management Contracting D&M	Partnering Joint Ventures Alliancing

		Novated, Concession Contracts All-in contracts		Voluntary Arrangements
R3	Design bid build	D&B, Design Partnership Novation	Design, Build and Manage Management contracting Construction management Building own operate transfer	Partnering

Sources: R1 - Love, *et al.* (1998); R2 - Shiyamini, *et al*. (2005); R3 - Vilasini, *et al.* (2011)

2.7 FACTORS AFFECTING SELECTION OF PROCUREMENT SYSTEMS TO THE CONSTRUCTION

The selection of suitable procurement system is a significant process in both employer and project participant perspective as the selection can affect the project failure or success.

Table 2: Success factors for selecting a procurement system

Reference	Factor
Mathonsi and Thwala, (2012)	Client's requirement
Davis, *et al.,* (2008); Jefferies *et al*., (2002)	Economical, Commercial, Technological, Political, Legal, Social
Cheung, *et al.,* (2010); Davis, *et al.,*(2008)	Resources, Project characteristics, Variations, Responsibility, Authority
Jefferies *et al*, (2002)	Environmental impact, complexity, support, Selecting the right project, Org. size-resource management ability, trust, Community support, Financial capability
Chan *et al.,* (2001)	Constrains imposed by End-Users

2.8 PROCUREMENT SYSTEMS IN GREEN BUILDINGS

Green building procurement is procuring concerning environmental impact of the building (Bohari *et al.,* 2017). As per the Stener (2002) the green building procurement system is also defined as a technical implication, construction procedure which involves the procurement aspect.

2.9 ADOPTION OF GREEN PROCUREMENT TO BUILDINGS

Green procurement is identifying, integrating and implementing of green practices in the procurement procedure which is a complex process and commences at the planning stage and continues to contract execution (Bohari *et al.,* 2017). A product base is concerned about the standard and the environmental friendliness of materials and products.

When implementing any procurement system such as conventional, design and building or partnering to green buildings there is an desired environmental criteria of the product and services as guideline for the design team and construction team (Bohari *et al.,* 2017).

2.10 APPLICATION OF PROCUREMENT SYSTEM TO GREEN BUILDINGS

Ahn, *et al.,* (2016) explained that the green building constructions are actions of multidisciplinary team. Further, as stated by Ahn, *et al.,* (2016) South korea has used the design bid build system with intergrated construction process which is considered as the most popular method in South Korea. According to Rose (2014), most suitable procurement system was identified as collaborative system and D&B and also the auther further stated that least suitable system as traditional procurement system. Therefore, according to unique features of the countries they have identified different procurement systems as suitable procurement system.

3. RESEARCH METHODOLOGY

The data collection commenced with a pilot survey and un-structured interviews of experts. Qualitative analysis was carried out to analyze data. Due to lack of experts who have involved in procurement systems and green building construction at the same time qualitative approach is selected. It was preceded with interviewing experts gathered with one pilot surveying which was carried out to clarify the research area, the interview guideline and also to verify literature findings and to clarify debatable points in literature and 9 expert interviews who have involved in different project with playing different roles such as consultant, contractor and site engineer. Content analysis method was used to analyse the data with the method of N-vivo (2012) software. Finally, after whole process is completed the expectation of the researcher is to identify all objectives and answer the research problem.

4. RESEARCH ANALYSIS AND FINDINGS

4.1 PILOT SURVEY AND EXPERT SURVEY

Through the survey, barriers that influence to green building construction which have integrated to procurement system were identified and also identified the client's perspective regarding the selection of a suitable procurement system to the relevant project. The concerns and facts of the respondents were also emphasized through this survey.

Main concerns of this analysis were factors affecting the selection of a suitable procurement system and the barriers that has to overcome in selecting green buildings.

4.2 STATUS OF PROCUREMENT SYSTEMS IN GREEN BUILDINGS

It was recognized that the awareness of other procurement systems to green buildings such as management oriented and collaborative systems are less than traditional and D&B procurement systems (see Figure 3). Based on the results, 50% of projects are conducted by D&B procurement system. Thus, it clarifies that the most of the green building constructions are proceeded through D&B procurement system. Yet, as the traditional procurement system provides 43%, it can be considered that traditional procurement system is also used reasonably.

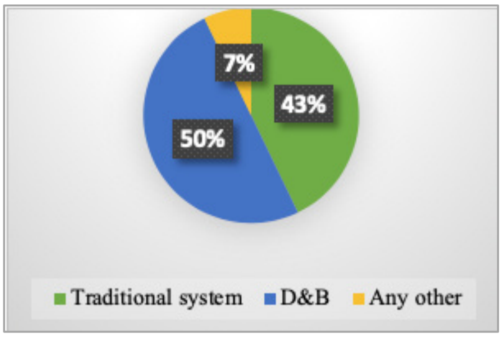

Figure 3: Selection of procurement systems of green buildings

4.3 BARRIERS IMPLEMENTING GREEN BUILDING TECHNOLOGY

According to respondents, green buildings have a major impact on global changes in sustainability. Also, most of the respondents agreed that economic features have a higher impact for global change in sustainability than the social impact. There are seven barriers as identified as Cost, Human, Market, Government involvement, Risk, Knowledge and Interest of People and they have relationship with each other (refer Figure 4).

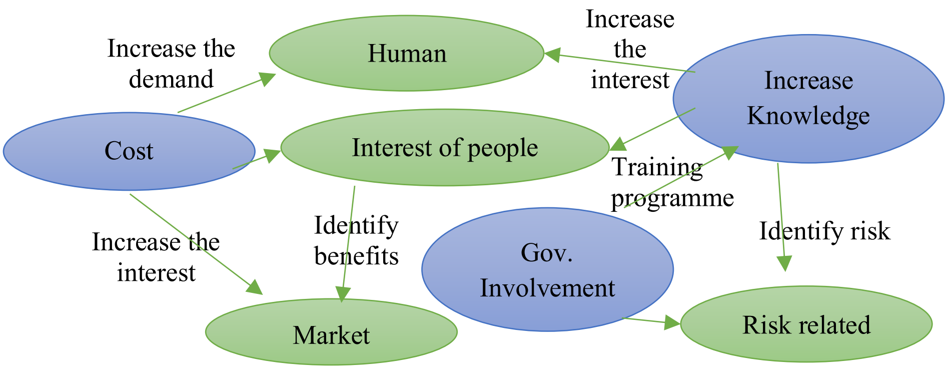

Figure 4: Impact of barriers and mitigation of barriers

Green building construction is a complex construction system. With identified barriers it gets more complicated. Hence, these barriers should be addressed to reduce the complexity of the project itself. As shown in Figure 4 cost reduction helps to increase the interest of people and also the interest of the market. It helps to increase the demand of human as well. With the increasing knowledge, people will aware of the risk beforehand. Further, it helps to identify the benefits resulting interest among the people. Also, human related barriers will be reduced with the people's interest. With the government involvement, it increases the knowledge due to the implementation of programmes and reduce the risk.

Those identified solutions are general solutions which can be addressed to mitigate the barriers. Other than above identified solutions, the barriers can be addresses in construction aspect as well.

4.4 SELECTION OF TRADITIONAL PROCUREMENT SYSTEM (TPS)

Selecting a suitable procurement system has a major impact on the development of green building construction. It can be changed due to several reasons such as cost, time, project characteristics and client's requirements as identified factors.

Selection of a procurement system depends on the current status, internal factors and external factors as identified in the literature review. There are seven critical factors of traditional procurement system which identified through success factors of procurement system as in, Cost, time, complexity, client involvement, project characteristics, technology and variation.

There is high involvement of cost, client involvement and project characteristics in selecting traditional procurement system. So, with analyzing responses it further identified that the positive impact of those identified factors when implementing traditional procurement system.

Table 3: Impact of the factors to select traditional procurement system as suitable system to green buildings

Factor affecting TPS	Level of Impact	Reason for the impact
Cost	Highest impact	Due to less variation, Prior identification of the cost
Time	Impact	Due to less variation
Complexity	Higher impact	Work commence with client's involvement
Client involvement	Highest impact	Direct involvement
Project characteristics	Higher impact	Follow client's scope
Technology	Impact	Reduced unnecessary cost

Consequently, it identified that most of factors have high impact when selecting a traditional procurement system as suitable system. There is less impact in time and technology compared to other factors. Yet, through the respondents' opinions it verified that how those factors affect to selection and what are the benefits that can be gain through selection of traditional procurement system. Therefore, through critical factors of traditional procurement system it can address the barriers of green building construction and helps to increase the green construction in long run.

Considering barriers identified and factors affecting to TPS, the relationship can be identified as illustrated in Figure 5. Figure 5 illustrates what factors address the barriers. According to that there can be one factor that can address several barriers.

5. CONCLUSIONS

Development of construction industry has become obliging with involvement of sustainability. In Sri Lankan construction industry, there is less increment of green building construction due to numerous reasons highlighting the lack of knowledge on green aspects. There are different types of procurement systems which are involved in construction industry. The proper selection can address the client's requirement, financial issues, management risks and procedure of the work. Implication of suitable procurement system influenced to reduce the complexity of the green building construction. This research is based on mapping above two concepts of green construction and procurement systems. Therefore, with providing the solution to research aim, which is investigating applicability of traditional procurement system to the procurement of green building in Sri Lanka was established alone with identifying objectives.

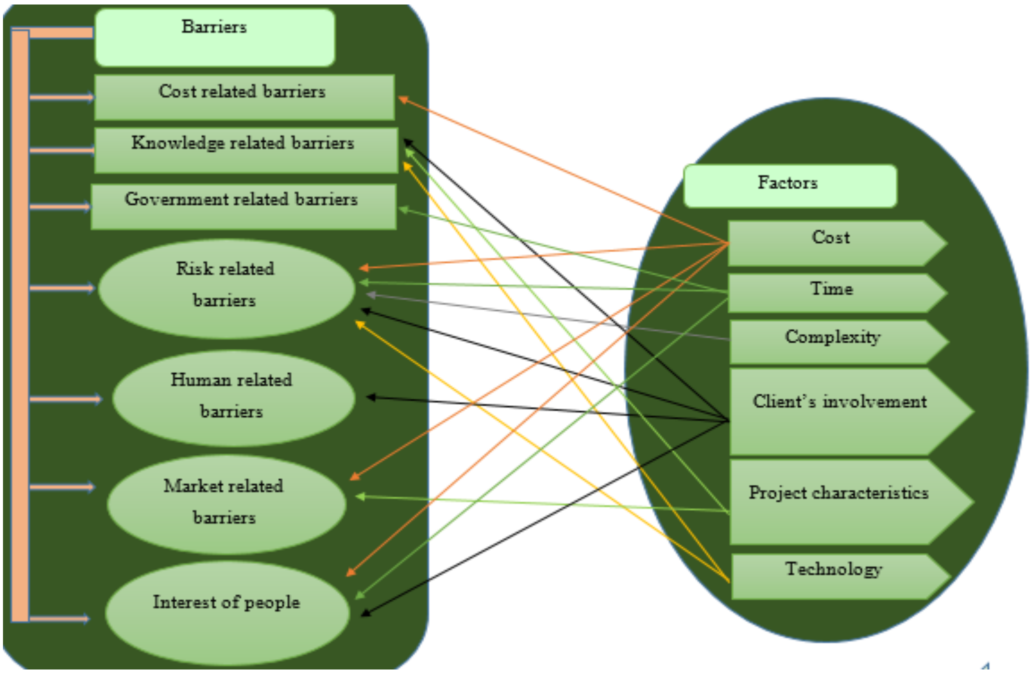

Figure 5: Address the barriers through critical factors

As main identification the application of procurement system in green building construction is analysed. As a result, the status of applying traditional procurement system to Sri Lankan context has identified as second highest implication in Sri Lanka. Then identified how the barriers can be addressed through procurement system and finally involvement of traditional procurement system with critical factors to address the barriers. It identified there is significant involvement in traditional procurement system and it can successfully address the barriers of green building construction. Accordingly, this research has addressed the research problem and contributed to knowledge on increasing the green building construction through procurement systems.

6. REFERENCES

Ahn, Y.H., Jung, C.W., Suh, M. and Jeon, M.H., 2016. Integrated construction process for green building. *Procedia Engineering*, *145*, pp.670-676.

Bohari, A.A.M., Skitmore, M., Xia, B. and Teo, M., 2017. Green oriented procurement for building projects: Preliminary findings from Malaysia. *Journal of Cleaner Production*, *148*, pp.690-700.

Bombugala, B. A. and Atputharajah, A., 2010. *Sustainable development through green building concept in Sri Lanka. In: Proceedings of International Conference on Sustainable Built Environment (ICSBE-2010)*, Kandy, Sri Lanka, 13-14 December 2010. pp.19-24.

Chan, A.P., Darko, A., Olanipekun, A.O. and Ameyaw, E.E., 2018. Critical barriers to green building technologies adoption in developing countries : The case of Ghana. *Journal of Cleaner Production,* 172, pp.1067-1079.

Chan, A.P., Yung, E.H.K., Lam, Patrick T.I., Tam, C.M., and Cheung, S.O.l., 2001. Application of delphi method in selection of procurement systems for construction projects. *Construction Management and Economics,* 19(7), pp.699-718.

Cheung, S., Lam, T.I., Leung, M.Y. and Wan, Y.W., 2001. An analytical hierarchy process based procurement selection method. *Construction Management and Economics,* 19(4), pp.427-437.

Davis, P., Love, P. and Baccarini, D., 2008. *Building procurement methods,* Brisbane Austrailia: Icon.Net Pty Ltd.

Hettige, N.C., Perera, B.A. and Mallawaarachchi, H., 2016. Adoptability of green lease in developing countries*. In: Proceedings of the 5th World Construction Symposium,* Colombo, Sri Lanka, pp.44-52.

Hwang, B. G. and Leong, L. P., 2013. Comparison of schedule delay and casual factors between traditional and green construction projects. *Technological and Economic Development of Economy,* 19(2), pp.310-330.

Jefferies, M., Gameson, R. and Rowlinson, S., 2002. Critical success factors of the BOOT procurement system: reflections from the Stadium Australia case study. *Engineering, Construction and Architectural Management,* 9(2), pp.352-361.

Li, H., Ng, S.T. and Skitmore, M., 2018. Stakeholder impact analysis during post-occupancy evaluation of green buildings – A Chinese context. *Building and Environment,* 128, pp.89-95.

Liu, J.Y., Low, S.P. and He, X., 2012. Green practices in the Chinese building industry: drivers and impediments. *Technology Management in China,* 7(1), pp.50-63.

Love, P.E., Skitmore, M. and Earl, G., 1998. Selecting a suitable procurement method for a building project. *Construction Management and Economics,* 16(2), pp.221-233.

Low, S.P., Gao, S. and Tay, W.L., 2014. Comparative study of project management and critical success factors of greening new and existing buildings in Singapore. *Structural Survey,* 32(5), pp.413-433.

Mathonsi, M.D. and Thwala, W.D., 2012. Factors influencing the selection of procurement systems in the South African construction industry. *African Journal of Business Management,* 6(10), pp.3583-3594.

Oyegoke, A.S., Dickinson, M., Khalfan, M.M.A., McDermott, P. and Rowlinson, A.S., 2009. Construction project procurement routes: An in depth critique. *Managing Projects in Business,* 2(3), pp.338-354.

Purasinghe, R. and Maguino, E., 2010. Sustainable green building rating system for energy efficiency for new residential buildings in US. *In: Proceedings of the International Conference on Sustainable Built Environment (ICSBE-2010),* Kandy, Sri Lanka, 13-14 December 2010*,* pp.164-173.

Shiyamini, R., Rameezdeen, R. and Amaratunga, D., 2005. Macro Analysis of Construction Procurement Trend in Sri Lanka. *In Proceedings of the 5th international Postgraduate Research Conference of the Research Institute for the Built and Human Environment,* University of Salford, UK (pp.525-536).

Rose, M.R., 2014. *The client satisfaction of green building procurement systems,* (Doctoral Dissertation) University of Witwatersrand.

Seyis, S. and Ergen, E., 2017. A decision making support tool for selecting green building certification credits based on project delivery attributes. *Building and Environment,* 126, pp.107-118.

Shafii, F., Ali, Z.A. and Othman, M.Z., 2006. Achieving sustainable construction in the developing countries of Southeast Asia. *In: Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006),* 5-6 September 2006, Kuala Lumpur, Malaysia (pp.29-44).

Shi, Q., Zuo, J., Huang, R., Huang, J. and Pullen, S, 2013. Identify critical factors of green construction - An empirical study in china. *Habitat International, 40,* pp.1-8.

Stener, E., 2002. Green procurement of buildings: A study of Swedish clients' considerations. *Construction Management and Economics,* 20(1), pp.21-30.

Thatcher, A. and Milner, K., 2016. Is a green buildig really better for building occupant? A longitudinal evaluation. *Building and Environment,* 108, pp.194-206.

Vilasini, N., Neitzert, T.R. and Rotimi, J.O., 2011. Correlation between construction procurement methods and Lean principles. *International Journal of Construction Management,* 11(4), pp.65-78.

Waidyasekara, K.G. and Fernando, W.N., 2012. Benefits of adopting green concept for construction of buildings in Sri Lanka, *In Proceedings of the 2nd International Conference on Sustainable Built Environments,* Colombo, Sri Lanka: University of Moratuwa, pp.1-13.

Wong, J.K., Chan, J.K. and Wadu, M.J., 2016. Facilitation effective green procurement in construction project: An empirical study of enablers. *Journal of Cleaner Production,* 135, pp.859-871.

Wu, X., Peng, B. and Lin, B., 2017. A dynamic life cycle carbon emission assessment on green and non-green buildings in china. *Energy and Building,* 149, pp.272-281.

Hyderaly, H., Thayaparan, M. and Aarifkhan, F., 2019. The concept of value engineering and its assimilation in Sri Lankan construction industry: A literature review. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 556-566. DOI: doi.org/10.31705/WCS.2019.55. Available at: https://2019.ciobwcs.com/papers

THE CONCEPT OF VALUE ENGINEERING AND ITS ASSIMILATION IN SRI LANKAN CONSTRUCTION INDUSTRY: A LITERATURE REVIEW

Hammadh Hyderaly[1], Menaha Thayaparan[2] and Fayasa Aarifkhan[3]

ABSTRACT

Value is an ideational thought by which a worth of a good or service is expressed. Value Engineering is one of the tools used to evaluate such value and provide solutions for best fit value in real time. The core principle of practicing value engineering is to achieve value for money in construction projects, but it also bestows practitioners with added advantages such as innovative alternatives and enhanced quality. Even though value engineering is practiced globally, application of value engineering in Sri Lanka is highly limited due to lack of knowledge and awareness of the concept of value engineering, lack of realisation of the benefits it can bring to the construction projects and lack of government support. Hence, Sri Lankan construction industry lacks initiatives to pursue integration of value engineering in construction projects. The objective of this paper is to explore the idea behind the term "value" through value engineering and manifest previously identified causes and mitigation strategies to enhance value engineering practices within Sri Lanka. A comprehensive literature review has been carried out to disclose facts and cues of value engineering identified globally and to contextualise the concepts of value engineering within Sri Lankan construction industry. This paper emphasises that value engineering enhances the total value of the project while irradiating unnecessary costs associated with the projects. However, Sri Lankan construction industry is not practising value engineering in its full potential due to barriers identified above. Recommendations were, therefore, proposed to reveal the importance of standardising value engineering practice in Sri Lankan construction industry.

Keywords: *Construction Industry; Value; Value Engineering; Value Management; Sri Lanka.*

1. INTRODUCTION

Construction industry is evolving into seeking the need of value over cost (Rad and Yamini, 2016). Cost is an inevitable notion in construction industry whereas value is a concept by which such notion can be manipulated to best fit purpose (Dell'Isola, 1997). Mechanism of seeking value was developed in 1947 by Lawrence D. Miles in formulating an approach to reduce cost by a set of methodical functions and such technique was known to be value analysis (Kelly *et al*., 2015). Since such focus was given to value, it

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has been remained prominent in many industries and noteworthy in the case of construction industry (Kelly *et al*., 2015). Seeking value for a product in construction industry is generally initiated by client (Kelly and Duerk, 2002). They also stated that in such case, client would go through a system to define the needs and wants in an elaborated manner.

Value can be expressed through value for money (VFM), and in its entirety, opting for such change from analysis should not prevent the system from performing its basic predefined functions (Younker, 2003). VFM can be simply stated as worthiness of the investment on the project by client or optimal combination of quality, function and cost to meet the end clients' requirement, thus, bringing out meaning of value relative to the client (Kelly *et al*., 2015). VFM is being actively sought in construction sector due to its dynamic and risk prone environment (Ekanayake and Sandanayake, 2017). Value for Money (VFM) in construction is the optimum balance between managing costs without compromising on quality (Shaw, 2016). There are several mechanisms to obtain VFM in construction. Few to name are zero-based budgeting, target costing, benchmarking, total quality control, quality function deployment (Richard, 1998). Among these, value engineering (VE) has been considered as one of the best method for expressing VFM (Green, 1990; Chavan, 2013; Rad and Yamini, 2016).VE is defined 'as the process of analysing the functional benefits a client requires from the whole or parts of the design' (Potts, 2008, p.92; Potts and Ankrah, 2013). VE stands out to be an exceptional value seeking technique as it emphases on elevating quality of construction elements through creativity of professionals by focussing on the functions of such element when compared to other existing mechanisms in the construction industry (Rad and Yamini, 2016). VE is also identified as a procedural value enhancing management mechanism which is applied into a construction project (Male *et al*., 2007).

However, regardless of the merits expressed and implied by practicing VE, its application in Sri Lanka is highly limited (Karunasena and Gamage, 2017). VE is not been explicitly identified by previous studies within Sri Lanka. Importance of VE relies on global reference of VE being a better value seeking mechanism, thus, such practice could be followed in Sri Lanka to enhance the products of construction industry. Also, since there is no standardised procedure to seek value rich construction projects in Sri Lanka, VE would be a best fit technique to achieve such project which subsequently would enhance better economic output of Sri Lankan construction industry. Commonly identified reasons for drawbacks in practicing VE in Sri Lanka were lack of awareness of VE and its application among personnel in construction industry, vagueness of the results derived from such analysis, shortcomings in the extended support by government or governing bodies, extra cost involved when performing VE and formalising into a report, increased time duration to conduct analysis, unavailability of proper expertise and absence of rules and regulations to such practice in construction industry (Karunasena and Gamage, 2017).

Even though the benefits of practising VE are understood, it is mainly due the barriers mentioned above, the VE is not considered as a feasible option to be implemented in Sri Lankan construction industry. There is currently a dearth of research conducted to analyse the significance of VE for Sri Lankan construction industry. There have been no projects in Sri Lanka where the VE has been performed with its full potential. As Sri Lankan construction industry is developing with increased number of major scale projects with foreign investments, it is now the high time for the industry to adopt VE practices. Hence, a study is required to address research gaps associated with VE practices in Sri Lankan construction industry. In this context, this paper presents an in-depth literature review on the aspects of understanding the term ‘value’ and ‘VFM’ in order to emphasise the significance of VE in achieving VFM. It also explores the optimal stages to establish VE in a construction project, merits and demerits of VE practices in Sri Lanka and the reasons why such practices were not standardised. The paper also proposes the necessary recommendations to enhance VE practices in Sri Lankan context.

2. METHODOLOGY

The objectives of the paper are to explore the concepts of value, value for money and value engineering, VE practices with their merits and demerits and barriers of practicing VE in construction industry. These objectives were achieved through a comprehensive literature review associated with VE concepts and its applications. The analysis was streamlined to depict aforementioned details in the context of Sri Lankan construction industry. However, there is a dearth of research and reporting on VE within Sri Lankan construction industry in comparison to global frame of reference. Thus, literature claiming VE as one of the best value seeking mechanisms in global context was reviewed and critiqued to determine the suitability of VE practices in Sri Lankan construction industry and to propose some recommendations to enhance VE with the support of above mentioned sources. The next section reviews the literature that explores the concepts of value and value seeking mechanism, merits and demerits of VE, barriers of practicing VE in construction industry, followed by key recommendations to enhance the VE applications in Sri Lankan construction industry.

3. LITERATURE SYNTHESIS

3.1 VALUE AND VALUE SEEKING MECHANISMS IN CONSTRUCTION INDUSTRY

“Value is a measure expressed in currency, effort, exchange or on a comparative scale, which reflects the desire to obtain or retain an item, service or ideal” (Kelly and Male, 2005, p. 9). Potts (2008, p.92) defined that value is the level of importance that is placed upon a function, item or solution. Value can be stated under four economic values, such as esteem value, exchange value, use value and cost value (Mukhopadhyaya, 2009). It is further stated that esteem value is a driving force which would lead a person or organisation to pursue on selected item of interest, exchange value is worth of an object or service which is used as a base for interchange, use value defines the nature of the purpose which was used to create the commodity and cost value encompasses all cost from the beginning to the final disposal of a product or service. But, when focussed on value in construction industry, it can be stated as a network of all performance indicators including the traditional indicators such as time, cost and quality and emerging indicators which comprises of client satisfaction, environmental impact and sustainability (Oke and Aigbavboa, 2017).

Concept of value incorporates many characteristics, such as, objective, subjective, relative, context dependent and dynamic (Salvatierra-Garrido and Pasquire, 2011). Dell'Isola (1997) expresses value as the most cost effective way to meet clients’ or users’ needs and wants through a derivative which is met by using a desirable function. Furthermore, he also specified that value can be explained as shown in equation (01).

$$Value = \frac{function + quality}{cost} \qquad (01)$$

Where, function = the specific work that a design or item must perform, quality = the owner's or user's needs, desires and expectations, and cost = the life cycle cost of the product.

However, the above stated mathematical function could not be directly applied to gain the end result of "value", but merely to understand its concept. The are several alternative techniques such as zero-based budgeting, target costing, benchmarking, total quality control, quality function deployment, failure mode and effect analysis, design for assembly and value management etc. (Richard, 1998) to achieve VFM in the construction industry. Rad and Yamini (2016), after comparing 15 such alternatives across 20 systems such as budget control, creating new ideas, improving quality and function etc. using a 5-scale method, concluded VE has been scored the highest indicating it is the most suitable option to achieve VFM in construction management.

3.2 VALUE ENGINEERING AND ITS APPLICATIONS

Value management is a process whereby the project is evaluated and scrutinised to obtain maximum value for money by following a prescribed methodology (Olawumi *et al.,* 2016, p.40) where VE is one key phase that is undertaken in the process of value management. VE is an integral part of value management which is diversified into value planning, value analysis, value control, value methodology, value improvement, and value assurance (Oke and Aigbavboa, 2017). They also stated that VE is the aim and definition of value management. VE is not only applied in construction industry but also in manufacturing industries (Mukhopadhyaya, 2009). Potts (2008) identifies VE as a phase in the whole value process of value management, where it is also closely connected to value planning and value reviewing as other stages of value management. Figure 1 indicates interactions between value planning, value engineering and value reviewing and means by which these are achieved.

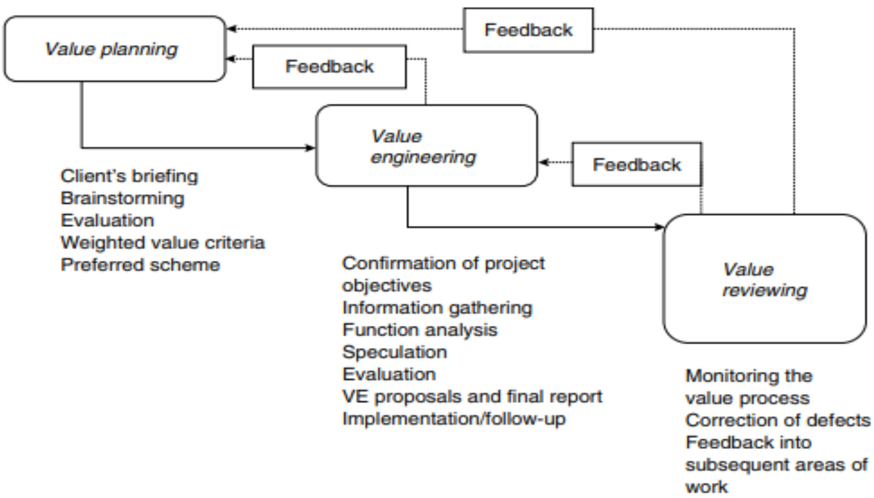

Figure 1: Process of value management (Source: Institute of Civil Engineers, 1996)

VE perceives to achieve VFM by allowing all indispensable functions to be accomplished with lower total cost through a systematic technique (Male *et al*., 2007). It was deduced by Chavan (2013) that VE is one of the most appropriate systematic approaches to seek a better value in construction projects and to elevate the options in a standard manner. VE, in general targets to obtain better functionality of construction projects at the least possible cost. Zhang *et al*. (2009) identified VE as a management tool, which is used in achieving essential functions of a product, service or project with a lowest cost, whereas Male *et al*. (2007) mentioned VE as a methodological value enhancing management style.

The concept of VE is also perceived as a systematised application which combines the idea of technical knowledge along with common sense to find potential situations or method of executions where cost for such can be deduced unnecessary and eliminates such cost which subsequently leads to better VFM (Chen *et al*., 2010). Process of VE would reveal constructability, manufacturability and maintainability of an ongoing or proposed project at early stages of its execution, hence suggests solutions or mitigation strategies for forthcoming problems (Nawi *et al*., 2014).

VE is one of the best fit practice for regulating a better value in construction projects as other techniques lean on the prime focus of quality and time than VFM (Zhang *et al*., 2009; Rad and Yamini, 2016; Oke and Aigbavboa, 2017). Furthermore, Ellis *et al*. (2005) mentioned that VE is a system which induces creativity, innovative ideas, alternative solutions, and generally indulge in some 'out-of-the box' thinking in introducing proper changes to the construction procedures. The basis of VE is not a standalone cost cutting technique, but it plays the role of analysing, evaluating and reporting best valued approaches or in simpler terms triangulates a better VFM for a project (Perera *et al*., 2011). VE is classified as a disciplined methodology and a ground which utilizes creativity to provide the client with reliable alternatives for cost saving purposes by negating deleterious outcomes on performance and quality (National Research Council, 2009). VE can be applied in multitude of stages in construction as shown in Figure 2.

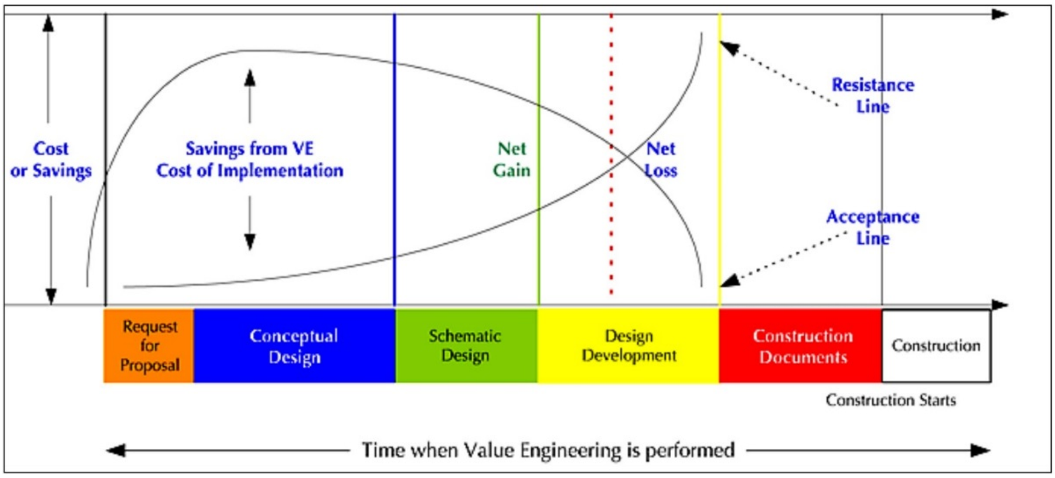

Figure 2: Application of VE in stages of construction (Source: Rad and Yamini, 2016)

Figure 2 clearly shows that VE triggers maximum cost savings only when applied during conceptual design stage mainly due to flexibility of choosing alternatives and diversified options available to express VFM. In agreement to this view, Potts and Ankrah (2013) argues cost reduction potential is high at the initial stages of a project as the opportunities for making changes will tend to reduce as the project progress with an increased cost to such changes at later stages. Conversely, when such practice is executed in latter stages like design development, it creates excessive resistance to choose and as a result could reduce the potential savings or incur cost in the perspective of value. This phenomenon is due to the fact that early stages of construction projects being susceptible to change as a result, could be advantageous to find proper alternatives without significantly harming the progress of construction (Yin *et al*., 2016). Since value engineering is not explicitly realised to be a best fit value attaining standard in Sri Lanka, application of such system is much linear and selective (Kosala and Karunasena, 2015).

3.3 MERITS AND DEMERITS OF VALUE ENGINEERING

A proper establishment of VE could reap many advantages. The basis of VE starts with a brainstorming session which incorporates ideas of many who are involved in the project (Norton and McElligot, 1995; Connaughton and Green, 1996; Younker, 2003; Potts, 2008; Mukhopadhyaya, 2009; Potts and Ankrah, 2013). Whilst the contribution of every personnel involved in a project reaches the common goal of finding VFM, the coordination between parties to be elevated to much further level to reach the VE objectives (Connaughton and Green, 1996; Kelly *et al*., 2015). The brainstorming also contributes towards effectively working in a team based environment with less difference of opinions. Such coordination also encourages all personnel to ruminate in diversified ways, in simpler terms, “out-of-the-box” thinking is much motivated among the personnel. This thinking process leads to increased innovation on delivering the best fit product or alternative within the project and elevates alternative seeking capabilities. Subsequently, it paves the way towards elimination of unnecessary cost associated with the project, which happened to be part of it prior to VE initiatives (Norton and McElligot, 1995; Connaughton and Green, 1996). This does not dictate that VE only relinquishes cost related to the face values of a project, but it also analyses the total life cycle cost of a component to deliver best VFM (Norton and McElligot, 1995; Kosala and Karunasena, 2015). It is further stated that however, by doing so, parties of the construction project are able to detect and seek remedies for deficiencies and eradicate superfluous items in the initial scope of construction.

VE applied on a construction project, reviews the whole of project than a specified element or set of elements (Dell'Isola, 1997; Potts, 2008; Kelly *et al*., 2015). Hence, brings about multitude of value rich aspects within a project. As VE is a process which details features of a project, it focuses even on a miniscule detail, refining the status quo and identifying project constraints which would not otherwise have been encountered (Norton and McElligot, 1995). Furthermore, such actions result in management of the project to take key decisions which are derived from the nature of arriving to alternatives of best value. At critical stages, such decision would immensely prove beneficial to the project itself. Periodically, when following VE practices, an organization could identify and prioritise needs to deliver optimal VE results within specific frame of time to aid the most concerned party (Norton and McElligot, 1995; Connaughton and Green, 1996). Subsequently, through effective practice of VE initiatives, it paves the way to maximum return on minimal investment (Norton and McElligot, 1995; Dell'Isola, 1997; Younker, 2003; Kelly and Male, 2005).

However, VE practices is not always perceived to be universally advantages. It also carries certain disadvantages when applied into a project. As stated above, VE initially starts with a brainstorming session. Even though this action divulges great concerns on the project, it could also lead to confrontational arguments between parties of the construction project (Kelly and Male, 2005; Kelly *et al*., 2015). This subsequently could result in development of a communication barrier between stakeholders of the project.

Moreover, using the internal design team in VE study can be time and cost saving as the internal group has been already identified and payments could be negotiated in a positive manner. However, it is considered rather suboptimal because of the fact that ideas generated from internal design team is brought forward to be agreed upon, any changes in such design could generate resistance for such team as they would hesitate to contemplate their own ideas and creativity (Norton and McElligot, 1995; Kelly and Male, 2005). VE can also be initiated with outsourcing VE application to an external entity comprising of personnel skilful in value management, but this could incur additional cost to the project. It is mainly due to the fact that VE generally saves more than 10% of the project cost, thus payment requirement of personnel would not be less than such margin of potential savings (Norton and McElligot, 1995). An effective VE also consumes time due to its nature of elaborative study which in critical situations could be a roadblock to the entire project (Potts, 2008). Effective application of VE could reap the aforementioned benefits, but due to certain barriers, the full potential of VE is not generally observed in the construction industry.

3.4 BARRIERS TO VALUE ENGINEERING PRACTICES IN CONSTRUCTION INDUSTRY

Lack of support extended by government in incorporating VE or value management policy in standards of the construction industry is a prime reason for lack of widespread use of VE within Sri Lanka (Kosala and Karunasena, 2015; Oke and Aigbavboa, 2017). If initiatives are taken through a regulating body such as Construction Industry Development Authority (CIDA) by providing guidelines to the use of professionals from the construction industry, VE could be made into a mandatory standard. Further, shortcoming in knowledge on VE and value management also is a contributing factor for its unpopularity (Rad and Yamini, 2016). Restricted practice of VE arises due to said reasons, which consequently could reduce stakeholders' interest on considering VE as an option. Creating awareness among stakeholders could minimise the restrictions on VE practices in practical execution of the project (Xiaoyong and Wendi, 2012; Oke and Aghimien, 2018). It is much suited if such social awareness is detailed with benefits to all the construction industry practitioners, especially client. Presenting sentience on VE to the client is most crucial, as client is the drive force of a project and elevated importance and involvement of client in VE practice could prove to its acceptance in construction industry (Oke and Aigbavboa, 2017). Absence of an induction programme within an organization is also a barrier for practicing VE as organisation itself is not keen on incorporating VE practices (Xiaoyong and Wendi, 2012). Drawback of VE in electronic medium, i.e. as a computer aided programme, can be a major setback as almost every operation in construction industry is revolutionised with support by information technology systems (Oke and Aigbavboa, 2017).

However, in Sri Lankan context, VE is often perceived in the form of proposal submitted by the contractor during project execution, where contractor aims to achieve hidden benefits along with delivering the work for lesser cost with reduced time (Kosala and Karunasena, 2015). Implementation of alternatives derived from VE practices generally depend on the experience and expertise of the stakeholders in a project (Karunasena and Gamage, 2017). Furthermore, it was also disclosed that VE practices are executed as per the project stakeholders to correspond with the project. Also, a common misconception in Sri Lanka is that VE is performed only on the basis of reducing the face value of the cost, whereas in reality it evaluates and analyses all cost related elements from inception to disposal of a project. It clearly indicates that the VE are not practised with its full potential in Sri Lankan construction industry. Hence, the benefits of VE practice discussed previously are not fully realised.

3.5 RECOMMENDATIONS TO ENHANCE VE PRACTICES IN SRI LANKAN CONSTRUCTION INDUSTRY

Value is a measure of worth which is constantly sought by human beings. The clients of Sri Lankan construction are no exception to this scenario. However, there is no defined technique in Sri Lanka to achieve VFM in building constructions. The literature review confirms that VE is a mechanism that has proven advantages in global context of construction industry. The literature further indicates that the VE is one of the best value seeking mechanisms and has a potential of being practiced while executing construction projects. However, VE practices are seldom recognized in Sri Lankan context. Lack of awareness, poor realisation of benefits, inability of the government to extend support and unavailability of proper expertise are some of the reasons why VE has not been popular in Sri Lankan construction industry. This section, therefore, discusses the recommended practices to enhance VE practices.

As a standalone organisation in construction industry, many changes could be made into one of organizations' practice on VE techniques which could disperse rapidly due to the merits of such work (Kosala and Karunasena, 2015; Karunasena and Gamage, 2017). One best recommendation is that each organisation should conduct an induction or training programme on VE among workers of the firm (Xiaoyong and Wendi, 2012; Oke and Aghimien, 2018). This training would greatly enhance future practices of VE. Following an accepted brainstorming session in a VE analysis is of due importance because, this action could reduce confrontation, arguments and could act as a knowledge pool since every member would be given an equal opportunity to express their own concerns (Norton and McElligot, 1995; Kelly and Male, 2005). In order to adopt VE practices in Sri Lankan construction industry, the industry practitioners can be motivated by providing incentives (Younker, 2003). Diversifying knowledge base through awareness by educating client should also be made to encourage the increased use of VE in selected projects. Provision of extended support by felicitating units which practice and execute VE in construction projects could act as a driver for other members of the organisation to follow such practices (Kosala and Karunasena, 2015; Karunasena and Gamage, 2017; Oke and Aghimien, 2018). Integrating a VE expert into a design team could significantly progress an entity towards following VE practices and its importance in construction projects. This could also pave the way to seek alternatives during design development stage which can later be made a standard in the practicing organization (Kelly *et al*., 2015).

Initiating changes within organization is in fact an effective principle. But, to make a major overhaul in the construction industry, it is necessary for the government or governing body to make the change. In such trend, regulating VE using construction law would make VE to be followed mandatorily when executing construction projects (Xiaoyong and Wendi, 2012; Oke and Aghimien, 2018). Increased government support in the form of tax incentives and reduced constraints for projects that practice VE would act as a driving force to follow VE practices by teams which do not usually follow such standards (Kosala and Karunasena, 2015; Karunasena and Gamage, 2017). Further, the contribution that can be provided by governing bodies such as CIDA should be emphasised to enhance the VE practices. CIDA as a governing body of construction can easily influence the professionals of the industry, as such it will be an ideal hub though which awareness and importance of VE can be disseminated. Incorporating VE related clauses into binding contracts between stakeholders will also help to improve the application of VE in construction.

4. CONCLUSIONS

Value is an often actively sought commodity in day-to-day life. However, parameters of value within construction industry dictates terms so that maximised VFM can be obtained through proper value seeking practices. Such trend led to execution of VE in the construction industry as VE proved to be the best fit technique to find VFM. Analysis and alternatives approach derived from VE during the pre-construction stage leads to maximum cost saving with much flexibility to choose without compromising quality whereas VE during construction could lead to additional cost and in some cases would act as a roadblock for construction projects.

It is conspicuous that VE and its practices are highly limited in Sri Lankan construction industry. Although construction projects are executed with certain degree of value seeking mechanisms, it lacks standardised practice of the most acclaimed technique. Factors such as lack of regulatory body or government support and lack of awareness of VE techniques among construction industry personnel has led to curtailment of VE application and practices. However, if involvement and dedication of client in seeking VFM is realised by either parties i.e. consultant or contractor, initiatives taken by client could lead to improved practice of VE. Hence, a value rich product can be delivered by cohesion of VE techniques in construction industry especially during design development stage of a construction project. As such this paper concludes that the VE practices are evidently limited in Sri Lankan construction industry mainly due to lack of knowledge, awareness and expertise among the professionals, lack of realisation of the benefits and lack of support from government or other relevant authorities. Increasing awareness and expertise on VE through training and education and encourage the government to support VE practices were the key recommendations proposed to address these barriers. As a way forward of this on-going research primary data have been collected from the industry practitioners who have either possessing the relevant knowledge or practising some form of VE. The primary data finding will be provided in subsequent publications.

5. REFERENCES

Chavan, A., 2013. Value engineering in construction industry. *International Journal of Application or Innovation in Engineering and Management*, 2(12), pp.18-26.

Chen, W., Chang, P. and Huang, Y., 2010. Assessing the overall performance of value engineering workshops for construction projects. *International Journal of Project Management,* 28(5), pp.514-527.

Connaughton, J. N. and Green, S. D., 1996. *Value Management in Construction: A Client's Guide.* London: Construction Industry Research and Information Association.

Dell'Isola, A., 1997. *Value Engineering: Practical Applications for Design, Construction, Maintenance and Operations.* Kingston: RSMeans.

Kelly, J. and Duerk, D., 2002. Construction project briefing/architectural programming. *Best value in construction*, pp.38-58.

Ekanayake, E. and Sandanayake, Y., 2017. LiVE approach: lean integrated value engineering for construction industry. *Built Environment Project and Asset Management,* 7(5), pp.518-533.

Ellis, R., Wood, G. and Keel, D., 2005. Value management practices of leading UK cost consultants. *Construction Management and Economics.,* 23(5), pp.483-493.

Green, S., 1990. The essentials of value engineering. *Facilities,* 8(10), pp.15-17.

Gudem, M., Steinert, M., Welo, T. and Leifer, L., 2013. Redefining customer value in lean product development design projects. *Journal of Engineering, Design and Technology,* 11(1), pp.71-89.

Institute of Civil Engineers, 1996. *Creating Value in Engineering – Design and Practice Guide.* London: Thomas Telford.

Karunasena, G. and Gamage, K. R., 2017. A decision-making formula for value engineering applications in. *Journal of Financial Management of Property and Construction,* 22(1), pp.77-91.

Kelly, J. and Male, S., 2005. *Value Management in Design and Construction: The Economic Management of Projects.* London: E. & F.N. Spon.

Kelly, J., Male, S. and Graham, D., 2015. *Value Management of Construction Projects.* 2nd ed. West Sussex: John Wiley & Sons.

Kosala, R.G. and Karunasena, G., 2015, August. Value engineering practices and its impact to construction industry. *In Proceeding of the 4th World Construction Symposium 2015: Sustainable Development in the Built Environment: Green Growth and Innovative Directions* (pp. 538-546).

Male, S., Gronqvist, M., Kelly, J. and Graham, D., 2007. Managing value as a management. *International Journal of Project Management,* 25(2), pp.107-114.

Mukhopadhyaya, A.K., 2009. *Value Engineering Mastermind from Concept to Value Engineering Certification.* New Delhi: Sage Publications.

National Research Council, 2009. *Advancing the competitiveness and efficiency of the U.S. construction industry,* Washington, DC: The National Academies Press.

Nawi, M.M., Jalaluddin, S.M.F.W.S., Zulhumadi, F., Ibrahim, J.A. and Baharum, F., 2014. A strategy for improving construction projects sustainability through value management approach. *International Journal of Applied Engineering Research*, *9*(24), pp.28377-28385.

Norton, B. R. and McElligot, W. C., 1995. *Value Management in Construction: A Practical Guide.* London: Macmillan.

Oke, A.E. and Aghimien, D.O., 2018. Drivers of value management in the Nigerian construction industry. *Journal of Engineering, Design and Technology,* 16(2), pp.270-284.

Oke, A. E. and Aigbavboa, C. O., 2017. *Sustainable Value Management for Construction Projects.* Cham: Springer International.

Olawumi, T.O., Akinrata, B.E. and Arijeloye, B.T., 2016. Value Management – Creating Functional Value for Construction Project: An Exploratory Study. *World Scientific News,* 54, pp.40-59.

Park, R., 1998. *Value Engineering: A Plan for Invention.* New York: CRC press.

Perera, S., Hayles, C. and Kerlin, S., 2011. An analysis of value management in practice: The case of Northern Ireland's construction industry. *Journal of Financial Management of Property and Construction.,* 16(2), pp.94-110.

Potts, K., 2008. *Construction Cost Management.* Oxon: Taylor & Francis.

Potts, K. and Ankrah, N., 2013. *Construction Cost Management: Learning from Case Studies.* 2nd ed. Oxon: Taylor and Francis.

Rad, K. M. and Yamini, O. A., 2016. The Methodology of Using Value Engineering in Construction Projects Management. *Civil Engineering Journal,* 2(6), pp.262-269.

Salvatierra-Garrido, J. and Pasquire, C., 2011. Value Theory in Lean Construction. *Journal of Financial Management of Property and Construction,* 16(1), pp.8-18.

Shaw, J., 2016. *Value Management vs Value Engineering.* [Online] Available at: https://www.fgould.com/uk-europe/articles/value-management-vs-value-engineering/ [Accessed 23 August 2019]

Xiaoyong, L. and Wendi, M., 2012. Appraisal of Value Engineering Application to Construction Industry in China. *Future Wireless Networks and Information Systems*, 144, pp.303-311.

Yin, H.-W., Yang, H.-J. and Gao, H.-J., 2016. *Analysis on Cost Management Application of Value Engineering at Design Phase of Real Estate Projects.* Paris, Atlantis Press, pp.361-371.

Younker, D. L., 2003. *Value Engineering Analysis and Methodology.* New York: Marcel Dekker, Inc.

Zhang, X., Mao, X. and Abourizk, S., 2009. Developing a knowledge management system for improved value engineering practices in the construction industry. *Automation in Construction,* 18(6), pp.777-789

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TYPOLOGIES OF OFFSITE CONSTRUCTION

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ABSTRACT

In the 21st century, where smart and modern technologies are developed at an expeditious rate, construction industry has survived over centuries, despite its slow rate of technology adaptations, poor productivity, lower sustainability and vastly reported skill shortage. Technological advancement is the catalyst to solve these issues attaching extreme significance to transform the construction industry in line with industrialisation, digitalisation and globalisation. Sequential industrial revolutions have evolved to the present day's Fourth Industrial Revolution which is also known as Industry 4.0, under which offsite construction leads to the reduction of onsite labour intensity and shift the tasks to factory based manufacturing paradigms. Study on offsite construction revealed different types of offsite construction available in literature; none of which specified a logical method of offsite construction types development to suit the current technology advancements in the global construction arena. Available literature rather mention types of offsite construction based on examples and not the construction technology or combination of onsite to offsite work component. Therefore, this research was carried out to develop typologies of offsite construction using 10 available types of offsite construction. Literature was analysed using content analysis method through the NVivo 2012 (QSR) computer software. Findings revealed six typologies of offsite construction with incrementing portions of offsite construction in the order of; Components, Panels, Pods, Modules, Complete buildings and Flat pack. Therefore, this research contributes to knowledge by the development of typologies of offsite construction through a scientific approach while addressing the 21st century technology advancements available in the construction industry worldwide.

Keywords: *Offsite Construction; Technology Development; Typologies.*

1. INTRODUCTION

There is a large volume of published studies on Offsite Construction (OSC), which allows to gather a plethora of knowledge (Abanda, *et al*., 2017). OSC is manufacturing and assembly of building elements, components and modules within a factory to be transported onsite for installation (Arif and Egbu, 2010), which is visible in any construction project in varying degrees. There are different types of OSC such as pre-finished manufactured products (doors, windows, light fittings), panelised walls, pre-furnished modules and the like (Steinhardt and Manley, 2016). However, an arguable

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weakness in OSC research is the unavailability of a valid typology of OSC representing different mixes of onsite and offsite combinations. Therefore, this research aims to develop typologies of OSC by evaluating the available secondary sources of literature.

There are 5 objectives to be achieved for the whole study, "Developing a skill profile prediction model for typologies of offsite construction", out of which this paper indicates the realisation of the first objective by developing typologies of OSC. Developed typologies establish the different mixes of onsite and offsite construction combinations to be applied in the later stages of the research in achieving the remaining 4 objectives. They are *(a) to classify skill profiles required for typologies of offsite construction*; because substantial varieties of skills used in different typologies of OSC projects need to be classified to countable categories. Next objective is *(b) to develop a conceptual model that embeds the skill profile classifications and typologies of OSC.* The developed conceptual model is used *(c) to develop a detail model incorporating different types of buildings in various predominant materials such as concrete, timber and steel.* This objective is to be achieved using data simulation modelling technique, in order to predict the future skill requirements for different typologies of OSC. The final objective is *(d) to test, validate and develop a prototype system that helps the prediction of onsite and offsite skill requirements*.

2. LITERATURE REVIEW

2.1 WHAT IS OFFSITE CONSTRUCTION?

Traditional construction is the onsite erection of buildings with the involvement of cast in-situ reinforced concrete and delivery of materials to be used in a step by step onsite construction process opposed to the factory manufacturing and site assembly of buildings under OSC (Abanda, *et al*., 2017). Current state of OSC will be largely affected in the future due to industrialisation and the increasing shift of previously onsite construction activities to offsite factory-based prefabrication (Ginigaddara, *et al*., 2019). Hence onsite works will be minimal and only focussed on the assembly of buildings or building components performed by advanced self-directed work package gangs (Goulding, *et al*., 2014). In this regard, mix of onsite to offsite combination varies depending on the type of OSC carried out in the particular construction project. Similarly, depending on the type of OSC, requirement for skilled workers and professionals both onsite and offsite changes (Southern, 2016).

A typology is different to basic types as a type is a group of items with shared features while a typology is a systematic classification of types, analysed through a scientific notion (Jacoby, 2016). Hence, this research will develop the typologies of OSC, based on previously developed types of OSC in literature.

2.2 AVAILABLE TYPES OF OFFSITE CONSTRUCTION

There are many literature findings on different types of OSC based on the amount of onsite and offsite work carried out. These classifications establish severe resemblances as a result of the influence by literature of Gibb (2001). Next, different types of OSC identified by different authors worldwide is tabulated in Table 1 mentioning the definitions and examples. Evaluation of these categorisations will lead to the development of typologies of OSC in order to explore the current practice in the industry.

Table 1: Available types of offsite construction

Author	Types	Term/Definition	Examples
Gibb (2001); Gibb and Isack (2003)	Component manufacture and sub-assembly	Small scale sub-assembly of construction project components and the items which are never considered to produce onsite	Door furniture, light fittings, windows
	Non-volumetric pre-assembly	Factory assembled prior to final positioning. Encompasses a major structural part of the project yet do not create usable space	Wall panels, pipework assemblies, structural sections, cladding panels
	Volumetric pre-assembly	Makes a closed unit within an independent structural frame	Plant-room, toilet pods, lift shafts
	Modular/ complete building	Similar to volumetric units, yet it is the entire project with usable space. External finishes are done on site	Retail outlets, offices, prisons, multi-storey residential units
POSTnote (2003)	Panels	Panels with mechanical services	Ready-made walls, roofs and floors
	Modules	Ready-made 'pods' pieces are fixed together to compile the building	Bathrooms, kitchens
Blismas *et al*. (2009)	Non volumetric pre-assembly		Precast concrete items and pipes, timber and steel wall panels
	Volumetric pre-assembly		Wet room modules
	Modular building		Schools, homes and shelters
Kempton (2010)	Site-based methods	Onsite construction activities which are not classified under OSC	Thin joint blockwork, glulam timber
	Sub-assemblies and components	Building component manufacturing which are inadequate to be called direct OSC, yet comes under OSC	Floor cassettes, roof cassettes, pre-assembled mechanical services
	Hybrid	Combination of panelised and volumetric, serviced and repeatable units	Bathrooms
	Panellised construction	Flat panel units; open and closed.	
	Volumetric construction	Modular or pod construction with from basic shells to fully fitted units.	Bathrooms, kitchens
Boyd *et al.* (2013)	Off-site preassembly	Producing building components, materials, and equipment.	Trusses, staircases, precast elements,
	Hybrid systems	Pods which are fully prefabricated buildings with completed finishes.	
	Panelised system	The use of pre-manufactured structural framing systems.	Doors, windows, cladding, timber frames
	Modular buildings	Pods accompanying several rooms including finishes and services.	Complete houses, apartment blocks

Author	Types	Term/Definition	Examples
Lawson *et al*. (2014)	Manufactured components	10% - 15% OSC in value terms	Precast elements, cladding panels
	Elemental/ planar systems	15% - 25% OSC in value terms	Panels, steel/ timber frames
	Modular and mixed construction systems	30% - 50% OSC in value terms	Plant rooms, modular lifts and stairs, podium levels, bathroom pods
	Complete building systems	60% - 70% OSC in value terms	Fully modular buildings
Steinhardt and Manley (2016)	Significant assemblies	These do not encompass space	Wall panels
	Non-structural volumetric		Bathroom pods
	Structural volumetric	Complete houses or enclosed modules	
Goh and Loosemore (2016)	Traditional building	Construction carried out by hand based on various crafts or trades	Installation of prefabricated components
	Onsite prefabricaiton	Assembly of building components onsite into the specific position	Handmade roof trusses, framing, façade
	Offsite prefabrication	Offsite assembly of building components	Roof trusses, air conditioning units
	Pods	Pre-assembled units that enclose space	Toilets, bathrooms
	Complete modular	Highest level of industrialisation with fully finished unit	Complete structure
Abanda *et al*. (2017)	Panellised	Flat panels which are assembled onsite to obtain the 3D structure	
	Volumetric	3D units which enclose usable space, yet do not encompass the building structure. These are also known as non-structural volumetric spaces.	Bathroom pods, plant rooms, lift shafts
	Hybrid	Combination of both volumetric and panellised systems.	
	Modular systems	Pre-assembled volumetric units with an onsite work component	Hotel modules
	Components and sub-assembly systems	Factory produced items which are not considered under full systems; yet become parts of the structure.	
Nguyen *et al*. (2018)	Manufactured components	Site intensive construction	
	Linear or 2D manufactured assemblies	Popular in 1950's and 1960's	
	3D volumetric modules	Major parts of the buildings being factory made in 1960's and 1970's	

Author	Types	Term/Definition	Examples
	Complete building systems/ Modular	Modules that are completed up to 70% offsite from the end of 20th century	

3. RESEARCH METHOD

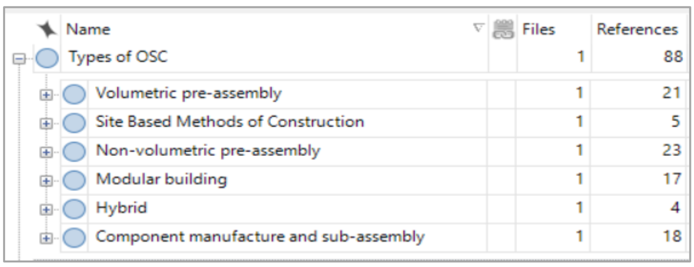
Previous studies on OSC types are based on the industry usage and past theoretical data. It is surprising that all these types are formed without an overarching classification. Furthermore, none of the identified types of OSC have given considerations for the labour component of each type of OSC. Additionally, only 01 out of the 10 considered types (Lawson, *et al*., 2014) indicated onsite and offsite combination in each type of OSC in value terms of a construction project. However, this also lacks the predominant measures in how the percentage terms of onsite and offsite combination was developed.

A systematic literature review was conducted to identify researches or reports which include types of OSC with definitions and examples. A variety of journal articles, books, conference proceedings, reports, theses, the world wide web and other resources were referred to explore and understand the existing knowledge on types of OSC. Composition of the literature sources indicated in Table 1 has a majority of journal articles (7) and each one of conference proceedings, books and reports. Literature was evaluated by identifying themes, patterns and biases through content analysis which contributes for the development of the typologies of OSC.

Categorisations which did not provide proper definitions were removed from the study with the aim of obtaining higher validity in the findings. A qualitative approach was employed to obtain a more meaningful categorisation of typologies of OSC using NVivo 2012 (QSR) computer software, similar to the work of Nadim and Goulding (2011). This approach was also given consideration to obtain valid inference from the collected data which is in "text" format (Goulding, *et al*., 2014). Therefore, a content analysis was conducted for the data collected on available types of OSC indicated in Table 1 as it allows to systematically review literature in order to identify common themes and patterns (Steinhardt and Manley, 2016).

4. FINDINGS AND DISCUSSION

Nodes were created based on available types of OSC as shown in Figure 1.



Name	Files	References
Types of OSC	1	88
Volumetric pre-assembly	1	21
Site Based Methods of Construction	1	5
Non-volumetric pre-assembly	1	23
Modular building	1	17
Hybrid	1	4
Component manufacture and sub-assembly	1	18

Figure 1: Nodes created for available types of offsite construction

Findings disclose that there are six major typologies of OSC which have various relative considerations according to the number of references. Out of the four references for hybrid construction, one example was given as "bathrooms" and the other three references signified the below definition.

> *"hybrid construction is combining panelised and volumetric offsite construction which is heavily used for repeatable units inclusive of panel technology"*

This definition seems to be incosistent simply due to the nature of the construction industry where combination of different materials, methods and processes (E.g.: labour and machine integration) is prominent. Hence the word "hybrid" can be substituted to any of the construction industry activities which makes it meaningless to be used as a typology of OSC. Arif and Egbu (2010) state that there is always possibility for adapting hybrid OSC which does not necessarily need to be a separate typology of OSC. Moreover, the less number of references for hybrid OSC in the collected data set also establishes the inappropriateness of using "hybrid" as a seperate typology. Hence it is confirmed that hybrid is not a typology of OSC and is rather a combination of two other types of OSC.

Site based construction identified in the content analysis refers to the "*traditional onsite activities which are not classified under OSC* (Kempton, 2010)". Provided definition is self-explanatory indicating that site based traditional construction is not a part of OSC and hence it proves to be incomparable with the typologies of OSC. On the contrary, it is observed that site based construction is evidenced in each typology of OSC in varying degrees depending on the amount of factory manufacturing and onsite construction occured. Therefore, it is confirmed that site based construction does not qualify to be considered as a typology of OSC and rather it is the opposite of OSC which is inevitable in any typology of OSC.

Additionally, almost all the materials which are used in construction processes such as bricks, blocks, steel, tiles, timber panels and the like are also either produced or treated in factory facilities. Similar to the exclusions made by Goodier and Gibb (2004) this material manufacturing procedure is excluded from typology development process in this research. Remaining major types of OSC are the same as what was initially introduced by Gibb (2001) almost 20 years before current technology advancements. There are different names provided for each of the types of OSC as shown in Figure 2.

Present findings seem to be consistent with industry practices especially relevant to the basic 02 types of OSC; i.e. (1) component manufacturing and sub-assembly and (2) non-volumetric pre-assembly. Sub-assembly of components refer to the breakdown of original assembly task to several smaller sub tasks while pre-assembly indicates the assembly of components offsite prior to transportation to the site (Gibb, 1999). Therefore, all OSC types are related to some proportion of both sub-assembly and pre-assembly activities which signifies the little use in including the terms in OSC typology. Hence, developed OSC typologies in this study do not incorporate the wordings "sub-assembly" and "pre-assembly" as it improves the logicality of the research.

4.1 COMPONENTS

Examples of component sub-assembly are doors, windows, ironmongery, and light fittings which are typically considered as non-structural building elements. Components are "*required in smaller scale, comprising up to 10 - 15% of project value, do not come under full systems yet becomes a part of the structure*". Furthermore, components require delivery, storage and skilled assembly onsite (Taylor, 2009), which "*involves a significant amount of onsite construction prior to the final usage*". Gibb and Isack (2003) also signify that none of these components are to be constructed onsite under any circumstances.

Evaluation of the terms used to refer components reveal that manufacturing and sub-assembly are common terms used to differentiate the types of OSC by various authors. However, manufacturing is the basis of OSC which is common to any typology. Likewise, sub-assembly involves the step by step installation of elements to the building structure either onsite or offsite. This leads to the redundancy of both terms; manufacturing and sub-assembly to provide a clear and a focussed meaning. Hence **Components** can be considered as the basic typology of OSC which involves the minimal percentage of offsite production and the highest percentage of onsite fixing and installation.

Name	Files	References
Other Terms	1	26
Component manufacture and sub-assembly	1	6
Components and sub-assembly systems	1	1
Manufactured components	1	2
Offsite pre-assembly	1	1
Sub-assemblies and components	1	1
Traditional building	1	1
Modular or complete building	1	5
Complete building systems	1	2
Complete modular	1	1
Modular systems	1	1
Structural volumetric spaces	1	1
Non-volumetric pre assembly	1	8
Elemental or planar systems	1	1
Linear or 2D manufactured assemblies	1	1
Offsite prefabrication	1	1
Panelised construction	1	2
Panelised system	1	1
Panels	1	1
Significant assemblies	1	1
Volumetric pre-assembly	1	7
3D volumetric modules	1	1
Modular and mixed construction systems	1	1
Modules	1	1
Non-structural volumetric spaces	1	1
Pods	1	1
Volumetric construction	1	2

Figure 2: Other terms used for types of offsite construction

4.2 PANELS

Panels are structural elements such as walls, roofs, floors accompanied by mechanical services. These account for 15 - 25% of a project value and yet, do not create usable space. Panels rather create an enclosed structure onsite followed by the assembly and erection. There are several types of panels or panelised assembly as classified by (NHBC, 2006) such as open panels, closed panels, concrete panels, composite panels, structural insulated panels, infill panels and curtain walling. Each of these panels exhibit different features causing for the typology to be dispersed over various items. There are several other terms (Figure) referring to panels, all of which provide a similarity to components. It creates confusion with components as they are also non-volumetric, elemental, mostly 2D and linear. Moreover, content analysis reveals that 04 out of 08 references (50%) used terms similar to panels to denote a type of OSC. Hence, the term; **Panels**, is dominant among the others and can be identified as the second typology of OSC.

4.3 PODS

Third and the most profound typology of OSC is pods which is the *manufacturing of 3D structures to develop an enclosed unit* that are detachable and self-contained. Some authors complicate the term with volumetric and modular which means the collection of 3D elements to construct a more complex structure. Volumetric means accompanying volume or space and it is common to any typologies of OSC beyond panels. In order to avoid confusion, the term volumetric is abandoned from the OSC typology development procedure. Also, modules refer to far more complex and unique structures which are not necessarily repetitive as pods. Hence both these terms; volumetric and modular are overridden by the term "pod" due to the repetitive production of enclosed spaces to suit a definite purpose.

In a simpler notion, Lawson, *et al*. (2014) refer pods *as 04 sided enclosed structures that account for 30 - 50% of a construction project in value terms*. Examples are bathroom pods, kitchen pods, prison pods and plant room units. Pods are to be installed onsite within or onto an independent structural frame (Gibb, 2001). Hence this typology of OSC requires a heavy portion of skills for transporting the pods, handling and installing them onsite and offsite manufacturing along with fully furnished interior and mechanical services (Taylor, 2009). Similar to the views of Gibb (2001), Abanda, *et al*. (2017) also suggest that pods are non-structural. Interestingly, none of the other authors who introduced types of OSC do not indicate a strong implication on the structural capacity of pods. This is due to the small space coverage by an enclosed pod out of the entire building area. Based on the findings, it is confirmed that **Pods** are the third typology of OSC which is a non-structural, volumetric section of the building.

4.4 MODULES

Next level of advancement in typology of OSC is modules, which is also defined as the composition of the whole building in different modules. A module is a ready to use building element as it is manufactured offsite including complete fixtures and fittings (Pan, *et al*., 2008). Modules provide structural strength to the building and *up to 60 - 70% of construction project value happens offsite* (Lawson, *et al*., 2014). Conversely, a recent report by Prefab Logic (2019) on module construction in USA, shows how 90 - 95% of the building is completed within a factory including service installations. Similarly, modules shift 90% of project activities to factories (Johansson and Meiling, 2009).

Modules are not complete buildings and rather account for a portion of a complex structure. Entire usable space of the building is manufactured offsite as several different modules including internal finishes and mechanical services to be transported onsite, erected and complete external finishes (Gibb, 2001). This onsite assembly and erection only leads to the realisation of whole building which is why modular cannot be referred to as complete buildings. Retail outlets, office blocks, school buildings, multi storey residential units and apartment blocks are the examples of modular buildings, of which skills requirement for onsite assembly is limited to a 05 carpenter's group (Johansson and Meiling, 2009). Hence **Modules** are the fourth typology of OSC which encompasses the structure of the building.

4.5 COMPLETE BUILDINGS

This is the extension of modular buildings to the next level of OSC, where the entire building is manufactured offsite as a single unit and then transported onsite to be installed and connected to the foundation. One critical aspect of complete buildings in OSC is logistics management as the building itself is to be transported to the site location, which involves not only site access but also route access inspection. All the considered literature on types of OSC included complete buildings within modules which does not differentiate the two. Therefore, **Complete buildings** are another typology of OSC which involves a significant amount of offsite skills and an extremely minimal amount of onsite skills due to the overall completion of the building within a factory facility.

4.6 FLAT PACK

Interestingly, none of the authors who took part in defining types of OSC (Table 1) included flat pack manufacturing to consideration even though it has been in the industry for more than a decade. Many authors have identified flat-pack to be available in the OSC industry; as a complete building manufacturing and assembly method (Goodier and Gibb, 2004), as an example of bathroom and kitchen manufacturing in UK (Pan, *et al*., 2008), as a mode of floor manufacturing using timber (Lawson, *et al*., 2014), and a popular OSC mode in Australia (Boyd, *et al*., 2013).

Current industry practice reveals more advanced uses of flat pack OSC, where even the onsite assembly is less prevalent. A Swedish construction firm (Skanska) in collaboration with famous IKEA furniture manufacturers, apply flat pack technique for OSC, leading to minimal onsite work by using standard parts and reducing project construction time to half (The Economist, 2017). Furthermore, a USA based OSC firm (MADI) manufacture the complete building indoors within the factory, fix the floor, wall and roof panels to each other using hinges, fold all components to be a single pack and simply unfold the building after cautious transportation to site (MADI, 2019). This allows easier transportation for the entire building which is not visible in other complex typologies of OSC. **Flat pack** is the final typology of OSC where onsite skills requirement becomes insignificant.

5. CONCLUSIONS

The research aimed to develop typologies of OSC, that resemble the current advanced technology involvement in the construction industry which also reduces the traditional onsite skills usage. Typologies are of six number; **components, panels, pods, modules, complete building and flat pack**. These were developed after rigorous scrutiny of literature on both available types of OSC and latest industry practices. Therefore, the developed typologies of OSC is the most updated and reliable version of OSC which indicates different combinations of onsite and offsite mixes. Furthermore, MMC categories introduced by (MMC Working Group, 2019) also incorporates similar typologies with different terminologies which justifies the development process.

Findings of this study suggest that, OSC has evolved through the years from the initial four types to more progressions. The paper has highlighted the usage of complex technology by the industry practitioners in order to meet the absolute targets of offsite constructed structures. Therefore, the current findings add to a growing body of literature on typologies of OSC which is a significant component of industrialisation. It contributes to the field of OSC by introducing a logical approach to identify typologies of OSC. However, these findings are limited by the use of secondary data from literature sources. Therefore, it is recommended that further research to be undertaken by collecting data from primary sources which will also be a validation of the current study.

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7. REFERENCES

Abanda, F. H., Tah, J. H. M. and Cheung, F. K. T., 2017. BIM in Offsite Manufacturing for Buildings. *Journal of Building Engineering,* 14, pp.89 - 102.

Arif, M. and Egbu, C., 2010. Making a Case for Offsite Construction in China. *Engineering, Construction and Architectural Management,* 17(6), pp.536 - 548.

Blismas, N., Arif, M. and Wakefield, R., 2009. Drivers, Constraints and the Future of Offsite Manufacture in Australia. *Construction Innovation,* 9(1), pp.72 - 83.

Boyd, N., Khalfan, N. M. A. and Masqood, T., 2013. Off-site Construction of Apartment Buildings. *Journal of Architectural Buildings,* 19(1), pp.51-57.

Gibb, 1999. *Off-site Fabrication: Prefabrication, Pre-assembly and Modularisation.* New York Toronto: John Wiley and Sons.

Gibb, 2001. Standardization and Pre-assembly - Distinguishing Myth from Reality using Case Study Research. *Construction Management and Economics,* 19(3), pp.307 - 315.

Gibb and Isack, 2003. Re-engineering through Pre-assembly: Client Expectations and Drivers. *Building Research and Information,* 31(2), pp.146-160.

Ginigaddara, B., Perera, S., Feng, Y. and Rahnamayiezekavat, P., 2019. *Skills Required for Offsite Construction.* Hong Kong, CIB World Building Congress.

Goh, E. and Loosemore, M., 2016. The Impacts of Industrialization on Construction Subcontractors: A Resource Based View. *Construction Management and Economics,* 35(5), pp.288-304.

Goodier and Gibb, 2004. *The Value of the UK Market for Offsite,* Buildoffsite.

Goulding, Rahimian, P., Arif, M. and Sharp, M. D., 2014. New Offsite Production and Business Models in Construction: Priorities for the Future Research Agenda. *Architectural Engineering and Design Management,* 11(3), pp.163-184.

Jacoby, S., 2016. Type versus Typology Introduction. *The Journal of Architecture,* 20(6), pp.931-937.

Johansson, H. and Meiling, J. H., 2009. Defects in Offsite Construction: Timber Module Prefabrication. *Construction Management and Economics,* 27(7), pp.667-681.

Kempton, J., 2010. Modern Methods of Construction and RSL Asset Management: A Quantitative Study. *Structural Survey,* 28(2), pp. 121 - 131.

Lawson, M., Ogden, R. and Goodier, C., 2014. *Design in Modular Construction.* CRC Press.

MADI, 2019. *MADI Home.* [Online] Available at: https://www.madihome.com/ [Accessed 12 February 2019].

MMC Working Group, 2019. *Ministry of Housing, Communities and Local Government.* [Online] Available at: https://www.gov.uk/government/publications/modern-methods-of-construction-working-group-developing-a-definition-framework [Accessed 22 July 2019].

Nadim, W. and Goulding, J. S., 2011. Offsite Production: A Model for Building Down Barriers. *Engineering, Construction and Architectural Management,* 18(1), pp.82-101.

Nguyen, Q. C., Perera, S. and Jin, X., 2018. *The Status of Offsite Construction in Vietnam.* Singapore, Curtin University.

NHBC, 2006. *A Guide to Modern Methods of Construction,* United Kingdom: BRE Press.

Pan, W., Gibb, A. G. F. and Dainty, A. R. J., 2008. Leading UK Housebuilders' Utilization of Offsite Construction Methods. *Building Research and Information,* 36(1), pp.56-67.

Pan, W., Gibb, A. G. F. and Sellars, A. B., 2008. Maintenance Cost Implications of Utilizing Bathroom Modules Manufactured Offsite. *Construction Management and Economics,* 26(10), pp.1067-1077.

POSTnote, 2003. *Modern Methods of House Building,* London: Parliamentary Office of Science and Technology.

Prefab Logic, 2019. *Modular Myth busting: 5 Facts about Manufactured Construction,* Idaho: Prefab Logic.

Southern, J., 2016. *Smart Construction - How Offsite Manufacturing can Transform our Industry*: KPMG International.

Steinhardt, D. A. and Manley, K., 2016. Adoption of Prefabricated Housing - The Role of Country Context. *Sustainable Cities and Society,* 22, pp.126-135.

Taylor, 2009. *Offsite Production in the UK Construction Industry: A Brief Overview,* HSE.

The Economist, 2017. *Efficiency Eludes the Construction Industry.* [Online] Available at: https://www.economist.com/business/2017/08/17/efficiency-eludes-the-construction-industry [Accessed 12 February 2019].

Tennakoon, T.M.M.P. and Kulatunga, U., 2019. Understanding liveability: Related concepts and definitions. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 578-587. DOI: doi.org/10.31705/WCS.2019.57. Available at: https://2019.ciobwcs.com/papers

UNDERSTANDING LIVEABILITY: RELATED CONCEPTS AND DEFINITIONS

T.M.M.P. Tennakoon[1] and U. Kulatunga[2]

ABSTRACT

The rapid unplanned urbanization of metropolitan areas has manifested number of challenges in terms of infrastructure, energy consumption, health care, waste management and resilience. Thus, forming "liveable" city for its citizens is an aspiration of the policy makers, designers and city planners. Yet, a detailed exploration of the concepts of liveability and liveability indicators has not been carried out. Thus, to this end, this paper advocates to define liveability and related concepts. For that an exhaustive literature synthesis has been conducted which simultaneously follows two different paths to define liveability. Firstly, it has reflected number of direct definitions from indexed literature related to liveability and contrasting the definitions of associate fragments of accustomed concepts such as sustainability and urbanization misapprehended as liveability. Secondly, a definition for liveability was derived through considering the liveability indicators of different liveability indexes According to the indicators, liveability represents social and economic approach. Yet, the concepts of sustainability was based on social, economic and environmental aspects when discussed along with liveability. Hence, Liveability is the balanced and favourable living conditions within a geographical area and liveable cities are such centralized communities with comparatively high population to the rest of the region. The policy making, planning, and political authorities need to ensure the balance of the habitats by defining liveability to reflect the social, economic aspects emerged through the existing indicators and the environmental focus of sustainability concepts.

***Keywords**: Liveability; Liveable City; Liveability Index; Urbanisation.*

1. INTRODUCTION

As an integral part of urbanization, cities have a main role in providing social and economic wellbeing to its inhabitants (Mori and Christodoulou, 2012). As a result of this, cities have become centres of consumption of energy and material, greenhouse gas production, generation of waste and pollutants of water and air. The ecological footprints of cities have extended far beyond the physical boundaries of cities due to the emissions, consumptions and human activities resulting in negative impacts on the surrounding rural, regional and global ecosystem. Furthermore, cities are associated with uncontrolled and unplanned development, waste management, traffic congestion, crime and complicated access to resources (Peris-Ortiz *et al*., 2017).

This brings out the urgent need of rethinking our approaches to design, construct and operate the cities in order to make them 'liveable' to its inhabitants. Thus, policy programs, business initiatives and political strategies have been designed to increase the

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livability of cities (Kaal, 2011). Liveability has been characterized as "a discursive frame that both enables and legitimates entrepreneurial policy initiatives" (McCann, 2004) and as a discourse which enables the individuals to take decisions regarding their consumptions despite the overall responsibilities and ethical usage (Hankins and Powers, 2009). With the emergence of the concepts of liveability over the recent past becoming more than a conceptual objective of policy making, political propagandas but a method of reflecting the quality of the urban lifestyle (Uitermark, 2009). Liveability is used in number of contexts including in the field of planning, community development, transportation and resilience. Greenwood (2008) emphasized that the ideologies of liveability enhanced competitiveness in the economy, provision of more transportation choices, and promotion of reasonable and affordable housing, value communities and neighborhoods and coordinate and influence policies and investment.

This paper is focused on defining liveability and liveable cities by exploring the existing literature on parallel and divergent contexts such as urbanization and sustainability. The liveability indexes that are used in different countries, cities and environments is discussed throughout paper.

2. PROCESS OF SYSTEMATIC LITERATURE REVIEW

The systematic procedure to identify, select and critically evaluate a clearly formulated question through literature, is known as a systematic literature review. Hence, an evidence based set of items were selected through the process known as Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) for the critical identification and selection of the related literature. According to that 376 items were selected through database searches using the key words; "liveability/livability", "liveable cit*/ livable cit*" and "liveability ind*/livability ind*". There were 313 records once the duplications were removed and 178 records were screened after reading of the abstracts. Lastly, 9 indexed journal articles were eligible after the full text review to define liveability. In order to define liveability, firstly, the concept was clarified by reviewing already defined concepts such as sustainability and urbanization. Secondly, unalike definitions of liveability in various context were considered to derive key components of liveability to apprehend the concept better.

3. UNDERSTANDING LIVEABILITY

Due to the novelty of the concept of liveability, exact definition of the concept is challenging to pinpoint. Therefore, this paper attempts to compare and contrast few concepts within which the word liveability is mentioned, to apprehend liveability.

3.1 LIVEABILITY VS SUSTAINABILITY

In order to best define the concept of liveability, it is apt to be contrasted against a related prevalent notion: sustainability. Sustainability is a vague concept, which is comparatively hard to comprehend by people and practically challenging to instrument at small scale as it is conceptualized in global scale to fortify the well-being of the next generations (Chazal, 2010). The principles such as use of renewable energy reduce the carbon footprint, reduced emissions within the environmental adjustment capacities and recycling are available for sustainability (Innes and Buhuor, 2000; Sanford, 2013), but then the extent to which they should be executed is not defined firmly. Thus, the long-term approaches to achieve sustainability is subjective and convenient. In contrast, liveability has more immediate concerns which are localized compared to the long term and globalized perspective (Evans, 2002). The tree pillars of social, economic and environmental sustainability are addressed in health, economic, cultural and environmental concepts of liveability (Bijl, 2011). Thus, the two concepts are focused on the social well-being, yet with a different scope. The policy makers, local authorities, investors, designers are more conscious in developing liveable communities than sustainable communities since liveability is more tangible, immediate and attainable.

Nonetheless, there are co- benefits of planning sustainable and liveable cities and complementary for environment, urban planning, and public health sectors. In order to maximally, fructify the benefits of sustainability concepts to the liveability, an effective collaboration of the public and private sector and a consistent polices for urban development need to be attained (Rayner and Howlett, 2009; Holden, 2012). Thus, the common notion emerged comparing the characteristics of sustainability through its definition provides that despite the differences in the scope in terms of time and boundaries, the goal is the well- being of the society.

3.2 LIVEABILITY VS. URBANISATION

The word liveability generally associated with urbanization since well-developed infrastructure, increased opportunities in the society for publicly available healthcare, jobs of diverse disciplines denotes liveable surroundings. However, it is questionable if liveability is limited to the characteristics of an urbanized environment. Urbanization has been defined as a superficial growth in the environment in response to, increased human activities in social, political and economic grounds over the encompassing physical boundaries of communities (Sudhira *et al*., 2007; Ramachandra *et al*., 2014). Currently, there are 34 cities which have a population over 10 million (UNDESA, World Urbanisation Prospects, 2011). Out of the world's population, 54% lives in cities or similar urban areas as reported in 2014. However, from 2050, world population living in urban areas will be increased by 3 billion (UNDESA, 2011). According to Figure 1, the urban population is at the highest level in less developed regions. It can be assumed that the rapid urbanization in developing region is due to the positivity of the opportunities that are available in cities.

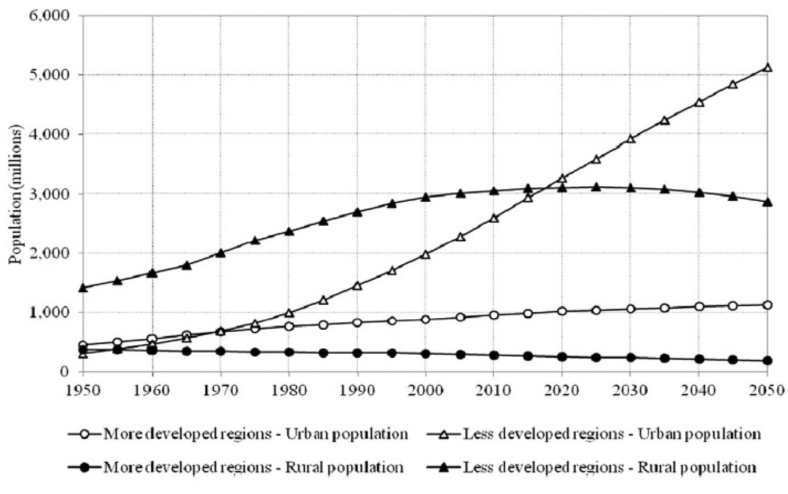

Figure 1: The growth of population in the world over 100 years of time (Source: Adapted from United Nations Department of Economic and Social Affairs, 2015).

Thus, it is unfair to interpret that liveability is represented through the urbanisation because the physical infrastructure of a city is not the mere factor that attracts people. Therefore, there is a requirement to distinguish the key characteristics of liveability to accommodate a planned and controlled urbanisation. In Section 3.3 direct definitions of liveability has been listed down to identify how the defining has been done to different contexts.

3.3 LIVEABILITY AS DEFINED IN OTHER LITERATURE

The three definitions considered in Table 1 has been developed for three different purpose. The first definition provides a scope to implement a series of policies to improve the living conditions of aged population in United State of America. The second definition is provided by the local authorities in Australia to benchmark developing cities against the developed cities. The third definition is a scientific definition quoted from an indexed journal.

Table 1: Definitions for liveable cities in different contexts

Definition	Keywords
"A liveable community is one that is safe and secure, has affordable and appropriate housing and transportation options, and offers supportive community features and services" (AARP, 2011).	safe and secure, housing, age in place, personal independence
"…the degree to which a place supports quality of life, health and wellbeing…. broad terms, liveable cities are healthy, safe, harmonious, attractive and affordable. They have high amenity, provide good accessibility and are environmentally sustainable..." (Australian Cities Report, 2013; Major Cities Unit, 2013, pp. 139)	quality of life, safe harmonious, high amenity, environmentally sustainable
"…liveable and healthy neighbourhood is one that is safe, attractive, socially cohesive and inclusive, and environmentally sustainable; with affordable and diverse housing linked by convenient public transport, walking and cycling infrastructure to employment, education, public open space, local shops, health and community services, and leisure and cultural opportunities" (Lowe, Chirombo, and Tompkins, 2013)	safe, environmentally sustainable public transport housing cultural opportunities

The most evident fact from the above three definitions is that liveability is quality of life. Yet, it is subjective to the habitats within the entity. The elements such as housing, safe and security, environmental sustainability are commonly available in the latter two definitions. The gravity on supportiveness of the community features are high in the first definition since it has been defined for aged people. Form that it is confirmed that the liveability requires to be defined based on the special needs of the habitants and the fulfilment of those needs will make the liveability increased in the perception of the habitants.

3.4 LIVEABILITY COMPREHENDED THROUGH LIVEABILITY INDICES AND INDICATORS

3.4.1 Liveability Indexes

The methodical constant identification, learning and implementation of the best practises and ways to improve cities through learning through other cities, is considered as city benchmarking (Badland *et al*., 2014). The liveability indicators are used for city bench marking (Herrman and Lewis, 2015). The liveability indexes consist of liveable indicators shortlisted, used, and updated over a period, which provide a basis to apprehend liveability (Lin *et al*., 2009). The Global Power City Index (The Mori Memorial Foundation, 2011), EIU Liveability Index (Economic Intelligence Unit, 2011) and the Quality of Living Index (Mercer, 2011) are some of the globally recognised liveability indexes. Consequently, the selection of the indicators of liveability is based on the purpose, the indexes are designed for. For an instance Economist Intelligent Unit's Liveability Index is focused to benchmark cities to reflect their suitability for investments. Alternatively, the Quality of Living Index by Mercer focus the liveability to the foreign employees. The Global Power City Index is focused on comparing liveability of different regions and influence policy development. Hence, the urban liveability is defined according to the context that is being under study.

3.4.2 Liveability Indicators

In the process of apprehending the concept of liveability, the indicators from various indexes are identified in Table 2. In order to improve the reliability of each indicator number of literature sources such as reports, World Bank Records, journal papers and web articles have been cross-examined.

Table 2: Liveability indicators

Liveability Indicator	Mentioned sources
Stability	
Occurrence of trivial crime	Evans (2002); Mitchell (2005); Van, *et al*. (2010); Jalaladdini and Oktay (2012); Miller *et al*. (2013); Sanford (2013); EIU (2018)
Occurrence of violent crime	Jalaladdini and Oktay (2012); Sanford (2013); EIU (2018)
Risk of terrorism	McCann (2004); Mitchell (2005); Timmer and Saymoar (2005); EIU (2018)
Risk of political conflict	Capon (2007); Perogordo (2007); Gleeson *et al*. (2010); EIU (2018)
Risk of civil unrest	Forum for the Future (2010); Pierson, *et al*. (2010); EIU (2018)
Healthcare	
Accessibility to private health facilities	Van, *et al*. (2010); Zhao (2010); AARP (2011); Centers for Disease Control and Prevention (2011); Dempsey *et al*. (2012); EIU (2018)
Standard of private health facilities	Centers for Disease Control and Prevention (2011); Dempsey *et al*. (2012); Holden (2012); EIU (2018)
Accessibility to public health facilities	Van, *et al*. (2010); Zhao (2010); The Population Division: DESA - United Nations (2014); Abdelbaset and Mahmoud (2015); EIU (2018)
Standard of public health facilities	Connecticut's Legislative Commission on Aging (2014); EIU (2018)

Liveability Indicator	Mentioned sources
Accessibility of over- the-counter drugs	Centers for Disease Control and Prevention (2011); Dempsey *et al*. (2012); EIU (2018)
Common health indicators	Capon (2007); EIU (2018)
Culture & Environment	
Humidity/temperature rating	Evans (2002); McCann (2004); Mitchell (2005); Timmer and Saymoar (2005); Sanford (2013); The Population Division: DESA - United Nations (2014); EIU (2018)
Uneasiness of climate to tourists	Perogordo (2007); Holden (2012); Jalaladdini and Oktay (2012); Miller *et al*. (2013); Sanford (2013); Abdelbaset and Mahmoud (2015); EIU (2018)
Cultural accessibility	Li *et al*. (2009); Forum for the Future (2010); EIU (2018)
Level of suppression	Zhao (2010); AARP (2011); Centers for Disease Control and Prevention (2011); Jalaladdini and Oktay (2012); Sanford (2013); EIU (2018)
Presence of corruption	Dempsey *et al*. (2012); Miller *et al*. (2013); Sanford (2013); EIU (2018)
Food and Beverages	AARP (2011); Centers for Disease Control and Prevention (2011)
Sporting accessibility	Sanford (2013); Connecticut's Legislative Commission on Aging (2014)
Availability of consumer goods and services	Van, *et al*. (2010); Zhao (2010); AARP (2011); Holden (2012); EIU (2018)
Social and religious restrictions	Elysia (2008); Zhao (2010); Sanford (2013); Connecticut's Legislative Commission on Aging (2014)
Education	
Accessibility of private education	Zhao (2010); AARP (2011); Centers for Disease Control and Prevention (2011); Holden (2012); Miller *et al*. (2013); Sanford (2013); EIU (2018)
Standard of private education	Holden (2012); Jalaladdini and Oktay (2012); The Population Division: DESA - United Nations (2014); Abdelbaset and Mahmoud (2015); EIU (2018)
Public education indicators	Abdelbaset and Mahmoud (2015); Capitanio (2017); EIU (2018)
Infrastructure	
Standard of road network	Zhao (2010); AARP (2011); Centers for Disease Control and Prevention (2011); EIU (2018)
Standard of public transport	Van *et al*. (2010); Zhao (2010); Dempsey *et al*. (2012); Holden (2012); Miller *et al*. (2013); Sanford (2013); EIU (2018)
Accessibility to quality housing	Abdelbaset and Mahmoud (2015); Kashef (2016); Capitanio (2017); EIU (2018)
Standard of energy provision	Dempsey *et al*. (2012); Holden (2012); Jalaladdini and Oktay (2012); Miller *et al*. (2013); Sanford (2013); EIU (2018)
Standard of water provision	Holden (2012); Miller *et al*. (2013); The Population Division: DESA - United Nations (2014); Abdelbaset and Mahmoud (2015); EIU (2018)
Standard of telecommunications	Li *et al*. (2009); Forum for the Future (2010); Gleeson *et al*. (2010); Pierson, *et al*. (2010); Kashef (2016); EIU (2018)

The stability, healthcare, culture, environment, education and infrastructure are the key determinants of liveability. The scores obtained for the liveability indicators determines the level of liveability of cities. The score for occurrence of trivial and violent crimes, risk of terrorism, risk of political conflicts and the risk of civil unrest require to be at a minimum to a city to be more liveable. The accessibility to private health facilities, standard of private health facilities, accessibility to public health facilities, standard of public health facilities are key indicators of liveability in terms of healthcare while cultural accessibility, level of suppression defines the liveability in terms of culture. Among the identified indicators the accessibility to quality housing has been mentioned in the majority of the literature sources considered.

4. DISCUSSION: CONCEPT OF LIVEABILITY

Since the aim of this research paper is to understand the concept of liveability, based on the limited indicators listed above can be utilized to clarify the notions of liveability. Figure 2 has been developed based on the different notions emerged during the process of apprehending the concept of liveability.

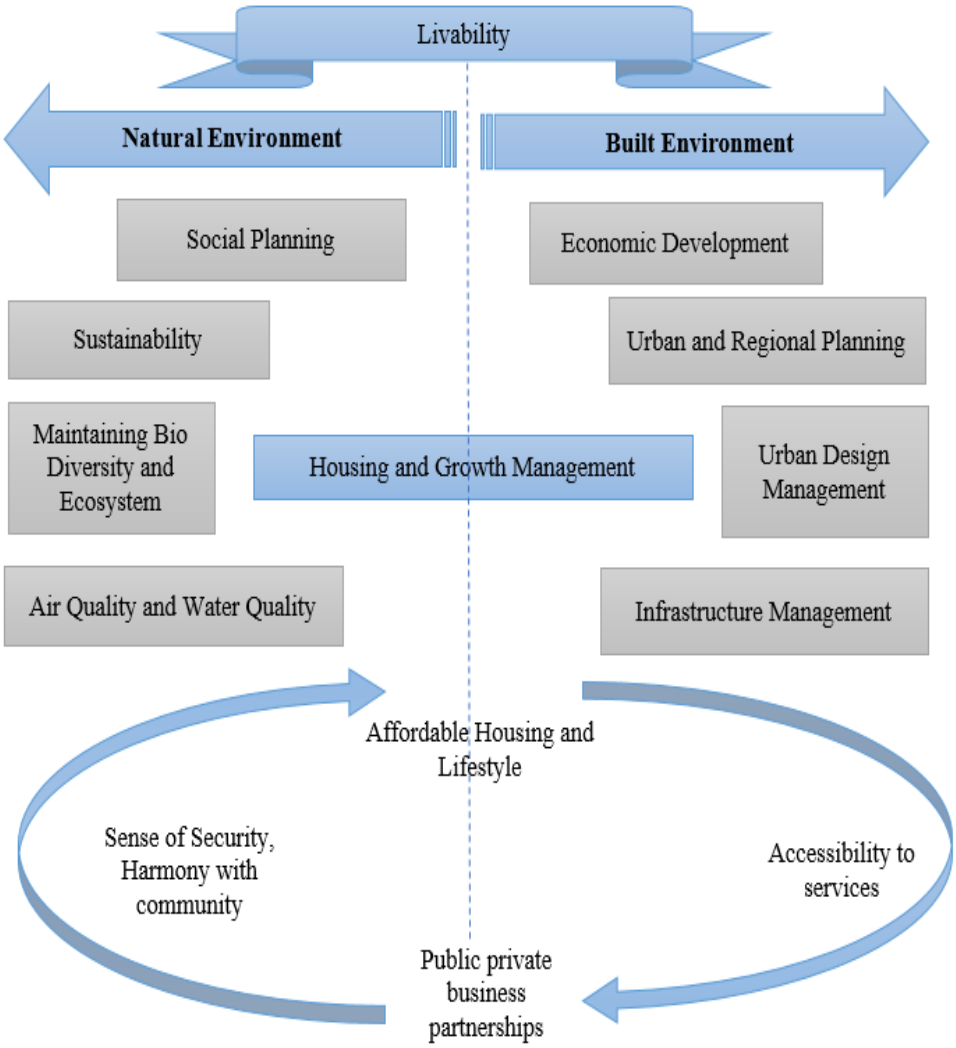

Figure 2: Concept of liveability explained

Nonetheless, developed through the concepts of sustainability, urbanization or resilience, the concept of liveability was broadly identified under the liveability related to natural environment and built environment. The sustainability views highlighted the importance of considering the liveability within the natural environment as a short term approach, to maintain the ecological sustainability in the long term. Alternatively, the concepts on urbanization stressed upon the liveability in the built environment as a key constituent which needed to be addressed along with the urban sprawl. Hence, liveability is the balanced and favourable living conditions within a geographical area and liveable cities are such centralized communities with comparatively high population to the rest of the region.

Yet, the concepts of sustainability was based on social, economic and environmental aspects when discussed along with liveability. It can be argued that exceling environmental sustainability is not directly beneficial a city if it has not robustly achieved the economic and social benchmarks. Further, the indexes that has been developed with commercial intentions has not stressed out the importance of indicators related to environment. However, when considered in the long- run, the responsibility lies with the policy making, planning, and political authorities to ensure the balance of the habitats by defining liveability to reflect the social, economic aspects emerged through the existing indicators and the environmental focus of sustainability concepts.

5. CONCLUSIONS AND RECOMMENDATIONS

This research highlights the concept of liveability, which includes number of elements, discusses the association among the individuals and the environment that offers a habitation. Despite the fact that, definitions of liveability varied according to the context it is used, the notions such as safety and stability, quality of life, amenities, public transport, infrastructure were emerged in most of the definitions. Some of these indicators are tangible such as amenities and infrastructure while safety, quality of life and alike are intangible. The concepts of sustainability and urbanization are often confused with the concepts of liveability. Nevertheless, the literature provided that liveability is a subset of concepts of sustainability but is defined in the point of view of the individuals. The definition of liveability in the light of urbanisation provides that the cause of urbanisation is not the positive liveability of those cities yet the needs of the public. It was confirmed through the second approach to define liveability. That is through various liveability indicators that are established by different authorities and organisations. These liveability indicators which are measured in region wise or country wise, materialised the concepts of liveability such as stability, environment, culture, economy, healthcare and built environment.

The finding through literature highlighted the importance of defining liveability to the applied context as it facilitates the policy makes to correctly bench mark the status quo of a city with top ranked indexed liveable cities in order to develop rules, regulations and to monitor that. Even the conditions that need to be fulfilled in the built environment will be realized through a better definition of liveability.

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7. REFERENCES

AARP, 2011. Aging in Place: A State Survey of Liveability Policies and Practices, *National Conference of State Legislatures, AARP Public Policy Institute,* Washington, DC, pp.1-2.

Abdelbaset, S.A. and Mahmoud M., 2015. *Livability of High-rise Districts, Case Study of West Bay in Doha.* (Master's Thesis). Department of Architecture and Urban Planning, AUP.

Badland, H., Whitzman, C., Lowe, M., Davern, M., Aye, L., Butterworth, I., Hes, D. and Giles-Corti, B., 2014. Urban Liveability: Emerging Lessons from Australia for Exploring the Potential for Indicators to measure the social determinants of health*, Social Science and Medicine,* 111, pp.64 -73.

Bijl, R., 2011. Never Waste a Good Crisis: Towards Social Sustainable Development, *Social Indicators Research,* 102(1), pp.157-168.

Capitanio, M., 2017. The Relativity of Liveability Rankings Examining the Japanese Case against the Global Discourse. *World Journal of Social Science*, 1(5), pp.12-18.

Capon, A., 2007. The Way We Live in our Cities*, Medical Journal of Australia*,187(11/12), pp.658-661.

Centers for Disease Control and Prevention. 2011. *Physical activity - Healthy Places*, pp.2-6.

Chazal, J. D., 2010. A Systems Approach to Livability and Sustainability: Defining Terms and Mapping Relationships to Link Desires with Ecological Opportunities and Constraints. *Systems Research and Behavioral Science,* 27(5), pp.585-597

Connecticut's Legislative Commission on Aging. 2014. *Connecticut for Livable Communities*, State Capitol.

Department of Infrastructure and Transport 2011. *Major Cities Unit*. Canberra: Department of Infrastructure and Transport.

Dempsey, N., Brown, C. and Bramley, G., 2012. The key to sustainable urban development in UK cities? The influence of density on social sustainability. *Progress in Planning*, *77*(3), pp.89-141.

EIU. 2018. *Liveability Report-Global Liveability Survey*, A report by The Economist Intelligence Unit. London.

Loewus, S.E., 2008. Downtown living: for families?: the Vancouver, BC urban livability experience and lessons for other cities (Doctoral dissertation, Massachusetts Institute of Technology).

Evans, P.B. ed., 2002. *Livable cities?: Urban struggles for livelihood and sustainability.* Univ of California Press.

Forum for the Future, 2010, *Sustainability and system change* [Online], Available from: https://www.forumforthefuture.org.

Gleeson, B., Dodson, J. and Spiller, M. 2010. *Metropolitan Economist Intelligence Unit (2012) A Summary of the Liveability Ranking and Overview*. London: Economist Intelligence Unit.

Greenwood, T. 2008. Bridging the divide between community indicators and government performance measurement, *National Civic Review*, 97(1), pp.55-59.

Hankins, K. B., and Powers, E. M., 2009. The Disappearance of the State from "Livable" Urban Spaces. *Antipode*, *41*(5), pp.845-866.

Herrman, T., and Lewis, R., 2015. *Research Initiative 2015-2017: Framing Livability - What is livability?*. University of Oregan.

Holden, M., 2012. Is integrated planning any more than the sum of its parts? Considerations for planning sustainable cities. *Journal of Planning Education and Research*, *32*(3), pp.305-318.

Innes, J. E. and Booher, D. E., 2000. Indicators for Sustainable Communities: a Strategy Building on Complexity Theory and Distributed Intelligence, *Planning Theory & Practice*, 1(2), pp.173-186.

Jalaladdini S,Oktay D. 2012. Urban Public Spaces and Vitality: A Socio-Spatial Analysis in the Streets of Cypriot Towns. *Social and Behavioural Sciences*, 35, pp.664-674.

Kaal, H. 2011. A Conceptual History of Livability. *City*, 15(5), pp.532-547.

Kashef, M., 2016. Urban livability across disciplinary and professional boundaries. *Frontiers of Architectural Research*, *5*(2), pp.239-253.

Li, F., Liu, X., Hu, D., Wang, R., Yang, W., Li, D. and Zhao, D., 2009. Measurement indicators and an evaluation approach for assessing urban sustainable development: A case study for China's Jining City. *Landscape and Urban Planning*, *90*(3-4), pp.134-142.

McCann, E. J. 2004. Quality of Life and Popular Media Discourse. *Urban Studies*, 41(10), pp.1909-1929.

Mercer. 2011. *Mercer's 19th Quality of Living Ranking* [Online], Available from: https://www.mercer.com/newsroom/2018-qualityof-living-survey.html.

Miller, L., Louise, M., Rexstad, A. and Thomas, L., 2013. Spatial Models for Distance Sampling Data: Recent Developments and Future Directions. *Methods in Ecology and Evolution*, pp.1001-1010.

Mitchell, D., 2005. The SUV model of citizenship: Floating bubbles, buffer zones, and the rise of the "purely atomic" individual. *Political Geography*, *24*(1), pp.77-100.

Mori, K., and Christodoulou, A. 2012. Review of Sustainability Indices and Indicators: Towards a new City Sustainability Index (CSI). *Environmental Impact Assessment Review*, 32(1), pp.94-106.

Peris-Ortiz, M., Bennett, D., and Yábar, D. 2017, *Sustainable Smart Cities: Creating Spaces for Technological, Social and Business Development*. Springer.

Pierson, B.J., Eberli, G.P., Al-Mehsin, K., Al-Menhali, S., Warrlich, G., Droste, H.J., Maurer, F., Whitworth, J. and Drysdale, D., 2010. Seismic stratigraphy and depositional history of the Upper Shu'aiba (Late Aptian) in the UAE and Oman. *Barremian–Aptian stratigraphy and hydrocarbon habitat of the eastern Arabian Plate. GeoArabia Special Publication*, *4*, pp.411-444.

Rayner, J. and Howlett, M., 2009. Introduction: Understanding integrated policy strategies and their evolution. *Policy and Society*, *28*(2), pp.99-109.

Ramachandra, T. V., Bharath, H.A. and Sowmyashree, M.V., 2014. Urban Footprint of Mumbai - The Commercial Capital of India. *Urban Regeneration*, 6(1), pp.71-94.

Sanford E., 2013. *What Is the Difference between Livability and Sustainability?* [Online]. Available from: http://www.camsys.com/kb_experts_livability.htm

Sudhira, H.S., Ramachandra, T.V., Jagadish, K.S., 2004. Urban Sprawl: Metrics, Dynamics and Modelling using GIS. *Journal of Applied Sciences*, 5, pp.29-39.

Timmer, V. and Seymoar, N.K., 2005, March. Vancouver Working Group Discussion Paper. In *The World Urban Forum 2006*.

Uitermark, J., 2009. In Memoriam for the Just City of Amsterdam. *City*, 13(2-3), pp.347-361.

UNDESA, 2011. *World Urbanization Prospects: the 2018 Revision*. New York: UNDESA.

Van A., Block T., Reynaert H. 2010. Can Community Indicators Live Up to Their Expectations? The Case of the Flemish City Monitor for Livable and Sustainable Urban Development, *Applied Research Quality Life,* 5, pp.341–352.

The Population Division: DESA - United Nations, 2014. *World Urbanization Prospects (ST/ESA/SER.A/352)* [Online]. Available from: https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf ISBN 978-92-1-151517-6

Zhao, P., 2010. Sustainable Urban Expansion and Transportation in a Growing Megacity: Consequences of Urban Sprawl for Mobility on the Urban finance of Beijing. *Habitat International*, 34(2), pp.236-243.

Palliyaguru, R., Nawarathna, A. and Jayalath, C., 2019. Untapped potentials of built environment professionals in national disaster resilience action plans in Sri Lanka. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 588-597. DOI: doi.org/10.31705/WCS.2019.58. Available at: https://2019.ciobwcs.com/papers

UNTAPPED POTENTIALS OF BUILT ENVIRONMENT PROFESSIONALS IN NATIONAL DISASTER RESILIENCE ACTION PLANS IN SRI LANKA

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ABSTRACT

Even though many governments have ambitious plans for speedy and effective post disaster recovery a less success rate has been recorded in many parts of the World including Sri Lanka. In light of this situation, a growing call has been evident for greater engagement of the construction industry in the global effort of disaster resilience. This research is therefore aimed at recognizing the specific role(s) of built environment professionals previously unidentified in disaster resilience action plans in Sri Lanka. The research commenced with a literature review including the Sendai Framework which was the first major agreement of the post-2015 sustainable development agenda. A detailed desk review involved mapping the currently defined roles of the public sector in disaster resilience building in the National Disaster Management Plan (NDPM) in Sri Lanka with the open-source guideline called "The Built Environment Professions in Disaster Risk Reduction and Response" co-authored by Lloyd- Jones et al. (2009) that defines 29 distinct roles of built environment professionals. This research reveals that the built environment professionals in Sri Lanka have been heavily unrecognized and underutilized in the cause of disaster resilience where only 10 roles have been earmarked.

Keywords: *Built-environment Professionals; Disaster Resilience Building; National Disaster Management Plan (NDPM); Sendai Framework.*

1. INTRODUCTION

Since the last two-three decades, there have been a growing recognition of the importance of the construction industry in disaster resilience building. As a matter of fact, the role of built environment professionals in building disaster resilience is highly recognised and reasonably well discussed in the existing academic research, national and local governmental publications, international intergovernmental organisation publications etc. (Haigh and Amaratunga, 2010; Maththews and Warren, 2010; Thurairajah, *et al*., 2011). Additionally, a critical need for incorporation of concerns of disaster resilience into the education of built environment professionals has been pointed out by many authors

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including Hecker *et al*. (2000), Godschalk (2003), Liso *et al*. (2003), Prieto (2004), Lorch (2005), Aldunate *et al*. (2006), Rees (2009), Haigh and Amaratunga (2010), and Bosher and Dainty (2011).

'Sendai Framework for Disaster Risk Reduction 2015-2030', as the underpinning source that defines the key pillars of "disaster resilience" recognizes that the State has the primary role to reduce disaster risk. More significantly, it recommends such responsibility be shared with other stakeholders including local government, the private sector and other stakeholders. The framework is aimed at minimizing disaster risks, loss of lives and other harmful effects of disasters on livelihoods, health, economic, physical, social, cultural and environmental aspects of communities over the coming 15 years (Amina and Virginia, 2015). As it addresses a diverse range of factors endangering masses, Sendai's focus on inclusive and participatory capacity building from local to global level is multi-dimensional. It essentially requires a diversity of stakeholders to mirror the debate centered on prevention vis-a-vis the built environment.

As far as the disaster resilience arena is concerned, Sri Lanka is presently served with a national legislation (Sri Lanka Disaster Management Act No. 13 of 2005), national policy on disaster management, institutional arrangements led by the Ministry of Disaster Management and Disaster Management Centre, a National Emergency Operation Plan and a National Disaster Management Plan. Even though the built environment professionals' roles in the resilience building are well recognized within the context of the built environment, it is not clear whether this is fully recognized in defining the public-sector roles in the above mentioned legislative and policy frameworks. Thus, it is worth investigating the extent to which the specific role(s) of built environment professionals piteously unidentified in disaster resilience legislative and policy frameworks in Sri Lanka, especially in the national action plan (National Disaster Management Plan 2013-2017), if any which is the aim of this study.

2. RESEARCH METHODOLOGY

In order to achieve the aim of this study, an in-depth literature review was conducted. Further to that, a desk review was made on the NDMP 2013-2017 to demystify the currently defined role of the public sector in resilience building across the four priority areas specified in the Sendai Framework 2015-2030 which is considered a global benchmark of disaster resilience building. The next step was to map the foregoing with the Lloyd-Jones's key roles defined for built environment professionals in the disaster management cycle in order to capture the areas untapped for built environment professionals in NDMP which ultimately advocates future potential for inclusion (See Table 1). Content analysis technique was used during this mapping exercise which adopted key functional attributes (themes) identified from Lloyd-Jones *et al*. (2009).

3. LITERATURE REVIEW

3.1 BUILDING DISASTER RESILIENCE

As defined in the voluntary, non-binding post-2015 agenda which is endorsed by the UN General Assembly, Sendai Framework for Disaster Risk Reduction 2015-2030, disaster resilience is '*the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure*' (UNISDR, 2015). Similarly, DFID (2011, p.6) defines it as '*the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses – such as earthquakes, drought or violent conflicts without compromising their long-term prospects*'.

It is widely agreed in the literature that disaster resilience is closely embedded in disaster risk management (DRM). However, on the other hand, authors are in the view that approaches and tools for disaster resilience encompass a wider perspective than DRM and it draws and brings together knowledge and practices from fields such as climate change adaptation, poverty reduction, state-building and conflict resolution (Combaz, 2014). Therefore, in the international agenda on disaster resilience, UN's Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015) is actively engaged in building resilience of nations and communities through incorporation of DRM, poverty reduction, climate change adaptation, good governance and sustainable development (UNISDR, 2015). It sets out four priority areas for disaster resilience action namely: understanding disaster risk; strengthening disaster risk governance to manage disaster risk; investing in disaster risk reduction for resilience and enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

3.2 Roles of Built Environment Professionals in Resilience Building as Defined in the Context of Built Environment

As stated by Lloyd- Jones *et al*. (2009) the built environment refers to human settlements, buildings and infrastructure such as transport, energy, and water distribution. The built environment professionals include the practitioners who are primarily concerned with design, construction, planning, procurement, management and technological aspects related to construction and maintenance of built environment structures. It has been now realised that the built environment sector and its professionals have a vital role in disaster resilience (Ofori, 2004; Haigh and Amaratunga, 2010). Built environment professionals have varying roles and related capacities in terms of skills, and knowledge in each stage of disaster management cycle (McEntire *et al*., 2002; Haigh and Amaratunga, 2010; Siriwardena *et al*., 2013). Therefore, this section identifies their roles in general, with their available capacities to perform those roles. Taking a broader view of disaster management cycle, the roles are categorised into three phases as pre-disaster, emergency relief and early recovery and post disaster and reconstruction phase.

3.2.1 Pre-Disaster Phase

The role of built environment professionals during the pre-disaster phase is mainly associated with mitigating and preventing disaster impacts on the built environment and preparing communities for disasters in advance. Planning, designing and constructing quality and durable structures which can adapt for various disasters, including natural (ecosystems and natural buffers) and man-made infrastructures (e.g. flood drainage) can limit or largely reduce the impact of disasters (Palliyaguru and Amaratunga, 2008). Early identification of critical infrastructures prone to impacts from natural hazards together with measures for their rehabilitation is also necessary for reduction of impact (Oh *et al*., 2010). Burby and Dalton (1994), Mileti (1999), and UNISDR (2010) highlight the criticality of better land use planning in this regard. Nevertheless, the significance of traditional line of actions in mitigating disaster impacts such as structural protection and functional building regulations and codes yet remain the same (Burby and Dalton, 1994; UNISDR, 2010).

3.2.2 Emergency Relief and Early Recovery Phase

This phase of the disaster management cycle is mostly represented by personnel from government and non-government organizations, but the role of the built environment professionals is also not to be overlooked as it may result in serious repercussions (Stringfellow, 2014). The substantial knowledge and technical expertise of the construction industry personnel are crucial in ensuring early recovery following disasters, especially by quickly reinstating and making important infrastructures operational such as water and sanitation, roads, electricity, telecommunication lines, bridges etc.; and providing temporary shelter (Malalgoda *et al*., 2010; Hindustan Construction Company, 2016).

3.2.3 Post Disaster and Reconstruction Phase

Major reconstruction and rehabilitation works in critical sectors such as housing, health, education, railway, water and sanitation, electricity etc. are carried out during this phase. This is a phase where the construction professionals are actively engaged in and thus considered the most important phase for the construction industry (Malalgoda *et al*., 2010). The skills, competencies, knowledge and professionalisms of the built environment professionals are crucial in the decision-making and implementation of works during this phase in order to build back better so as to eliminate the possibility of future impacts from disasters (Malalgoda *et al*., 2010), including assessing the magnitude of damage caused by disasters.

On the foregoing discussion, it was realised that the built environment professionals are competent in many major activities of disaster resilience. In addition to the above findings, Lloyd- Jones *et al*., (2009) reveal the key roles of built environment professionals into disaster management cycle in a detailed manner. Therefore, in order to achieve the aim this study, those key roles were mapped with the current and emerging roles for built environment professionals as identified in NDMP (see Table 1).

4. DESK STUDY FINDINGS

4.1 ROLE OF THE PUBLIC SECTOR IN RESILIENCE BUILDING AS DEFINED IN THE NATIONAL ACTION PLANS

Firstly, the desk study identified the roles of public sector (national and local level) in Sri Lanka for resilience building with reference to the Sri Lanka National Disaster Management Plan (NDMP) 2013-2017, which is the national action plan for disaster resilience in Sri Lanka published by the Disaster Management Centre (DMC). Given the expiration of the Plan, an upgraded version is pending review and approval at the Ministry of Disaster Management Sri Lanka. The roles described in the NDMP were identified and categorized under four priority themes stated in the Sendai Framework for Disaster Risk Reduction 2015-2030 as discussed in Sections 4.1.1, 4.1.2, 4.1.3 and 4.1.4. Sri Lanka being a signatory to the Sendai Framework, it was adopted as a benchmark to classify the public sector roles in a more meaningful manner, in order to overcome the problems associated with the numerous differences in the way the phrase ‘disaster resilience’ has been defined in the literature.

4.1.1 Understanding the Disaster Risk

Apprehending disaster risk in all its dimensions of hazard characteristics and vulnerability (which is composed of capabilities to prepare for and respond to the hazards; and exposure of persons/assets) warrants the government a key role. These include hazard zonation mapping with the aid of computer modelling (i.e. urban flood zonation, landslide hazard zonation, Tsunami zonation), collating geographic information via GIS system, vulnerability and risk assessment, maintaining and coordination of disaster related data bases such as Inventory of Past Disaster Impacts (DesInventar) and Sri Lanka Disaster Resource Network (SLDRN) and fostering a culture of research.

4.1.2 Strengthening Disaster Risk Governance

It is accepted that the overall responsibility in strengthening disaster risk governance for prevention, mitigation, preparedness, response, recovery and rehabilitation through collaboration within and across sectors and partnership with other relevant stakeholders falls on the government. In relation to that, governments have the administrative and legislative power to enforce regulations and policies on building disaster resilience. Accordingly, its role is to review, develop, implement and promote the national and local framework of laws, regulations and public policies as well as disaster risk reduction strategies and plans (UNISDR, 2015).

In view of the national and local level commitments mentioned in the Sendai framework, NDMP 2013-2017 of Sri Lanka identifies few key roles as the government major responsibilities in strengthening the risk governance, namely the development of national and sub national level disaster management plans and emergency operation plans, preparation and implementation of disaster mitigation strategies, provision of training, public awareness and education. This essentially requires proper coordination among all the agencies related to land use and development controls such as Urban Development Authority, as well as all target groups such as vulnerable communities, government officials, school and university students, armed forces etc.

4.1.3 Investing in Disaster Risk Reduction for Resilience

Investing in disaster risk reduction for resilience is another important role of government. Allocating funds, logistics and other resources as appropriate at all levels of government for the development and implementation of disaster risk reduction strategies, policies, plans, laws and regulations in all relevant sectors is vital. This is while strengthening the public private investments to implement disaster prevention and reduction measures in physical infrastructure such as schools, hospitals etc. UNISDR (2015) further mention that investments in health care system is of high significance in disaster risk management. Developing the capacity of health workers in understanding disaster risk, implementing effective disaster risk reduction approaches in health work, supporting and training community health groups in disaster risk reduction approaches, and enhancing the training capacities in the field of disaster medicine are some of the investment opportunities in health care sector (UNISDR, 2015). Risk transferring and financing, planning capacity building and more importantly the private sector engagement have been stressed in the term of ‘investment’ in disaster resilience.

4.1.4 Enhancing Disaster Preparedness for Effective Response and to Build Back Better

Government requires to be well ahead of a disaster through integration of disaster risk reduction in order to ensure that capacities are in place for effective response and recovery at all levels. Accordingly, they require to invest in, develop, maintain and strengthen people-centred multi-hazard, multi-sectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; promote the resilience of new and existing critical infrastructure including water, transportation, educational facilities and hospitals to ensure that people remain safe, effective and operational during and after disasters, raise the public awareness, and consider relocation of public facilities and infrastructure to areas outside the risk range (UNISDR, 2015). Moreover, Kapucu and Wart (2006) and Ainuddin and Routray (2012) mention that extensive training and awareness programmes, land use plans and national mandates which limit the development in hazardous areas and evacuation plans, zoning and building standards, emergency response plans, emergency communication plans and early warning systems, transportation networks and arrangements for life lines and critical infrastructure are few such plans and procedures that need to be prepared by the government.

Government as an intermediary with local, national and global connections it has a major role in coordinating various stakeholders to achieve success in decision making, attract finance and other resources, technology and good practices and raise awareness and education on disaster resilience (UNDP, 2004 and UNISDR, 2015). Maintaining Emergency Operation Centre in DMC has been identified as a key function of readiness via the application of technical skills in operating high-tech equipment in the emergency operation system. Further, it includes hazard forecasting, early warning and dissemination, coordination of disaster response at different levels, getting the stakeholder involvement in emergency response, recovery, rehabilitation and reconstruction as well as relief and temporary shelter management.

4.2 MAPPING THE ROLE OF THE BUILT ENVIRONMENT PROFESSIONALS WITH THE DEFINED PUBLIC SECTOR ROLES IN RESILIENCE BUILDING

Secondly, the desk study involved delineating the specific roles of the built environment professionals in disaster resilience with reference to Lloyd- Jones's (2009) and exploring whether they have been recognized in the NDMP, as mapped in Table 1.

Table 1: Lloyd- Jones vs public sector defined roles

Roles of Built Environmental Professionals (Source: Lloyd- Jones et al., 2009)	Whether Defined in Public Sector Resilience Building	Key Functional Attributes
Pre-Disaster Phase		
Assess hazards and disaster risks and evaluate vulnerability	Yes	Vulnerability assessment
Assess the stability and vulnerability of existing structures	Yes	Structural integrity

Roles of Built Environmental Professionals (Source: Lloyd- Jones et al., 2009)	Whether Defined in Public Sector Resilience Building	Key Functional Attributes
Advice on the cost and delivery of disaster preparedness measures	Yes	Cost effectiveness
Identify the risks associated with areas; advise on risk reduction; plan for quality development in the right locations	Yes	Disaster risk reduction
Identify, survey and procure safe land for building purposes	Yes	Site selection
Review, implement and advise on the right and correct new and revised building statues	No	Technical review
Provide advice on building use in the event of hazard	No	Evacuation
Design and implement new constructions and engineering that are disaster resilient	No	Construction methodologies
Advise on development cost and financing, planning and managing finance, valuation and cost planning	No	Best value for money
Conduct training and transfer knowledge on construction methods that are safe and sustainable	No	Knowledge transition
Develop emergency response plans to provide vital services (water, wastewater, transport, logistics, communications, power)	Yes	Contingency planning
Emergency Relief and Early Recovery Phase		
Identify usability of existing infrastructure	No	Usability
Estimate the demand for clean water and the locations it will be required	No	Efficient use of water
Evaluate local access issues and plan for transportation and storage/shelter for supplies, services and rescuers to the disaster area	No	Preliminaries/enabling works
Estimate the demand for relief shelter, including number, types and locations; consider medium/long-term issues associated with shelter locations and design and advise on procurement	Yes	Shelter management
Assess initial infrastructure recovery requirements, particularly access, energy, water and food storage.	No	Recovery assessment
Post Disaster and reconstruction phase		
Carry out building condition surveys, including assessment of key buildings and overall damage assessment	No	Damage assessment
Evaluate overall housing needs, establishing the scale and type of infrastructure, and housing and land required for transitional and permanent housing	No	Needs assessment
Review mapping and establish boundaries and provide estimates (if not already available) of land use,	Yes	Mapping and impact assessment

Roles of Built Environmental Professionals (Source: Lloyd- Jones et al., 2009)	Whether Defined in Public Sector Resilience Building	Key Functional Attributes
transport and access lines, waterbodies and the impact on them after the disaster		
Prepare financial compensation package and advise on selection of building materials, construction methods and technology that are part of the package	No	Compensation assessment
Carry out surveys of land and property ownership at the ground level and advise on land boundary and land administration issues etc.	No	Land surveying and advice
Advise on suitability of areas of temporary/ permanent new development	Yes	Location studies
Supervise the removal and clearing of sites, reclaim building material (householders may want to claim material from their individual homes)	No	Deconstruction and supervision
Resolve ownership issues in consultation with authorities and communities	No	Ownership assessment
Project management focusing on resources and cost of provision of transitional shelter	No	Resource management
Advise on building and infrastructure regulations	No	Technical scrutiny
Supervision and advice as the buildings are constructed	No	Site supervision
Provide training in research and risk assessment when designing transitional and permanent settlements; monitoring and compliance of regulations/policies	Yes	Research
Providing guidelines for operations and maintenance to ensure resilience	No	O&M guidance

It is important to recognize the discourse on shared responsibility in disaster resilience as a new social contract, as what exactly the Sendai's focus is and where the role of built environment professional is considered pivotal. From Table 1 it is apparent that one half of the contract is frustratingly missing in the discourse: the potential is untapped. Most of the technical functions have not been adequately earmarked. A need to include a professional-based discourse is therefore evident in contention over core management dilemmas such as the protection of citizen and property holders' rights, the legitimacy and accountability of government agencies and so forth. Without seriously undermining the legitimacy of the new disaster resilience social contract, it is imperative to revisit the NDMP and redefine the role of built environment professionals in the local agenda which is currently pending scrutiny at the Ministry level.

5. CONCLUSIONS AND THE WAY FORWARD

The national disaster resilience framework is deemed to be compatible with the priorities of Sendai Framework for Disaster risk reduction, 2015 to 2030 namely, understanding risks, strengthening activities involved in risk governance, investing in disaster risk reduction and enhancing disaster preparedness for effective response in line with the concept of Build Back Better. On the other hand, a growing recognition is that those accountable for the built environment have a pivotal role in disaster resilience. However, if these professionals are to be able to contribute to reduce risk through resilient efforts effectively, it is important that they are properly integrated into the overall disaster resilience framework. However, it is evident that their role has been overlooked in the national action plans in Sri Lanka for some reason. This articulates a need for taking a holistic approach in formulating national level actions plans, giving due consideration to the construction life cycle, key stakeholders, their potentials and the elements of resilience. Unfortunately, most of the technical potentials and functionalities of built environment professionals have not been adequately addressed in the NDMP. Accordingly, it is suggested that still there is scope for the potentials of professionals engaged in the built environment to be effectively exploited in the context of disaster resilience building. The conclusion is to clearly delineate the role of built environment professionals in the NDPM as a prerequisite for integrating the role of built environment professionals in disaster resilience.

6. REFERENCES

Ainuddin, S. and Routray, J.K., 2012. Community resilience framework for an earthquake prone area in Baluchistan. *International Journal of Disaster Risk Reduction*, *2*, pp.25-36.

Aldunate, R., Ochoa, S., Peña-Mora, F. and Nussbaum, M., 2006. Robust mobile ad hoc space for collaboration to support disaster relief efforts involving critical physical infrastructure. *Journal of Computing in Civil Engineering*, 20(1), pp.13-20.

Amina, A. and Virginia, M., 2015. The Sendai framework: disaster risk reduction through a health lens, *Bulletin of the World Health Organization*, 93(6). p.362.

Bosher, L. and Dainty, A., 2011. Disaster risk reduction and 'built-in' resilience: towards overarching principles for construction practice. *Disasters*, 35(1), pp.1-18.

Burby, R.J. and Dalton, L.C., 1994. Plans can matter! the role of land use plans and state planning mandates in limiting the development of hazardous areas, *Public Administration Review*, 54(3), pp.229–238.

Combaz, E. 2014. *Disaster resilience: Topic guide*. Birmingham, UK: Governance and Social Development Resource Centre (GSDRC), University of Birmingham.

Department for International Development (DFID), 2011. Defining Disaster Resilience: A DFID Approach Paper. [online]. London, DFID. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/186874/defining-disaster-resilience-approach-paper.pdf [Accessed 07 January 2019]

Godschalk. G., 2003. Urban hazard mitigation: Creating resilient cities. *Natural Hazards Review*, 4(3), pp.136-143.

Haigh, R. and Amaratunga, D., 2010. An integrative review of the built environment discipline's role in the development of society's resilience to disasters. *International Journal of Disaster Resilience in the Built Environment*, 1(1), pp.11-24.

Hecker, E., Irwin, W., Cottrell, D. and Bruzewicz, A., 2000. Strategies for improving response and recovery in the future. *Natural Hazards Review*, 1(3), pp.161-170.

Hindustan Construction Company, 2016. Disaster Relief. [online]. Available from: http://www.hccindia.com/four_pillars.php?page=corporate_stewardship&id=13 [Accessed 16 January 2019].

Kapucu, N. and Van Wart, M., 2006. The emerging role of the public sector in managing extreme events: lessons learned, *Administration and Society*, 38 (3), pp.279–308.

Liso, K., Aadahl, G., Eriksen, S. and Alfsen, K., 2003. Preparing for climate change impacts in Norway's built environment. *Building Research and Information*, 31(3-4), pp.200-209.

Lloyd-Jones, T., 2009. *The built environment professions in disaster risk reduction and response: A guide for humanitarian agencies*. London: MLC Press.

Lorch, R., 2005. What lessons must be learned from the tsunami?. *Building Research and Information*, 33(3), pp.209-211.

Malalgoda, C. Amaratunga, D. and Pathirage, C., 2010. Exploring Disaster Risk Reduction in the Built Environment. In: Barrett, P., Amaratunga, D., Haigh, R., Keraminiyage, K. and Pathirage, C. (ed). 18th *CIB World Building Congress 2010*, Salford 10 - 13 May 2010. Salford: CIB.

Matthews, G. V. and Warren, C.M.J., 2010. The Role of Property Professionals in Building Disaster Resilience, *XXIV FIG Congress: Facing the Challenges and Building the Capacity*, Sydney, Australia 11-16 April 2010.

McEntire, D.A. Fuller, C. and Richard Weber, C.W.J., 2002. A comparison of disaster paradigms: the search for a holistic policy guide, *Public Administration Review*, 62 (3), pp.267-281.

Mileti, D.S. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States*, Washington, DC: Joseph Henry Press.

Ofori, G., 2004. Construction industry development for disaster prevention and response. In: (ed). 2nd International Conference on Post-Disaster Reconstruction: Planning for Reconstruction, Coventry, UK 22-23 April 2004.

Oh, E., Deshmukh, A. and Hastak, M., 2010. Disaster impact analysis base on interrelationship of critical infrastructure and associated industries: a winter flood disaster event, *International Journal of Disaster Resilience in the Built Environment*, 1(1), pp.25-49.

Palliyaguru, R. and Amaratunga, D., 2008. Managing disaster risks through quality infrastructure and vice versa: post disaster infrastructure reconstruction practices, *Journal of Structural Survey*, 26(5), pp.426-434.

Prieto, R., 2004. The 3Rs: Lessons learned from September 11, 2001. In: National Research Council. *Terrorism: Reducing vulnerabilities and improving responses: US Russian Workshop Proceedings*, Washington, DC: The National Academies Press.

Rees, W., 2009. The ecological crisis and self-delusion: implications for the building sector. *Building Research and Information*, 37(3), pp.300-311.

Siriwardena, M., Malalgoda, C., Thayaparan, M., Amaratunga, D. and Keraminiyage, K., 2013. Disaster resilient built environment: role of lifelong learning and the implications for higher education. *International Journal of Strategic Property Management*, 17(2), pp.174-187.

Stringfellow, P., 2014. Construction contractors' involvement in disaster management planning, *Australian Journal of Construction Economics and Building*, 14 (2), pp.120-132.

Thurairajah N., Palliyaguru R. and Williams, A., 2011. Incorporate disaster management perspective into built environment undergraduate curriculum. In: Amaratunga, D., Haigh, R., Keraminiyage, K., Kulatunga, U. and Pathirage, C. (ed). *International Conference on Building Resilience,* Kandalama, Sri Lanka 19-21 July 2011. Salford: University of Salford.

United Nations Development Programme (UNDP), 2004. *A Global Report: Reducing Disaster Risk: A Challenge for Development*. New York: UNDP Bureau for Crisis Prevention and Recovery.

United Nations International Strategy for Disaster Reduction (UNISDR), 2010. Terminology: basic terms of disaster risk reduction [online]. International Strategy for Disaster Reduction – ISDR. Available from: https://www.unisdr.org/files/7817_7819isdrterminology11.pdf [Accessed 2 February 2019].

United Nations International Strategy for Disaster Reduction (UNISDR). 2015. *Disaster Risk Reduction Private Sector Partnership: post 2015 framework-private sector blueprint five private sector visions for a resilient future*, Switzerland: UNISDR.

Punnyasoma, J.A.G., Jayasena, H.S. and Tennakoon, T.M.M.P., 2019. Use of BIM solutions to facilitate value management. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 598-607. DOI: doi.org/10.31705/WCS.2019.59. Available at: https://2019.ciobwcs.com/papers

USE OF BIM SOLUTIONS TO FACILITATE VALUE MANAGEMENT

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ABSTRACT

Value management is a practice of generating innovate alternative ideas to improve the value of a project where the goals are to achieve a more efficient design, identify alternative methods of constructions, identify and omit unnecessary cost components and managing the whole life cycle cost of the project. The aim of this research is to find the ability of BIM in incrementing efficiencies of value management process within Sri Lankan context. Case study method was used. The selected case is considered as a benchmark on sustainable buildings of the Sri Lankan construction sector. The seven-step value management approach following the Client's requirements identified for the project was first documented. BIM tools and features applicable for each step of value management process was then identified followed by clarification of the effect and the efficiency of each step of the process. A value management plan was built up with the use of BIM solutions for the studied case. BIM was identified as one of the most efficient and accurate media to extract the basic and detailed project information for value management process. Simulating, comparing and contrasting the information of rainfall, wind flow, daylight, cost, designs and resources for the implementation of passive cooling systems, lighting control systems, green roofing and alternatives to reduce grey energy was effectively analysed in this paper using BIM solutions.

Keywords: *Building Information Modelling; Sustainable Buildings; Value Management.*

1. INTRODUCTION

During the recent 10 years, Sri Lanka has shown a steady growth in construction industry which has emerged as an important sector in the economy. Sri Lanka's post-conflict growth has been fuelled by construction, which increased its share of GDP from 6.6 percent in 2009 to 8.7 percent in 2013 (Davies, 2014); and it still remains around 7 percent (Central Bank of Sri Lanka, 2019). The economic challenges in the sector continue to demand best value for every investment made without reducing the quality yet balancing the cost at an optimal level. Hence, value creating initiatives such as value management can be identified as vital procedure that should be followed in any building construction project.

Value management has been defined as a team orientated, multi-disciplinary well-structured analytical process which aids in systematic analysis of function to obtain the maximum value through the design and construction process to fulfil the client's exact needs (Jaapar *et al.*, 2016). The value management procedure commences from the

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planning stage and should be followed through the whole life cycle of the project to reduce cost without reducing the quality and functional efficiency of a project (Lin and Shen, 2007). A better value is gained though a balanced cost which is neither too less nor too high (Thiry, 2002). In order to gain a better output, the key factors of value management should be identified to allocate the limited resources (Shen and Liu, 2003). The possibilities to use novel information solutions to simplify the tasks involved in value management planning has been considered in the construction industry from some time.

Building Information Modelling (BIM) is such an information solution supported by digital machine-readable documentation about a building, its performance, planning, construction, and its operation and maintenance. BIM characterize the built environment of the building on a virtual platform (Succar, 2010). BIM has the ability to capture, manipulate and arrange large amount of data related to the built environment. It digitally represents the physical and functional characteristics of a building (Arayici *et al*., 2012).

Even though several researches have already been done on value management and applications of BIM for various aspects of building construction there is a research gap remaining to comprehend the ability of BIM in incrementing efficiencies of value management process within Sri Lankan context. Better information will help positive adoption of BIM in Sri Lankan industry which is yet to find its benefits (Rogers *et al*., 2015). To bridge this gap, an in-depth literature review was carried out which was followed by a case study from Sri Lanka.

2. VALUE MANAGEMENT

The term 'Value' implies different meanings for different disciplines. Value is defined as the ratio between the desired performance of a product and the overall production cost (Rangelova and Traykova, 2014). Value achieved by balancing the three cores of a product cost, time and quality (Ellis *et al*., 2005). Subsequently, value management practice approaches problem solving with a wider resolution than many other problem-solving techniques and it is a problem solving tool which includes a number of qualitatively different components. It is a commonly used management tool where the main focus is on innovating alternatives to improve value of a product (Spaulding *et al*., 2005). The definitive intention of value management is to deliver the maximum value without any cost cutting strategy (Perera *et al*., 2011).

Value management has become a popular tool used within the modern construction industry. It is a tool which is used by a design team to maximize the value of a project in respective to the clients' requirement. Furthermore, value management becomes a wider theory in construction technology, which focus on improving the value delivered to the customer through the entire life cycle of the building (Kelly *et al*., 2016). In construction industry, the concept of value management often focuses on the constraints such as cost, function, quality and durability (Salvatierra-Garrido and Pasquire, 2011). Function, time, quality and cost of every single activity and element that is includes in the construction process required to be identified, determined and estimated earlier. Thus, value management ensures that the construction process generates the value desired by the client.

2.1 METHODOLOGY OF VALUE MANAGEMENT PROCESS

In common practice, a team consisted of professionals lead by a value management expertise along with a facilitator conducts the value management studies in the form of workshops (Luo *et al*., 2010). The value management team must be consisted of expertise who are aware about the entire life cycle, the required needs and functions of the particular project (Perera *et al*., 2011).The value management job plan, facilitates to take a step-by-step approach have the following four basic steps (Ashworth and Hogg, 2000; Kelly *et al*., 2016):

1. Issues analysis - accumulating information (including information on values to be used in decision-making).
2. Function analysis - prioritizing information (normally as a set of functional requirements/objectives).
3. Creativity - creative thinking (to generate options and packages of options).
4. Evaluation - prioritizing options (making decisions which balance use of resources and functionality in meeting objectives).

In Table 1 the commonly used phases of value management which are extended from the main four phases has been summarised.

Table 1: Steps of value management process

Phase	Objectives
Pre study phase	• Identify problem statement and preparation for the value study • Establish Value Management study objectives
Information phase	• Identify functions of each elements of the project • Absorb and analyse information required to carry out the study, including, client and end-user requirements by the value management team • Confirm objectives of value studying
Creative phase	• Develop creative alternative solutions and ideas generation through brainstorming, Gordon technique or synoptic technique • Develop alternative ideas to achieve value improvement.
Evaluation phase	• Evaluate ideas generated, analysis and ranking of solutions • Determine the most suitable alternatives for the decision-maker
Development phase	• Develop the accepted ideas to investigate their technical feasibility and economical validity • Realize cost of outline designs.
Presentation phase	• Provide final recommendation to the client • Implement the recommendations.

Source: Adapted from Dallas (2006) and Rangelova and Traykova (2014)

3. BIM FOR VALUE MANAGEMENT

Building Information Modelling is one of the most important inventions in engineering, architecture and construction in latest periods. Eastman *et al*. (2011) elaborated BIM as "a new approach to planning, design and construction, in which digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format". Building Information Modelling has attracted many initiatives around the world since it is an efficient time saving technological solution. In the architectural design areas, BIM oriented high performing building designing is increasingly being used and allows professionals to efficiently generate and modify building models (Welle *et al*., 2011). According to Pikas *et al*. (2013) there are three main factors which affects the adoption of BIM in all construction projects.

1. The technological scopes which embraces the interaction among applications, compatibility of software, monitoring and controlling the quality and progress of construction, design clash detection and visualization of BIM standard and protocols.
2. The organizational dimension which includes BIM professionals, BIM vendors, professional trainings of BIM technologies, and support of senior management and clients. The compatibility of all these specialists affects the level and quality of implementation of BIM in a construction project.
3. The attitude factor which includes interest in learning BIM, BIM awareness, willingness to use BIM, perceived cost of BIM technology and platform and willingness to facilitate the implementation of BIM in a building project.

Consequently, Saieg et.al (2018) has highlighted that BIM based sustainability analysing tends achieve a significant time and cost savings in contrast to traditional design methods. Further, the ways in which BIM-based processes to facilitate sustainable design with high value, have been listed that includes promoting the selection of sustainable materials, reducing material consumption, and increasing the use of recycled materials. In order to identify the influence from BIM applications for VM the following research methodology is followed.

4. RESEARCH METHODOLOGY

Since the research scope is limited to Sri Lankan context, a case study approach was used to conduct the research. Furthermore, the research consists of how and why questions, the strategies available when conducting a case study facilitates to explore the questions in a more in-depth nature.

The selected case was the value engineering process of a sustainable factory building construction. The study regarding the case was carried out in two parallel phases. The first phase was to identify the value management process for the project. Semi structured interviews were conducted to identify the Client's requirements. The value criteria of the project were confirmed through analysing the Client's requirements. Then a document review with the assistance of the design team members. The phase two was specifically focused on the ability to apply BIM and BIM tools for each step of the value management process. The practical application of BIM solutions was comprehended through developed models and the experience of the project team.

5. DATA COLLECTION AND ANALYSIS

The necessary details regarding the project which are required to enhance the value of the project were surveyed and the decision for value enhancement were taken by the Client and the design team during the design and planning stages.

5.1 BIM SOLUTIONS FOR VALUE MANAGEMENT OF THE SELECTED CASE

In the selected case, the Client's requirement was to obtain a sustainable and eco-friendly building as the final product. An in depth analysis of the general information of the case is presented in Table 2 in Section 5.1.2. The selected case was well- known example of effective value management implementations. Therefore, an emphasis was given to analyse the use of BIM related solution for the success of the value management process of the project.

5.1.1 Pre-Study Phase

During the pre-study phase the problem statement was identified for the preparation for the value study. Under the problem statement three aspects were answered regarding the project.

- Strategic brief
- Project brief
- Project goal

A briefing process was done prior to the design stage. According to Figure 1, several requirements were emphasized above others for the selected case where the Client's requirements were identified and short-listed.

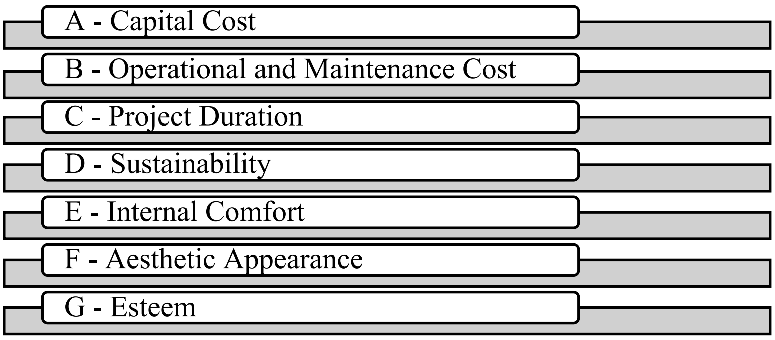

Figure 1: Value management study objectives

Capital cost and operation & maintenance cost were the major concerns of the client whereas the esteem and aesthetic appearance were not prioritized since the project is a construction of a factory building. The value management process was built up depending on those factors identified. However, use of BIM at this phase was limited to paper based exhaustive list of client requirements in the selected case, which is similar to Employer's Information Requirement (EIR) documents but with a special focus on value management.

5.1.2 Information Phase

In the information phase, the necessary information for the value management study was gathered and a sample of the collected information is given in Table 2.

The information that were collected was consisted of project details including identification of functions of all the elements of the project, client and end-user requirements and finalizing the value management objectives. During the information phase, the Client's requirements processed through a 'Client Value Matrix' and identify the priority level for each requirement.

Table 2: Main information collected

Site Details	Basic Building Details	Key Cost Details
• Location - Thulhiriya, Sri Lanka • Climate - Tropical, Humid • Terrain - Rolling, Moderately sloped • Area - 3.32 hectares • Parking - 10 spaces for vehicles and 25 for bicycles	• Construction period - September 2007 to April 2008 • Building type - clothing factory • Maximum number of occupants - 1,300	• Target construction cost - USD 2.66 million (338.50 USD/m^2) • Construction cost of typical factories in Sri Lanka - 308 USD/m^2 • Target annual operating cost - 0.4 USD/m^2 • Annual operating cost of comparable factories in Sri Lanka - 1.61 USD/m^2

5.1.3 Creative Phase

During the creative phase all the creative ideas regarding the project is produced and captured by the value management team. Therefore, specifically for this project during the creative phase, the design ideas were built up by the design team with the client's requirements taken into consideration. During the brainstorming session, new ideas that will meet the Client's requirements were generated. The value management proposal had the first five requirements in the Client's priority list as the focus.

1. High Sustainability
2. Less Project Duration
3. High Internal Comfort
4. Low Capital Cost
5. Low Operation and Maintenance Cost

In the selected case at Thulhiriya experts in civil engineering and architecture, sustainable development, design teams, mechanical engineers, electrical engineers, and facility managers were presented at creative phase to provide ideas for value management proposals. According to the respondents, use of BIM solutions were limited at this stage and only paper-based notes were taken down for further discussion.

5.1.4 Evaluation Phase

For the basic evaluation all the ideas generated during brainstorming session were checked to confirm the Client's requirements that each of the ideas fulfil. According to the results obtained, some design concepts met the key requirements. For some of the design concepts, Cost Benefit Analysis (CBA) and Whole Life Cycle Costing (WLCC) were carried out during this phase. BIM as an information solution work as a platform to store the data required for a project. Stored data combined along with the analytical ability of BIM supported in evaluating each idea generated during the brainstorming session in terms of cost, time and benefits and compare each of them to verify what design ideas have the highest cost benefits and lowest life cycle costing. For WLCC process BIM tools are required for calculations and analyzing. The following tools were identified for WLCC calculation.

<u>Solibri Model Checker (SMC) Ver. 8</u>

As a model-checking tool SMC has aided in verification the quality of BIM models produced by the architect/engineer following a specific set of rules. The functions consisted of quality checks to BIM models, including visualization, navigation and presentations compilation. SMC has supported test and control of the quality and accuracy of BIM models for various uses such as energy analysis, information take off, and spatial coordination.

Autodesk Quantity Take-Off (QTO)

Autodesk QTO was identified as a separate cost-estimating tool developed by Revit, to assist estimators and surveyors in quantifications and cost estimates through gathering and coordinating of accurate design information from both 3D BIM and traditional 2D environment.

Exactal CostX Estimating Software

Cost X as an estimating tool for BIM based cost management by enabling full integration of 2D and 3D digital design data with cost estimates. CostX capture and extract BIM information of object properties, dimensions and descriptions all in a single platform, including electronic measurements, spreadsheet calculations and estimates (Day, 2008; Exactal, 2010) enabling calculation of WLCC easier.

5.1.5 Development Phase

In the development phase, the design ideas that were generated during the creative phase and filtered during the evaluation phase were established further. In the Table 3 the innovative ideas were elaborated which were developed by considering the Client's requirements. Furthermore, Table 3 also provides a summarization of the BIM tools that are available for use to succeed each of the value management initiatives suggested in the considered case.

Table 3: BIM tools to achieve innovative value management proposals in the selected case

Innovative Idea	Useful BIM Tools and the applicability to implement the innovative value management proposal as a successful initiative
Passive Cooling Techniques	Climate Analysis: determine the passive cooling techniques achieved through **Autodesk, Ecotect, Revit, Vasari,** and **Green Building Studio**. Among the tools in **Ecotect**, tools to design shading and carry out solar analysis, thermal analysis, ventilation and air flow analysis are available to improve the value achieved through passive cooling. Wind Pattern of the Area: **Flow Design**, **Vasari/Revit** and Site **& Topography.** This tool indicates the positioning of site and vegetation around the area to get a better understanding about the wind patterns. Simulation CFD: A tool supporting in analysing the wind flow and thermal simulation capabilities of a designed building. Thermal loads on the Building: **Vasari/Revit** and **Ecotect** have tools for analysing how heating and cooling loads change throughout the year and what elements of the design contribute to it the most. (**Revit MEP: Heating & Cooling Loads)**
Lighting Control Systems	Day lighting analysis**:** Solutions such as **Vasari/Revit: Sun path & Visualization** operated as interactive 3D sun path diagram that visualized the shadows **and** position of sun throughout the day and year to quantify the amount of the sun light. This helps in to create comfortable and beautiful spaces, reduce lighting loads, and reduce cooling loads.

Innovative Idea	Useful BIM Tools and the applicability to implement the innovative value management proposal as a successful initiative
	Ecotect: a tool to create an analysis grid and perform day lighting analysis. It aids in qualitative analysis to visualize light rays and in quantitative analysis in calculating day light factors **Radiance:** aided in analysing day light factor, deciding illuminance values within specified ranges for specific tasks and day light autonomy. **3Ds Max:** used in detailing and accurate simulation of lighting. It aids in detailing effects of lighting provided by many sources including sunlight, day lighting, and artificial lights. It also evaluates factors that affect the quality of the lighting including level of lighting, distribution of light, glare, and intensity of light.
Using Green Alternatives to Reduce Grey Energy	**Green Building Studio**: a web (network) base whole building analyzing and energy-calculating tool that provided support in optimizing energy efficiency and work toward carbon neutrality earlier in the design process which is based on the DOE-2 calculation engine. **Revit**: Whole Building Energy Analysis tool that executed the whole building energy simulations on the entire building design including wall, window, floor, and roof constructions that all have unique materials with different embodied energy (Grey energy). **eQUEST:** provided more control over energy consumption of the building throughout the entire life cycle.
Green Roof	**Ecotect:** in designing the green roof with the intention of increasing thermal comfort within the building. **Green Building Studio:** calculating the energy loads and designing the building envelop directing it to the living rooftop.

It was a common feature for all of the design ideas suggested and developed in this phase stage to consume a comparatively high capital cost at the initial stage (for construction or installation) but later at the life cycle of the building in operation and maintenance stages to consume less energy and save the operation cost for the systems. These two features of energy conservation and low operation costs combined together enhance the value of the factory building in Thulhiriya while fulfilling certain number of client's requirements. Finally, the developed ideas are combined together to form the final design for the project.

The design development and considering design alternatives has proven to be an effective process when BIM based 3D platform was used. Compared to other phases of value management the development phase was identified as the easiest phase to implement BIM solutions. Green Building Studio and Vasari were the main two solutions that were used in the selected case.

5.1.6 Presentation Phase

In the presentation stage, the design team had presented the final design building to the Client. The finalized design included all the ideas generated during brainstorming session and developed during development stage. The developed 3D model with Revit and the simulations done regarding wind loads, day light analysis had been facilitated the Client to obtain a thorough idea about the value management proposal and to continue necessary discussions to do amendments.

6. CONCLUSIONS

The case study result illustrated the possibility to combine BIM together with value management to make the construction process more efficient and accurate. For pre study phase and the information phase of value management, the concepts of EIR of BIM can be implemented to increase the understanding of the overall project scope. This information included cost information, design details, drawings, structural details, and details about project timeline. However, it was observed that a creative phase could not employ BIM solutions since the mind storming sessions were imaginative process of creativeness and experience. The development phase was where BIM solutions were maximally utilized for design development, forecasting rainfall and day light patterns. Further, the comparison of value management proposal was facilitated through the 3D model at the presentation phase. Therefore, this research established the importance of using BIM solutions for value management of construction projects. The study can be extended in the current format to identify different novel BIM solutions to be used for value management success.

7. REFERENCES

Arayici, Y., Egbu, C.O. and Coates, S.P., 2012. Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. *Journal of Information Technology in Construction*, *17*, pp.75-92.

Ashworth, A. and Hogg, K. 2000. *Added Value in Design and Construction*. Pearson Education, Harlow.

Central Bank of Sri Lanka. 2019. *Annual Report of the Monetary Board to the Hon. Minister of Finance for the year 2018 (Vol. 1)*. Central Bank of Sri Lanka.

Dallas, M.F. 2006. *Value and Risk Management: A Guide to Best Practice.* Blackwell, Oxford.

Davies, N. 2014. Vibes from Building Boom. Available from http://lmd.lk/construction-industry-2/ [Accessed on 29 June 2016]

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*. Wiley: Hoboken, NJ.

Ellis, R.C.T., Wood, G.D. and Keel, D.A. 2005. Value management practices of leading UK cost Consultants. *Construction Management and Economics*, 23(5), pp.483-93.

Jaapar, A., Endut, I.R., Bari, N.A.A. and Takim, R., 2009. The impact of value management implementation in Malaysia. *Journal of Sustainable Development*, *2*(2), pp.210-219.

Kelly, J., Male, S., and Graham, D. 2016. *Value Management of Construction Projects.* (pp. 1-27). Oxford, UK: Blackwell Science Ltd.

Lin, G. and Shen, Q., 2007. Measuring the performance of value management studies in construction: critical review. *Journal of Management in Engineering,* 23(1), pp.2-9.

Luo, X., Shen, G., Fan, S., and Xue, X. 2010. A Group Decision Support System for Implementing Value Management Methodology in Construction Briefing. *International Journal of Project Management,* 29(1), pp.1003-1017.

Perera, S., Hayles, C. S. and Kerlin, S., 2011. An analysis of value management in practice: the case of Northern Ireland's construction industry. *Journal of Financial Management of Property and Construction*, 16(2), pp.94 – 110.

Pikas, E., Sacks, R. and Hazzan, O. 2013. Building Information Modeling Education for Construction Engineering and Management. II: Procedures and Implementation Case Study. *Journal of Construction, Engineering Management, 139*(11), p.05013002.

Rangelova, F. and Traykova, M., 2014. Value Management in Construction Project. *First Scientific-Applied Conference with International Participation 'Project Management in Construction',* University of Architecture. *Civil Engineering, and Geodesy*.

Rogers, J., Chong, H.Y., Preece, C., Lim, C. C., and Jayasena, H. S., 2015. *BIM Development and Trends in Developing Countries: Case Studies.* Bentham Science Publishers.

Saieg, P., Sotelino, E. D., Nascimento, D., and Caiado, R. G. G., 2018. Interactions of Building Information Modelling, Lean and Sustainability on the Architectural, Engineering and Construction industry: A systematic review. *Journal of Cleaner Production*, 174, pp.788–806.

Salvatierra-Garrido, J. and Pasquire, C., 2011. Value theory in lean construction. *Journal of Financial Management of Property and Construction,* 16(1), pp.8–18.

Shen, Q. and Liu, G., 2004. Applications of value management in the construction industry in China. *Engineering*, *Construction and Architectural Management*, 11(1), pp.9–19.

Spaulding, W. M., Bridge, A. and Skitmore, M., 2005. The use of function analysis as basis of value, management in the Australian construction industry. *Construction Management and Economics*, 23(7), pp.723-732.

Succar, B. 2010, *Building Information Modeling maturity matrix*, in Underwood, J. and Isikdag, U. (Eds), Handbook of Research on Building Information Modeling and Construction Informatics: Concepts and Technologies, Information Science Publishing, Hershey, PA, pp.65-103.

Succar, B., 2010. Building information modelling maturity matrix. In *Handbook of research on building information modeling and construction informatics: Concepts and technologies* (pp.65-103). IGI Global.

Thiry, M., 2002. Combining value and project management into an effective programme management model. *International Journal of Project Management*, 20, pp.221–227.

Welle, B., Haymaker, J. and Rogers, Z., 2011. Thermal Opt: A methodology for automated BIM-based multidisciplinary thermal simulation for use in optimization environments. *Building Simulation*, 4(4), pp.293-313.

Ishan, J.R.P., De Silva, N. and Withanage, K.T., 2019. Use of shipping container housing concept as a low cost housing solution for resettlement projects in urban areas. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 608-617. DOI: doi.org/10.31705/WCS.2019.60. Available at: https://2019.ciobwcs.com/papers

USE OF SHIPPING CONTAINER HOUSING CONCEPT AS A LOW COST HOUSING SOLUTION FOR RESETTLEMENT PROJECTS IN URBAN AREAS

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ABSTRACT

Today, one-third of the world's urban population live in slums and shanties., while prioritizing adequate housing as their basic need. They face a lack of basic needs such as clean air, water, sanitation and healthy foods. Rapid urbanization leads to increased demand for condominiums and focused on slum-free cities to get maximum utilization of high potential prime lands. As a solution, shipping container housing (SCH) concept has been successfully practiced in many countries in all over the world to promote low cost housing (LCH) for resettlement projects. Therefore, this research intends to explore the use of SCH concept as a LCH for permanent resettlement projects in urban areas of Sri Lanka. A comprehensive literature synthesis emphasizes the suitability of SCH concept as a LCH solution and it proved that approximately 60% of construction cost can be saved by using this SCH concept over the traditional construction methods. Selected case study for this research was "low income permanent resettlement programme in Colombo city". Finally, the study revealed that use of SCH concept as a LCH solution for resettlement projects in Colombo will not be a feasible solution due to the specific retarding factors from the low income groups, specific characteristics of shipping container boxes and climatic conditions of Sri Lanka. Moreover, this study was very useful for the governing authorities to identify the leading alter factors between the theoretical concept and practical implementation of low income permanent resettlement projects in Sri Lanka.

Keywords: *City; Low Cost Housing; Resettlement Projects; Shipping Container Housing.*

1. INTRODUCTION

Resettlement can be identified as relocating a group of people who lived as refugees from the existing place to another protective novel place that accepting them and to provide permanent settlement and better living status (UNHCR, 2011). Resettlement is needed for those who were affected by war, social hazards, disasters and urban development projects. In the Sri Lankan context, low income slum communities were the mostly affected group due to urban development projects (Deheragoda, 2008).

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Recently the Sri Lankan government is going ahead with mega development projects in Colombo and other urban areas in the Western province under the Ministry of Mega polis and Western Development. As a result of this, a wide range of people will lose their shelter (Ministry of Megapolis and Western Development, 2015). Under these circumstances, permanent resettlement of these families with better living standards becomes one of the major challenges that has to be overcome immediately. According to the Cohen and Bradley (2010), obtaining an adequate, suitable, immediate, affordable and sustainable housing was very important to a successful integration into a new society, especially at an initial stage of a permanent resettlement (as cited in Forrest *et al*., 2013). Different types of resettlement projects can be identified depending on the scale of the resettlement, financial levels of people, use of land area, price of land, etc (Wijayasinghe, 2010).

The common methods used as LCH in other countries are to build low-rise modular homes, panelised homes, pre-cut homes and container homes (Ford *et al*., 2014). Therefore, shipping containers have been used as an alternative and sustainable housing construction method which fulfilled the above all requirements of low income communities (Islam *et al*., 2016).

Shipping containers were made out with standard dimensions including some in-built properties to convert them for an excellent modular structural component. According to the standards sizes of a container boxes, it starts from 20 ft. X 8 ft. = 160 ft^2 which is similar to living area or size of master bedroom of a conventional house (Martinez-Garcia, 2014). Further it has an environmentally friendly way of construction and able to act as sustainable and economical method of construction while saving traditional construction materials, construction cost and additional working spaces. Some of the countries have been successfully adopted this SCH concept such as Netherlands, USA, Qatar, China, Haiti and etc. (Meinhold, 2010; Winter, 2013; Simon, 2014).

However, in Sri Lanka, no research has been carried out to analyse the suitability of shipping container housing concept for permanent resettlement projects as an alternative solution. Therefore, with the aim of filling this research gap, this research was conducted to investigate the use of shipping container housing concept as a LCH solution for permanent resettlement projects in the Colombo region.

2. LITERATURE SYNTHESIS

In mid of 1950s, governments of South Asian countries were attempted to fulfil the housing and shelter needs of the poor communities and they developed housing policies with the aim of supporting public backed by public finance (Joshi and Sohail, 2014). However, the rapid urbanization causes the lack of adequate and affordable housing, lack of pro-active approach to development and it was contributed to higher population densities to proliferation of slums and informal settlements in the most urbanized cities in these regions (Wijayasinghe, 2010). Often, living in these slums and shanties can be affected to both physical and psychological dangers (Brown, 2003).

2.1 RESETTLEMENT

Resettlement is the mechanism of compensation of the population affected by a large industrial investment (Bolt and Stănculescu, 2012). Moreover, resettlement involves transfer communities from the origin to a specific newly built area as destination.

Basically, resettlement covers all direct economic and social losses resulting from land acquisition and restrictions of access, together with the consequent compensatory and remedial measures (World Bank, 2004). There are several types of resettlements based on the decision of resettled population and inducement as voluntary resettlement, involuntary resettlement, disaster induced resettlement and development induced resettlement (Forrest *et al*., 2013).

2.2 APPLICATION OF SHIPPING CONTAINERS

In the past, shipping containers were used as stores and tool sheds without any modifications. In 1987, Phillip C. Clark obtained a patent for modifying shipping container boxes for habitable and productive buildings.

Through this patent, shipping container architecture were established by attaching one or more container boxes on a foundation with all infrastructural elements such as inner side walls, roofs, ceilings, doors and windows. Further Urban Space Management firm in London was completed a project called "container city" at 2001. Container city provided example for this alternative method of construction which can be used as living spaces, work spaces, offices, youth centres, studios and etc. (as cited in Vijayalaxmi, 2010). According to Abrasheva *et al*. (2012), shipping containers drive through a possible great success in the construction business because of its system based advantages such as wide availability, ease to prefabrication, mobility and modularity, short planning and implementation periods and low cost of construction.

2.3 SHIPPING CONTAINERS HOUSING CONCEPT AS A LCH SOLUTION

Sawyers (2008) have figured major reasons of using shipping container architecture for construction as;

- Modular design - has the same width, standard height and length, can be combined into larger structures and simplifies design and planning.
- Strength and durability - designed to carry heavy loads and to be stacked in high columns, resist harsh environments, such as on ocean-going vessels and long distance transportation on roads.
- Low cost of labour – Lower labour cost than conventional construction methods for the welding and cutting of shipping containers.
- Low initial cost – used shipping containers are available at very low prices.
- Transport convenience – Can be conveniently transported by ship, truck or rail.

3. RESEARCH METHODOLOGY

In this research, single case study approach was used due to lack of available practical cases and concept is very new to Sri Lankan industry. Therefore, this was limited to the exploring of use of SCH concept as a LCH solution for permanent resettlement projects in Colombo region only.

3.1 DATA COLLECTION METHOD

3.1.1 Data Collection - Phase 01

A comprehensive documentary survey was carried out under the phase 01 to collect the quantitative data as secondary data, with the help of Urban Development Authority and shipping container house manufacturers. Cost data of existing housing units were obtained from the quantity surveying (QS) division and detailed floor plans were obtained from planning and designing (P&D) division of the Urban Development Authority. After critically evaluation and analysis, new shipping container house was proposed by using 3 shipping container units. Summary of collected data and their sources were summarized in Table 1.

Table 1: Sources and collected information in phase 01

Document Sources/ Information Source	Collected Information
Obtained from the Urban Development Authority	
• Annual reports-Ministry of Finance (2011,2012,2013,2014,2015,2016)	• Summary of cost provisions for resettlement programme
• Monthly and quarterly progress reports prepared by the Urban Development Authority	• Progress and delaying causes of the resettlement programme
• Urban regeneration programme project plan (First edition and second edition)	• Details regarding the expected number of beneficiaries, expected progress measurements and floor plans of the housing units
• Website of the Urban Development Authority	• Summary of resettlement programme
• Contractual documents obtained from the QS division of the Urban Development Authority	• Cost details of completed part of project, contractual disputes of ongoing projects and delay causes
Obtained from the Shipping container home manufacturer	
• Bill of quantities of completed projects	• Average cost details and major cost components of a shipping container house
• Estimate for proposed SCH unit	• Cost details of SCH unit

3.1.2 Data Collection - Phase 02

At the end of the phase 01, there were few possible factors were identified that can be affected to success or failure of the solution proposed. To validate those qualitative factors as primary data, seven expert interviews were carried out with expert in shipping container manufacturing industry, civil engineers and key personnel representing Urban Development Authority as shown in Table 2.

Table 2: Details of respondents in phase 02

Respondent	Affiliation	Background
R1	Shipping container building manufacturing industry	Shipping container house manufacturer who has more than 15 years of experience in industry
R2	Freelancer	Charted structural engineer who has more than 20 years of experience in industry
R3	Urban Development Authority	Director of a one phase (low income) of resettlement programme

Respondent	Affiliation	Background
R4	Urban Development Authority	Director of a one phase (middle income) of resettlement programme
R5	Urban Development Authority	Deputy director of resettlement and senior architect
R6	Urban Development Authority	Senior quantity surveyor
R7	Urban Development Authority	Planning engineer

3.2 DATA ANALYSIS METHODS

Quantitative data (i.e. cost data and progress data) were analysed through necessary mathematical analysis and qualitative data were analysed with content analysis technique using NVivo software (version 11).

4. DATA ANALYSIS AND FINDINGS

4.1 CASE PROFILE

By a survey which has been conducted in the year 2010 and 2011, Urban Development Authority has identified a total number of 68,812 families living in 1,499 underserved settlements which haven't a healthy environment for human habitation and access to basic infrastructure facilities such as clean water, electricity, sanitation etc. In response, the Urban Development Authority planned out a program to construct 68,000 housing units for resettlement of these shanty dwellers with a view to liberating the prime lands presently occupied by them as well as uplifting the living standards of the occupants. This strategy would also help to clear out most of the derelict areas in the city while releasing these lands for urban developments. The urban regeneration project has been started with the aim of constructing LCH units with 550 ft^2 usable floor area as shown in Figure 1.

Further it intended to liberate 900 acres of valuable lands through relocation and to utilize 300 acres for re-housing projects, 150 acres for recreational and 450 acres for mix development projects.

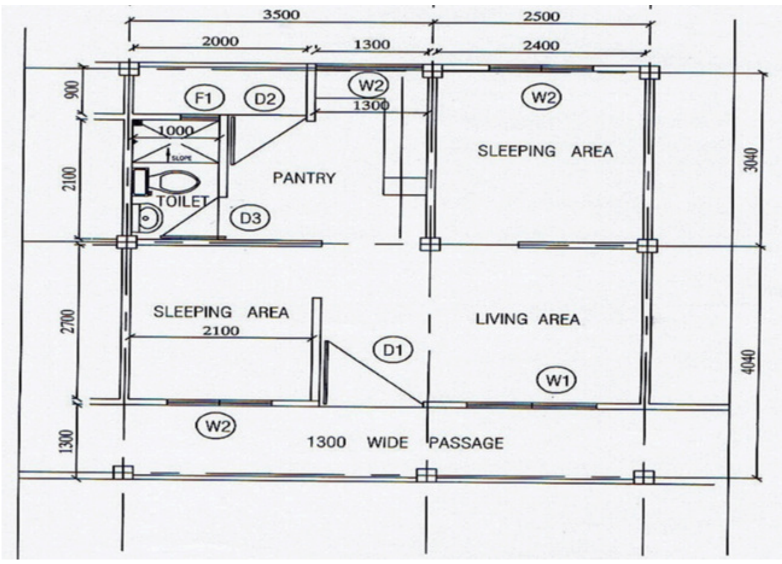

Figure 1: Typical house unit plan of resettlement project (Source: Urban Development Authority, 2012)

Urban Development Authority hopes to recover the one million rupees (Rs.1, 000,000.00) of the total construction cost (Rs.4, 500,000.00) of a housing unit through an affordable interest free loan system from the resettled families. This amount will be recovered at the end of 30 years of time. Under this urban regeneration programme, 5859 number of houses have been constructed up to now under Phase 01 as shown in Table 3.

Table 3: Completed housing units

No	Location	No of units	Approximate construction cost (Rs.)	Completed year
1	Dematagoda	500	1,220,707,371.16	2013
2	Orugodawatta	34	64,282,940.86	2014
3	Wanathamulla	718	2,291,796,269.58	2014
4	Wanathamulla	430	1,372,524,228.30	2014
5	Bloumendhal	366	1,039,250,144.38	2014
6	Wellawatta	118	487,511,150.10	2014
7	Henamulla	1137	3,228,511,767.39	2014
8	Fergusion road	872	2,528,819,327.20	2014
9	Edirisinghwatta	546	1,597,276,976.54	2014
10	Salamulla	216	597,645,570.39	2014
11	Pradeepa mawatha	266	759,428,706.54	2016
12	Thachchiwatta	68	150,244,845.90	2017
13	Maligawatta	192	285,102,576.53	2017
14	Salamulla	396	968,024,939.47	2017
Total		**5859**		

Source: (Urban Development Authority, 2017)

In addition to that there are 8 ongoing projects under phase 01 (4112 houses) and 7 ongoing projects under phase 02 (5947 houses). After completion of these ongoing phases, 15 918 numbers of housing units will be added to fulfil the housing requirement. Comparing to the construction programme Urban Development Authority has a challenge to build rest of 52 082 number of housing units at the end of 2020. It is nearly 76% of initial housing requirement.

4.2 COST COMPARISON BETWEEN A CONVENTIONAL HOUSE AND A PROPOSED SHIPPING CONTAINER HOUSE

4.2.1 Cost of a Conventional House Unit

Average unit cost of conventional housing unit which is calculated by the Urban Development Authority;

= Rs. 4 200 000/550 ft^2 = Rs. 7 336/ ft^2

4.2.2 Cost of a Proposed SCH Unit

Cost details and the technical details were obtained from a shipping container home manufacturer who having more than 15 years of experiences with over 50 successfully completed project all over the Sri Lanka. Based on the proposal 3 numbers of 20ft container boxes were combined together (480 ft^2) and developed a housing unit designs which is providing 450 ft^2 usable floor area. Total cost for proposed SCH unit is shown in following Table 4.

Table 4: Cost estimation for the proposed SCH unit

No	Description	Unit	Qty	Rate (Rs.)	Amount (Rs.)
1	Supplying of an empty shipping container box including all taxes and clearing charges from the custom	item	1	585,000.00	585,000.00
2	Modification cost including cutting, welding, preparing surfaces, fixing box bars for made openings and fixing container boxes together	item	1	240,000.00	240,000.00
3	Cost of steel reinforcement for openings of the unit	item	1	240,000.00	240,000.00
4	Insulation of the interior of shipping container boxes as per the engineer's instructions	item	1	90,000.00	90,000.00
5	Installation of electrical wiring and all related equipment, fittings, switches, socket outlets and luminaires	item	1	80,000.00	80,000.00
6	Installation of plumbing services including all bathroom equipment, sink and other fittings	item	1	100,000.00	100,000.00
7	protective paintings of the shipping container including both inside and outside	item	1	210,000.00	210,000.00
8	Transportation and miscellaneous items	item	1	200,000.00	200,000.00
Total Amount					**1,745,000.00**

Source: Shipping container home manufacturer (2017)

Average unit cost of proposed housing unit;

= Rs. 1 745 000/450 ft^2 = Rs. 3 878/ ft^2 (approximate)

Table 5: Cost comparison

Housing solution	No of houses	Cost of a housing unit (Rs)	Total cost (Rs)
Conventional solution	52082	4,500,000.00	234,369,000,000.00
Proposed solution	52082	1,745,000.00	90,883,090,000.00
Total saving (Approximately)			**143,485,910,000.00**

4.3 SUCCESS AND FAILURE FACTORS

There were few positive and negative factors identified through the discussions with the key personnel of the Urban Development Authority and the manufacturer of the proposed solution. Altogether, 7 factors which can be causes for success of the proposed solution were identified; namely easy access to materials, lower production cost, saving of labour cost, lower transportation cost, conformance with building biology, recyclability and reusability and lower waste generation during production and demolition process. In addition, 8 factors which can be causes to failure of proposed solution were also identified as attitudinal influence of communities, high land consumption, cost of thermal insulation techniques, risk of electrical hazards, unexpected live load of dwellers, uncertainty of following maintenance procedure, shorter lifetime of the building and legal issues (refer Figure 2).

Name	Sources	References
Factors leading to success or the failure of proposed solution	7	187
Factors leading to success	7	84
Easy access to materials	7	7
Lower production cost	7	9
Saving of labour cost	7	17
Lower transportation cost	7	7
Conformance with building biology	7	13
Recyclability and Reusability	7	11
Lower waste generation during production and demolition process	7	20
Factors leading to failure	7	103
Attitudinal influence of communities	7	17
Cost of thermal insulation techniques	7	26
High land consumption	7	7
Risk of electrical hazards	7	15
Unexpected live load of dwellers	7	12
Uncertainty of following maintenance procedure	7	12
Less lifetime of the building	7	7
Legal issues	7	7

Figure 2: Coding of factors leading to success and failure of proposed solution

All the respondents highlighted that saving of labour cost of this proposed solution as an important characteristic. Lower waste generation and recyclability and reusability of material which have used for proposed solution were recommended as sustainable construction method. When it comes to failing factors, attitudinal influence was indicated as a factor which can directly causes to failure of the proposed solution. According to the authorities, less concern on the maintenance of the residences of this community will tend to reduce the life time of the proposed solution. High electricity conductivity of shipping container steel will be a high potential risk to users at lightning. Moreover, as a topical country Sri Lanka is having high temperature throughout the year. Therefore, thermal insulation cost is definitely higher. Land use for the proposed solution is considerably higher than the traditional housing scheme solution. Therefore, this fact will mislead the aim of this resettlement program which releasing of high potential prime lands from unauthorized, informal settled low income communities.

5. CONCLUSIONS AND RECOMMENDATIONS

In 2020, Urban Development Authority has a challenge to build rest of 52082 number of housing units which represent 76% of initial housing requirement. This revealed that, there is a huge gap between the demand and supply of this houses. Based on the cost comparison, carried out between SCH solution and the conventional housing, it discovered that more than 60% of construction cost can be saved by this proposed solution over the conventional housing solution. Further, these findings revealed that, the approximate cost saving that can obtain by using this proposed SCH unit as 143 billion and another 82 226 SCH units can be built utilizing that cost saving.

In Sri Lankan context, acceptance of this SCH solution by the low income community is at a lower level though the cost benefits are high. This study can be considered as a pilot study to evaluate the feasibility of using SCH concept as a LCH solution for permanent resettlement projects in Colombo region. However, through the industry practitioners and the Urban Development Authority personnel, there are few suggestions were proposed as using shipping container homes for post disaster housing, using modified shipping container boxes for self-employed shops for low income people and using shipping container buildings for commercial buildings and shopping malls as well.

6. REFERENCES

Abrasheva, G., Senk, D., and Haussling, R., 2012. Shipping containers for a sustainable habitat perspective. *Revue De Metallurgie-Cahiers D Information Techniques*, 109(5), pp.381–389.

Bolt, G., and Stănculescu, M. L., 2012. *To an enclave-like city neighbourhood: case study of a development*. University of Bucharest, Romania.

Brown, V. J., 2003. Give me shelter: The global housing crisis. *Environmental Health Perspectives*, 111(2), pp.92-99.

Cohen, R., and Bradley, M., 2010. Disasters and Displacement: Gaps in Protection. *Journal of International Humanitarian Legal Studies*, 1(1), pp.95-142.

Deheragoda, C., 2008. Meeting global challenges in research cooperation. In *Addressing the Shelter Issue of Urban Poor: A Case Study from Sri Lanka*, Uppsala, Sweden: Collegium of Development Studies, Uppsala University, pp.512–525.

Ford, G., Han, Y., Don, A., and Choi, M., 2014. *Modular Building for Urban Disaster Housing: Case Study of Urban Post-Disaster Housing Prototype in New York*, 28(6), pp.82-89.

Forrest, J., Hermes, K., Johnston, R., and Poulsen, M., 2013. The housing resettlement experience of refugee immigrants to Australia. *Journal of Refugee Studies*, 26(2), pp.187-206.

Islam, H., Zhang, G., Setunge, S., and Bhuiyan, M. A., 2016. Life cycle assessment of shipping container home: A sustainable construction. *Energy and Buildings*, 128, pp.673–685.

Joshi, S., and Sohail, M., 2014. Housing futures: housing for the poor in Sri-Lanka. *Affordable Housing in the Urban Global South: Seeking Sustainable Solutions*, pp.192-201.

Martinez-Garcia, M., 2014. *Alternative Housing: The Shipping Container Home*. National Association of Realtors, pp.1-3.

Meinhold, B., 2010. *Pop-Up Village for Haiti Made From 900 Shipping Containers* [online]. Available from https://inhabitat.com/pop-up-village-for-haiti-made-from-900-shipping-containers/ [Accessed 21 December 2017].

Ministry of Megapolis and Western Development, 2015. *From island to continent-Western Region Master Plan Colombo*, Ministry of Megapolis and Western Development.

Simon., 2014. Latest Shipping Container Housing Projects from around the World [online]. Available from http://www.containerteam.co.uk/latest-shipping-container-housing-projects-around-world [Accessed 21 December 2017].

United Nations High Commissioner for Refugees (UNHCR)., 2011. UNHCR Resettlement Handbook [online], pp.1-19. Available from http://www.unhcr.org/3c5e55594.html

Vijayalaxmi, J., 2010. Towards sustainable architecture – a case with Greentainer. *Local Environment*, 15(3), pp.245-259.

Wijayasinghe, S., 2010. *Factors Contributing to the Failure of Development Induced Resettlement Projects: A Case Study of the Sahaspura Slum Relocation Project*, Colombo, Sri Lanka.

Winter, A., 2013. The charity that houses homeless people in shipping containers [online], Available from https://www.theguardian.com/housing-network/2013/oct/24/brighton-housing-homeless-shipping-containers [Accessed 21 December 2012].

World Bank., 2004. *Involuntary Resettlement Sourcebook - Planning and Implementation in Development Projects*. Washington, DC 20433.

Samarakkody, A.L., Kulatunga, U. and Bandara, H.M.N.D., 2019. What differentiates a smart city? A comparison with a basic city. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 618 -627. DOI: doi.org/10.31705/WCS.2019.61. Available at: https://2019.ciobwcs.com/papers

WHAT DIFFERENTIATES A SMART CITY? A COMPARISON WITH A BASIC CITY

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ABSTRACT

Distinctive nature of the problems a city holds, baptise a "smart city", which is a term, at the same time, is blamed for being befogged. Although defining the term "a smart city" is worth taking a risk, the maturity of the smart city definition in terms of practical use and research has not been reached. Even if it is defined, it would highly depend on the context and unique nature of cities. Yet there are city components that are only found in smart cities. A study of these components would be the most practical way of understanding "what make a smart city". Therefore, this study aims to analyse literature, review definitional elements of smart cities, and derive a comprehensive list of smart city components. Not being a one size fits all, smart city definitions are often interchangeable with other well-defined city conceptions. Those conceptions are a source to outline what smart cities are. Therefore, the terms digital city, intelligent city, ubiquitous city, global city, and sustainable city are compared with smart city characteristics. In the same way, definitional elements from ten latest literature sources were identified. Smart city components identified in the literature were then reviewed and combined to form a list of components under the themes; smart economy, smart people, smart living, smart environment, smart mobility, and smart governance which were supposed to integrate with Information and Communication Technology (ICT) infrastructure. While these components are the frontline, smart cities also intent to ensure urban, public services, and citizen development. With this, the paper presents a holistic summary of the characteristics that define the smartness of a smart city.

Keywords: *Definitional Elements, Smart Cities, Smart City Components.*

1. INTRODUCTION

According to the United Nations, it is expected that 60% of the World's population will live in urban areas by 2030 (United Nations, 2018). The growing urban population poses broad challenges across domains such as utilities, energy, transportation, health, safety, and environment to contemporary cities (Psyllidis *et al*., 2015). Correspondingly, these challenges create complex pressures on the aforementioned domains and several others (Caird, 2017). Such pressure urges the need of innovative arrangements which on the other hand become pressing invitations to make cities more intelligent in terms of sustainability, productivity, transparency, effectiveness, and efficiency (Gil-Garcia *et al*., 2015). With that arouse a reorientation of city conceptions in an economical, environment oriented, and provident setting (Anttiroiko *et al*., 2014). Consequently, cities have turned into knowledge cities, intelligent cities, smart cities, digital cities, or sustainable cities.

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These urban metaphors, as conceptual variants to each other, are reciprocally connected with partially overlapping definitions (Nam and Pardo, 2011). Out of them, adopting a "smart" approach via smart cities was a most celebrated phenomenon emerged aiming the mitigation of the aforementioned challenges (Chourabi *et al*., 2012). In fact, although the concept is used in various contexts and nomenclatures, it is said that smart cities are designed intending the optimal utilisation of data to ensure the quality of life, sustainability, and resource management (Loo and Tan, 2019).

However, the concept of smart cities, although proliferating in discussions, is difficult to delineate (Orlowski and Romanowska, 2019). In fact, a consensus was neither reached by the practice communities nor researchers (Gil-Garcia *et al*., 2015). Authors identified that some of the existing, narrower definitions as marketing solutions for different city-level issues. Rest of those definitions in literature depend on the interest areas of the author (Orlowski and Romanowska, 2019). Alternatively, this implies a practical problem in completely building a new city with confusing benchmarks; unless otherwise for an affinity of a particular city to overcome the existing problems with a smart city. Therefore, the most ideal way to understand and apply the term, having no intentions to compromise the identity of an existing city, is by identifying the retrofits in a smart city with compared to a basic city (Tomar and Gupta, 2019). In a way, it is the most empirical approach to enhance the effective engagement of all stakeholders, by making them aware about the required extra effort they are supposed to put in while developing and maintaining a smart city (Paskaleva *et al*., 2015). Therefore, in order to address the research problem; "what differentiate a smart city from a basic city?", the aim of this research is to review different factors that make a smart city different from a basic city by identifying the key components of smart cities.

2. RESEARCH METHOD

It can be seen that common city challengers related to education, traffic, health, energy, unemployment, waste, and crimes are accurately addressed by smart city provisions (Chourabi *et al*., 2012). Therefore, other than proposing a definition, understanding smart cities is more practical by identifying these components in a more comprehensive manner (Gil-Garcia *et al*., 2015). Thus, this paper mostly focuses on identifying the key components of a smart city. To achieve that outcome, different definitions and definitional elements were ascertained. To outline the major differences and to highlight the key components hidden in non-smart city definitions, firstly, smart city initiatives were compared with well-defined popular city concepts, namely digital city, intelligent city, ubiquitous city (U-city), global city, and sustainable city. It guided in identifying smart cities definitional element in literature. Subsequently, ten smart cities studies carried out in 2019 were reviewed and definitional elements were extracted. As defining the concept is still evolving, only the latest were selected. These definitional elements represented the key components which were identified afterwards. In fact, these definitional elements lead to the study by Giffinger *et al*. (2010) on which the identification of the key components was based. Therefore, literature since Giffinger *et al*.'s (2010) study up to date was reviewed.

3. COMPARISON OF CITY CONCEPTUALISATIONS WITH SMART CITY INITIATIVES

Several authors have identified that investigating the popularly used city concepts facilitate setting out a multidimensional facet about smart cities (Nam and Pardo, 2011). In other words, while defining a basic city is highly subjective, several highlights of different city conceptions allow identifying the novelty of smart cities. Table 1 includes a comparison (based on the most obvious differences) with some of the labels which were controversial in certain marketing contexts.

Table 1: Comparison of city conceptualisations with smart-city initiatives

Different City Conceptions	Smart City	Source
1. Digital city		
Main focus is on the technological attributes of a city	Focus is not limited; deals with enhancing the quality of life, sustainable development, pollution reduction, energy management, management of urban green spaces, and all other aspects of daily life.	Caragliu *et al*. (2011)
2. Intelligent city		
Solutions encourage advancing human intelligence and innovative/ quality decision-making / problem-solving using larger datasets and effective user engagement	Provision of solutions are on the basis of improving vibrant communities in urban systems with the use of ICT-based instrumentation, sensors, and smart devices.	Komninos (2015)
3. Ubiquitous city (U-city)		
Represents a sustainable and environmental conscious smart city	U-city's vital services include smart education, transport, homes, and medicare.	Lee *et al*. (2008)
4. Global city		
In means of the inception, smart cities are the advanced versions and are number of steps ahead of global cities	Although ICT infrastructure is significant in the both, smart cities are more community oriented and are apprehended to deal with community initiatives	Yadav and Patel (2015)
5. Sustainable cities		
Concept is developed on the basis that implementation of smart solutions in line with smart technologies leads to sustainability	The concepts were branched out and parallel. Therefore, can rather introduce the compatible version as "smart sustainable city".	Elgazzar and El-Gazzar (2017)

Based on the most obvious differences, it is apparent that a smart city represents something more than the above different types of cities, except for the U-city which defines itself revolving around the term smart city. Some chronological studies have identified that smart city is the upshot of the global city development process where it carries the major aspects of global cities, liveable cities, and sustainable cities plus knowledge-based urban development and community participation (Yadav and Patel, 2015). In the process of looking at the variances, ICT plays a main role resulting in most of the concepts to overlap (Hartley, 2005). Comparison with different city concepts remarkably bring out two cornerstones; urban development, attributing to the technology-oriented knowledge economy and public sector development in terms of high-quality government operations with ICT-driven corporate practice and cross-sectoral innovation (Goodspeed, 2014).

4. ELEMENTS OF RECENT SMART CITY DEFINITIONS

According to Batagan (2011), common root causes for problems in cities including inefficient communication, inefficient use of resources, limited access to administrative data, erroneous information, and poor disaster resilience are addressed in theming smart cities. Similarly, Monzon (2015) brought in European and international experience in addressing several problems related to economy, infrastructure, community, governance and services, and resources in European cities to the Mediterranean Region smart city projects. This implies that by introducing different themes, smart cities ensure the problems occurred in basic cities would not take place any longer. They are mostly the definitional elements that most authors highlight (Yigitcanlar *et al*., 2018). However, the smart city concept is still evolving (Tomar and Gupta, 2019); therefore, the concept should be understood in the latest context as shown in Table 2.

Table 2: Smart cities definitional elements

Source	Descriptions
Anthopoulos *et al*. (2019)	All means of innovations in the urban atmosphere (ICT-based, yet not necessarily) that purpose to improve the city dimensions including economy, people, government, mobility, environment, and living.
Xie *et al*. (2019)	Upgraded quality of life, sustainable urban environment, use of advanced ICT, public government openness, encouraged community participation, effective management of traffic and public transport, intelligent device control, optimum resource utilization, improved environmental protection, and improved public services.
Abbas *et al*. (2019)	Architecting the smart cities require innovative engineering approaches. Complex information, computation and communication systems, and critical infrastructure management
Ismagilova *et al*. (2019)	Intelligent use of ICT in an interactive infrastructure, innovative and advanced services to the community, having an impact on the quality of life, and sustainable administration of natural resources.
Samih (2019)	Living solution, integrates different facilities and improve the services for citizens, typify the importance in sustainability of resources, and applications for next generations.
Blanck *et al*. (2019)	Performs well in governance, environment, people, economy, living, and mobility. Built on the smart incorporation of contribution and activities of self-decisive, free, and updated citizens.
Tomar and Gupta (2019)	Makes mutual concessions between modern technology and native methods.
Qian *et al*. (2019)	Human and societal capital investments, modern-day communication infrastructure, sustainable economic growth, participatory governance, natural resources management, and advanced infrastructure (physical, modern ICT, social, and business) integration to sustain the city's collective intelligence
Sharma and Meyer (2019)	Integration of ICT into the urban structure including the operation of urban services, efficient management of shared resources by operators themselves

Source	Descriptions
	with the aid of electronic monitoring and control, implementation of ICT in different fields to encourage innovations, and knowledge that ICT can convey.
Heaton and Parlikad (2019)	Well-being and satisfaction of citizen. Building Information Modelling (BIM) acts as a catalyst to the development of smart cities, increasing number of documentations including specifications, reports, and guidance.

The above definitional elements are a result of studies on different smart city projects carried out by several researchers. Such lessons learned infer that intelligent use of ICT, sustainable urban environment, advanced infrastructure, encouraged community participation, well-being and satisfaction of citizen, optimum utilization of resource, well-performing governance, innovations, information management, and sustainable economic growth cannot be overlooked in understanding what makes smart cities phenomenal with compared to a basic city. Having mutual concessions between modern and natives' methods, as well as relationship with BIM are quite unpopular, especially, absent in similar reviews carried out earlier (Albino *et al*., 2015; Gil-Garcia *et al*., 2015; Yigitcanlar *et al*., 2018), yet worth noticing. By and large, with critical infrastructure and information management, modern advanced ICT applications, and urban innovations smart cities appear to upgrade the quality of life of its citizens and sustain the urban system development by addressing compulsory city dimensions and domains.

5. COMPONENTS THAT DIFFERENTIATE A SMART CITY FROM BASIC CITIES

While basic cities cannot be defined, basic cities in this study refer to all those cities which are in need of solutions with innovative systems for those complex challenges they face for just being that city. In line with smart cities definitional elements, researchers and industry players together with government and central agencies have come up with different models that invoke the aspects of urban life which are to be upgraded through smart cities (Bifulco *et al*., 2016). Dividing the study of the whole city into different dimensions allows a better understanding of each aspect in terms of strengths, weaknesses, threats, and opportunities (Orlowski and Romanowska, 2019). Different inventors of these models, named the content of their models. The "components" of the smart cities are referred by various names such as drivers and smart initiatives (Bifulco *et al*., 2016), technology capabilities that improve city responsibilities in a framework (Berst *et al*., 2014), characteristics (EU-European Parliament, 2014), and components (Gil-Garcia *et al*., 2015).

Among the considerable number of literature considered in summarising the components, the most cited and widely used include six characteristics and 33 basic requirements under each factor (Bifulco *et al*., 2016). These characteristics include smart economy, smart people, smart governance, smart living, smart environment, and smart mobility (Giffinger *et al*., 2010). This was used by EU-European Parliament (2014) as well.

In addition to other characteristics, Batagan (2011) and Kamrowska-Zaluska *et al*. (2016) also gave importance to smart education and smart healthcare, which were already identified under smart living by Giffinger *et al*. (2010). Economic competitiveness, image and trademarks, productivity, flexibility in the labour market, as well as international embeddedness and use of online trade were repeated in both Batagan's (2011) and Giffinger *et al*.'s (2010) studies. Authors identified production diversity, quality, and affordability of research and development newly under smart economy. This was again identified by Bosch *et al*. (2017) as well. Under smart governance, every component was repeated. Smart education included fondness towards lifelong learning and participation in public life which are included under smart people by Giffinger *et al*. (2010). Breakdowns under smart living and smart environment were the same.

Chourabi *et al*. (2012) have also identified few sectors under which they assigned similar components, namely management and organization, technology, governance, policy, people and communities, economy, built infrastructure, and natural environment. Their explanations for the economy were in line with Giffinger *et al*.'s (2010) smart economy. They further specified the desired outcomes as business and job creation, workforce development, and productivity. In fact, Bosch *et al*. (2017) identified employment as a component itself, as "people and community" aspect aims to enrich the quality of life by making the citizens more educated, informed, and participatory (Chourabi *et al*., 2012). As per Chourabi *et al*. (2012), in order to emphasise the success factors for projects with extensive use of ICT, related managerial and organisational attributes are addressed along with identifying e-government initiatives under "management and organization"; meanwhile "technology" here refers to sufficient resources to avoid a digital divide and provisions for smart computing technologies, "built infrastructure" refers to the ICT infrastructure and the related, and "policy" context discuss about removing legal and regulatory barriers. This "built infrastructure" was themed as smart architecture and technologies by Ismagilova *et al*. (2019).

Lee *et al*. (2013) in their framework mentioned smart governance which is one of the six characteristics by Giffinger *et al*. (2012). This too present a different angle of governance by bringing in the need of a dedicated organization and defining the roles of its team for promoting the development of smart cities with a proper performance measures, along with policy context as discussed by Chourabi *et al*. (2012). Rest of the concerns were on the areas of urban openness, service innovation, partnerships formation, urban proactiveness, and infrastructure integration.

Berst *et al.* (2014), sets out a list of vital services, namely built environment, energy, telecommunication, transportation, water and wastewater, health and human services, public safety, and payments that cities require. It also highlighted the technological capability in terms of instrumentation and control, connectivity, analytics, interoperability, data management, security and privacy, and computing resources. Kamrowska-Zaluska *et al*. (2016) also identified the same set of services.

Gil-Garcia *et al*. (2015), identified knowledge economy and pro-business environment as a new aspect that was not directly presented in other frameworks. Rest of the component include public services; city administration; collaborative governance, its engagement, policies and other institutional arrangements; human capital and creativity; city infrastructure and built environment; natural environment and ecological sustainability; ICT; and other technologies, data, and information.

Smart economy initiatives such as innovative spirit; economic competitiveness, image and trademarks; international embeddedness or use of on-line trade; smart people initiatives such as ethnic/social pluralism and participation in public life; smart governance initiatives such as participative decision-making; public and social services (including and related to health and human services, water and wastewater, energy, waste management, public safety, payments, and finance); services, infrastructure, and application integration; smart mobility initiative like sustainable and safe transport systems; smart environment initiatives like zero pollution; environmental protection; sustainable resource management and smart living initiatives such as community health; individual safety; housing quality, built environment, or city infrastructure; and education facilities (smart education) put forward by Giffinger *et al*. (2010) were identified by Bosch *et al*. (2017) as well. The authors newly brought in "green economy".

Yigitcanla *et al*. (2018) extracted four of the areas Giffinger *et al*. (2010) focused, namely productivity and innovations in economy, liveability and wellbeing of the society, accessibility and sustainability of the environment, and governance and planning by the government. Anthopoulos *et al*. (2019), after reviewing a number of city conceptualisation models, developed a unified model with eight viewpoints, namely governance, planning and management, city architecture, data and knowledge, people and environment, energy, and health together with six benchmarking tools addressing the smart city development, smart monitoring, policy impact, city capacity and sustainability.

All in all, with the reviewed studies it can be identified that in Ismagilova *et al*.'s (2019) study although they did not represent a framework, the grouping/theming was almost an amalgamation of the all related work. Especially, the representation took the form of an extended review of Giffinger *et al*.'s (2010) components with an understanding of Berst *et al.*'s (2014) framework. However, the outcome of the study would rather be an add on to Ismagilova *et al*.'s (2019) theming and breaking down of components by (Giffinger *et al*., 2010). Figure 1 presents the combined list of the components.

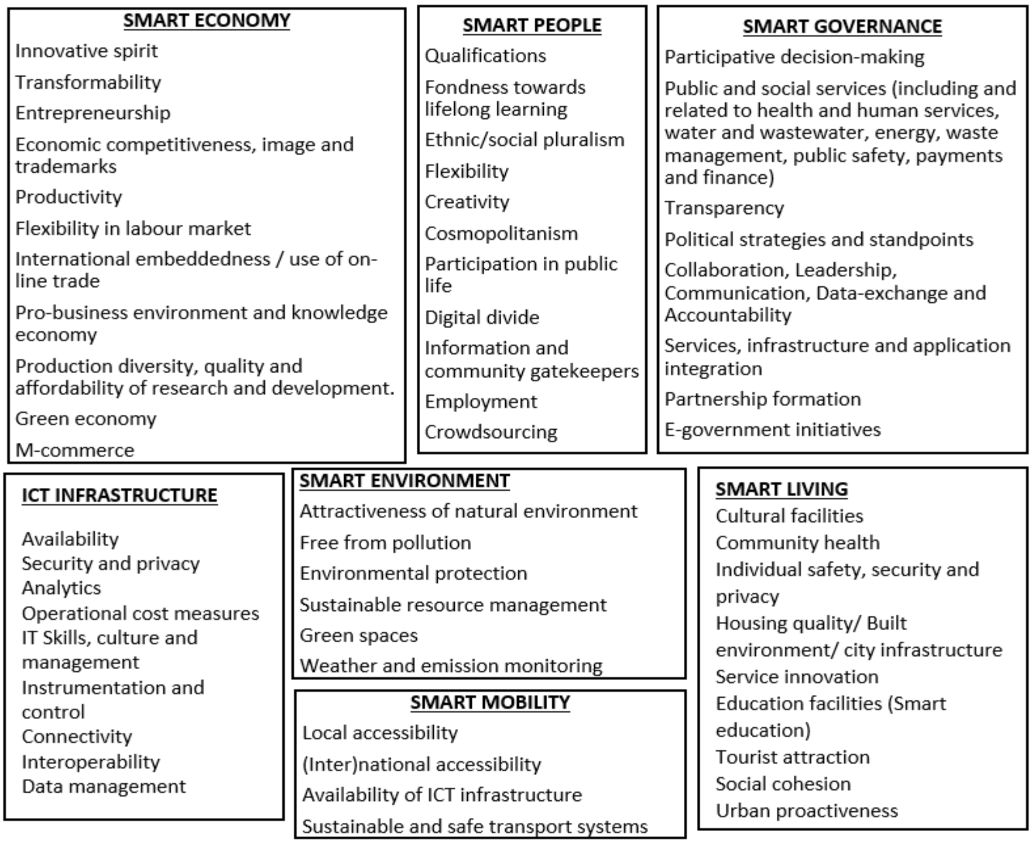

Figure 1: List of components that differentiate a smart city from a basic city

However, this classification does not form a framework, yet a representation as a list. Due to that reason, although Ismagilova *et al*.'s (2019) theming was not a framework but a list of interpretations by the authors, additional terms such as green spaces, weather and emission monitoring under smart environment, crowdsourcing under smart people, M-commerce under smart economy were also identified as components.

6. CONCLUSIONS

Smart cities can be built either as a solution to different existing and completely new problems basic cities face, so as to upgrade the quality lives of citizens and to remark the development in a country. In the corresponding cases, cities can be redeveloped or retrofitted and completely planned from the inception respectively. While the first scenario only focuses 'the challenges a basic city has' so that they can be addressed through smart cities, the second scenario is where the themes of smart cities and accepted characteristics comes in handy. Whatsoever, all definitional elements, components, comparisons with defined city concepts allow outlining the concept and identifying the difference between a basic city and a smart city through understanding the problematic conditions that required to be addressed and what more a smart city will have in compared to a basic city.

The definitional elements clarify that integration of ICT into the urban structure has not been defocused although a priority was given also to integration of infrastructure, data management, and smart people. In fact, while identifying the smart city characteristics some authors have identified smart economy, living, environment, people, governance, and smart mobility as characteristics while ICT facilitation, data management, and analytics as indicators under each of those components. Although the universality of definitions was a question, it can be identified that characteristics are more or less the same, provided that differences in city notion are acceptable. Therefore, although this study does not intent to outline a new framework, all the listed key components are what differentiate a smart city from a basic city. Similarly, by comparing smart city descriptions with other city concepts not only helps to identify smart characteristics but also signifies the existence of smart cities.

In conclusion, the difference of a smart city from a basic city lies with the "smart" prefix before economy, governance, environment, people, living, and mobility. Breaking down of economy, governance, environment, people, living, and mobility into components define the aforementioned smart prefix. Integration of them on an ICT infrastructure, data analytics, and real-time control completes a "smart city" which majorly aims on urban, public services, and citizen development.

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8. REFERENCES

Abbas, H., Shaheen, S. and Amin, M., 2019. *Engineering Large Complex Critical Infrastructures of Future Smart Cities as Self-adaptive Systems*: Springer, Cham.

Albino, V., Berardi, U. and Dangelic, R. M., 2015. Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technology*, 22(1), pp.3-21.

Anthopoulos, L., Janssen, M. and Weerakkody, V., 2019. A Unified Smart City Model (USCM) for smart city conceptualization and benchmarking. *Smart Cities and Smart Spaces: Concepts, Methodologies, Tools, and Applications*, pp.247-264.

Anttiroiko, A.V., Valkama, P. and Bailey, S. J., 2014. Smart cities in the new service economy: Building platforms for smart services. *AI and Society*, 29, pp.323–334.

Batagan, L., 2011. Batagan. *Journal of Applied Quantitative Methods*, 6(3), pp.27-34.

Berst, J., Enbysk, L. and Williams, C., 2014. Smart Cities Readiness Guide: The planning manual for building tomorrow's cities today. *Seattle: Smart Cities Council*.

Bifulco, F., Tregua , M., Amitrano, C. C. and D'Auria, A., 2016. ICT and sustainability in smart cities management. *International Journal of Public Sector Management*, 29(2), pp.132-147.

Blanck, M., Ribeiro, J. L. and Anzanello, M. J., 2019. A relational exploratory study of business incubation and smart cities- Findings from Europe. *Cities*, 88, pp.48-58.

Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.M., Airaksinen, M. and Huovila, A., 2017. CITYkeys indicators for smart city projects and smart cities. *CITYkeys report*.

Caird, S., 2017. City approaches to smart city evaluation and reporting: Case studies in the United Kingdom. *Urban Research and Practice*.

Caragliu, A., Del Bo, C. and Nijkamp, P., 2011. Smart cities in Europe. *Journal of Urban Technology*, 18(2), pp.65-82.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J.R., Mellouli, S., Nahon, K., Pardo, T.A. and Scholl, H.J., 2012, January. Understanding smart cities: An integrative framework. In *2012 45th Hawaii international conference on system sciences* (pp.2289-2297). IEEE.

Elgazzar, R. F. and El-Gazzar, R. F., 2017. *Smart Cities, Sustainable Cities, or Both? A Critical Review and Synthesis of Success and Failure Factors*. Portugal, pp.250-257.

EU-European Parliament, 2014. *Mapping Smart Cities in EU*. Available from: http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOLITRE_ET(2014)507480_EN.pdf

Giffinger, R., Haindlmaier, G. and Krama, H., 2010. The role of rankings in growing city competition. *Urban Research and Practice*, 3(3), pp.299-312.

Gil-Garcia, J.R., Pardo, T.A. and Nam, T., 2015. What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. *Information Polity*, 20(1), pp.61-87.

Goodspeed, R., 2014. Smart cities: moving beyond urban cybernetics to tackle wicked problems. *Cambridge Journal of Regions, Economy and Society*, 8(1), pp.79-92.

Hartley, J., 2005. Innovation in governance and public services: Past and present. *Public Money and Management*, *25*(1), pp.27-34.

Heaton, J. and Parlikad, A. K., 2019. A conceptual framework for the alignment of infrastructure assets to citizen requirements within a Smart Cities framework. *Cities*, 90, pp.32-41.

Ismagilova, E., Hughes, L., Dwivedi, Y.K. and Raman, K.R., 2019. Smart cities: Advances in research – An information systems perspective. *International Journal of Information Managemen*t, 47, pp.88-100.

Kamrowska-Zaluska, D., Elisei, P., Dimitriu, S. and Redweik, R., 2016. *The output report* of *Task 4.3 City information and indicator platform for the ESPRESSO Project* (systEmic Standardisation apPRoach to Empower Smart citieS and cOmmunities), Horizon 2020 Framework Programme, European Union.

Komninos, N., 2015. *The Age of Intelligent Cities Smart environments and innovation-for-all strategies*. 1st ed. New York: Routledge.

Lee, J. H., Hancock, M. G. and Hu, M. C., 2014. Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technological Forecasting & Social Change*, 89, pp.80-99.

Lee, S. H., Han, J. H., Leem, Y. T. and Yigitcanlar, T., 2008. Towards ubiquitous city: Concept, planning, and experiences in the Republic of Korea. *Knowledge-Based Urban Development: Planning and Applications in the Information Era*, pp.148-169.

Loo, B. P. Y. and Tan, W. S. M., 2019. "Mapping" Smart Cities. *Journal of Urban Technology*, 26(2), pp.126-146.

Monzon, A., 2015. *Smart cities concept and challenges: Bases for the assessment of smart city projects*. IEEE, pp.1-11.

Nam, T. and Pardo, T. A., 2011. *Conceptualizing Smart City with Dimensions of Technology, People, and Institutions*. ACM, pp.282-291.

Orlowski, A. and Romanowska, P., 2019. Smart Cities Concept: Smart Mobility Indicator. *Cybernetics and Systems*, *50*(2), pp.118-131.

Paskaleva, K., Cooper, I., Linde, P. and Peterson, B., 2015. Stakeholder Engagement in the Smart City: Making Living Labs Work. *Transforming City Governments for Successful Smart Cities*, pp.115–145.

Psyllidis, A., Bozzon, A., Bocconi, S. and Bolivar, C.T., 2015, July. A platform for urban analytics and semantic data integration in city planning. In *International conference on computer-aided architectural design futures* (pp. 21-36). Springer, Berlin, Heidelberg.

Qian, Y., Wu, D., Bao, W. and Lorenz, P., 2019. The Internet of Things for Smart Cities: Technologies and Applications (Guest editorial). *IEEE Network*, 33(2), pp.4-5.

Samih, H., 2019. Smart cities and internet of things. *Journal of Information Technology Case and Application Research.*

Sharma, S. K. and Meyer, K. E., 2019. The Role of Smart Cities or Regional Hubs. *Industrializing Innovation-the Next Revolution*, pp.163–168.

Tomar, A. and Gupta, N., 2019, April. Redefining Smart Cities–Tradition versus Branding–a Tale of Varanasi. In *Real Corp 2019–is this the real world? Perfect Smart Cities vs. Real Emotional Cities. Proceedings of 24th International Conference on Urban Planning*, Regional Development and Information Society (pp. 941-948). CORP–Competence Center of Urban and Regional Planning.

United Nations, 2018. *The World's Cities in 2016 - Data Booklet*. Department of Economic and Social Affairs: United Nations.

Xie, J., Tang, H., Huang, T., Yu, F.R., Xie, R., Liu, J. and Liu, Y., 2019. A Survey of Blockchain Technology Applied to Smart Cities: Research Issues and Challenges. *IEEE Communications Surveys and Tutorials*.

Yadav, P. and Patel, S., 2015. *Sustainable city, Livable city, Global city or Smart City: What value addition should smart city bring to these paradigms in context of global south*?. Johor Bahru, Malaysia.

Yigitcanlar, T., Kamruzzaman, M., Buys, L., Ioppolo, G., Sabatini-Marques, J., da Costa, E.M. and Yun, J.J., 2018. Understanding 'smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework. *Cities*, *81*, pp.145-160.

Kaluarachchi, M.S., Waidyasekara, K.G.A.S. and Rameezdeen, R., 2019. Workers' behaviour towards noise pollution control on construction sites. In: Sandanayake, Y.G., Gunatilake, S. and Waidyasekara, A. (eds). *Proceedings of the 8th World Construction Symposium*, Colombo, Sri Lanka, 8-10 November 2019, pp. 628-638. DOI: doi.org/10.31705/WCS.2019.62. Available at: https://2019.ciobwcs.com/papers

WORKERS' BEHAVIOUR TOWARDS NOISE POLLUTION CONTROL ON CONSTRUCTION SITES

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ABSTRACT

Noise pollution is a noticeable hazard in construction sites, which can cause severe damage to the health and safety of workers and the neighbouring community. Number of studies have investigated control measures for noise pollution, majority proposing regulatory and engineering control, which are expensive and mostly ineffective. While behavioural changes of workers could contribute to effective noise control, very few past studies have dealt with behaviour of construction workers. To fill this knowledge gap, this study used a questionnaire survey and analysed the responses using structural equation modelling by testing several hypotheses developed using the Norm Activation Model that investigates the relationship between attitudes and behaviour of construction workers. The sample belonged to a wide range of worker categories of major construction firms in Colombo, Sri Lanka. Results revealed that a positive relationship exists between personal norms and environmental behaviour. Furthermore, these personal norms are significantly informed by the awareness of consequences and a sense of responsibility to act to mitigate noise pollution in their sites. Thus, while workers are aware of the negative consequences of noise pollution and are responsible to act, an increase in environmental behaviour will occur via the activation of personal norms. Hence, workers tend to alter their behaviour when having altruistic moral norms. As a practical implication arising out of this research, these worker attributes could be strategically used by construction companies to create a conducive work environment where workers themselves take initiatives to deal with environmental destruction caused by construction activities.

***Keywords**: Construction projects; Health Issues; Noise Pollution; Norm Activation Model.*

1. INTRODUCTION

Noise is the most serious acoustic pollutant (Ballesteros *et al*., 2010) and is defined as 'undesired sound,' which is enough to cause damage to the environmental and health of people exposed to it (Golmohammadi *et al*., 2013). The environmental noise can be illustrated using simple measures such as the overall sound pressure level and fluctuation of levels with time and frequency of sound (Hamoda, 2008). Researchers have identified different sources of noise pollution on construction sites such as site traffic (Geetha and Ambika, 2015), noisy tools and equipment (Geetha and Ambika, 2015; Hamoda, 2008), and construction activities, which directly involve machinery with high noise level, particularly, earthworks consisting of site clearance, excavation, cutting, filling, and

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compaction (Haron *et al*., 2012). According to Ballesteros *et al*. (2010), excavation is the noisiest stage, mainly due to noise from engines of machinery and the peak levels caused by hoe loading. Several studies have attempted to identify noise emission levels from construction site sources (Thalheimer, 2000; Waddington *et al*., 2000; Fang *et al*., 2009). However, it is difficult to estimate the environmental impacts of noise due to size of the project, complex interactions between noise levels, types of construction equipment used, distance from the noise source, and duration of the construction stage (Hamoda, 2008). To mitigate environmental impacts of noise pollution, regulatory and environmental measures are the most popular in construction sites. However, their effectiveness is questionable. In addition, engineering control measures are very expensive to implement. Therefore, researchers and practitioners are now resorting to behavioural changes among workers to ameliorate environmental pollution on construction sites. Fuertes *et al*. (2013) emphasized that environmental behaviour (EB) of workers of construction projects can attain changes by eliminating negative environmental impacts. Thus, EB should address the necessity of collaboration of main roles among project participants to ensure it yields positive environmental effects on both the product and project outcomes (Weston, 2011). However, very little research has been undertaken on EB of construction workers towards noise pollution and its control. Past research on noise pollution has mainly focused on regulatory and engineering control methods. Hence, this study aims to investigate workers' behaviour towards noise pollution on construction sites, which causes severe health impacts on the workers and society if not properly managed.

2. LITERATURE REVIEW

2.1 IMPACT AND CONTROL OF NOISE ON CONSTRUCTION SITES

The most prevalent irreversible occupational hazard due to construction industry is identified as noise-induced hearing impairment, which has caused hearing difficulties to over 120 million people worldwide (Hamoda, 2008). The World Health Organization (WHO) has classified it as having specific effects psycho-physiological wellbeing, interference with speech communication and intended activities, mental health effects, disturbance to sleep, annoyance, effects on domestic behaviour, and diminished performance (WHO, 1990; Golmohammadi *et al*., 2013). Moreover, the National Institute for Occupational Safety and Health of US (NIOSH) (1990) stated hundred-thousands of construction workers are at risk of developing hypertension due to exposure to high levels of noise emission. The effect of noise may not be pronounced instantaneously, but its exposure duration will help decide the social, psychic, and physical detriments on people (Fernandez *et al*., 2009).

Removal of excessive noise is not just a legal responsivity of a construction firm, but also a moral and ethical responsibility. Table 1 highlights the solutions and practices identified in the existing body of literature for noise pollution control at construction sites. These practices help a safer and healthier workplace and further subject to cost savings through high performance and lesser absenteeism and accidents.

Table 1: Solutions and practices for controlling noise pollution at construction sites

Solutions and practices	Source of references
Comply with international standards such as ISO 1996 and 1999	Ballesteros *et al*. (2010)
Designing temporary facilities in each construction phase including strategic positioning of noisy equipment; Acoustic treatments; Monitoring sound level during construction activities; Maintain a good neighbourhood policy and better response regarding complaints	Thomas and Costa (2017)
Noise mitigation plans and assessment revised during construction stage; Use prefabricated and industrialized equipment; Favour equipment with lower noise and vibration emissions; Training and awareness programmes about sound pollution	Thomas and Costa (2017) Fernandez *et al*. (2009)
Keep equipment in good condition; Characterize activities that emit noise	Thomas and Costa (2017) Hamoda (2008)
Periodically conducting medical hearing check-ups for workers; Provide personal hearing devices for workers	Fernandez, *et al*. (2009)
Limit access to noisy zones and isolation of noisy procedures; Breakdown the noise propagation path through barriers and sound enclosures; Use of absorbent materials to reduce sound reflections; Transmit noise and vibration through floating floors; Divide noisy tasks into a limited number of workers to prevent exposure to noise	ISO (1996)
Involve Environmental Impact Assessment (EIA) practitioners during the planning stage of a project	Haron *et al*. (2012) Geetha and Ambika (2015)

2.2 BEHAVIOURAL CHANGES

When considering the characteristics of construction projects, every activity of a project has a direct interaction with the environment. Thus, the behaviour of workers of a project from the commencement of construction to the completion can make a considerable impact on the environment (Yusof *et al*., 2015). Positive environmental behaviour could accompany solutions to the negative impacts that construction activities have on the quality of air, water, land, resources exploitation, ecology, energy consumption, workers' and public health, and sustainability (Shen *et al*., 2011). Gradually the negative impacts from construction projects on the environment can be mitigated through these positive behaviours throughout the design (not only workers but also designers adopting such behaviour) and construction phases of the project (Mora, 2007; Yusof *et al*., 2015).

Environmental and social psychologists demonstrated behaviour is influenced through the attitudes, beliefs, and values of persons (Murray, 2013). Continuously, values, beliefs, and behaviours are rooted through generations and stabilized over the years by sharing the practices and experiences (Braungart, 2013). Thus, a quick change is difficult to achieve. According to Braungart (2013)'s point of view, the construction industry needs a holistic approach encompassing a cultural shift of behaviours and attitudes of various project participants to overcome endemic environmental issues. Further, Robin and Poon (2009) have interpreted "changes of attitudes and practices" is the sixth principle promulgated by the World Conservation Strategy of 1991 to originate a sustainable society. Therefore, the complete transformation of actions and mindsets can be achieved from changes happening in practices and behaviours (Udawatta *et al*., 2015). Wong and Yip (2004) highlighted that behavioural and attitudinal changes of contractors is more significant than adopting new technologies.

Environmental researchers have tried to investigate the relationship between attitudes and behaviours through which some theories have emerged. Most prominent among those theories which are used by many environmental researchers are the Norm Activation Model (NAM) and the Theory of Planned Behaviour (TPB) (Ajzen, 1993; Schwartz, 1977). Schwartz's norm-activation model (NAM) asserts that pro-environmental behaviour depends on directly the activation of altruistic moral norms rather than general environmental concern (Park and Ha, 2014). A person feels a sense of moral obligation if he is responsible for ameliorating consequences and if he expects serious negative outcomes for others. Thus, Schwartz explained the acceptance of personal responsibility and the intensity of awareness of consequences lead to the activation of personal norms (Onwezen *et al*., 2013). The TPB is a modified version of Theory of Reasoned Action (TRA) model, and it consists of a new variable, perceived behaviour control other than the variables of attitude, subjective norm, and intention (Kurisu, 2015).

3. MODEL CONCEPTUALISATION AND HYPOTHESIS DEVELOPMENT

Out of the theories discussed in the literature reviews, NAM is more suitable for this research because it is about intervention behaviour, which applies to when the events are already in place that someone believes will lead to harmful consequences for others and oneself collectively (Cordano *et al*., 2011). The relationship between independent latent variables and the latent dependent variable considered under this study is illustrated in Figure 1 as the conceptual model of NAM.

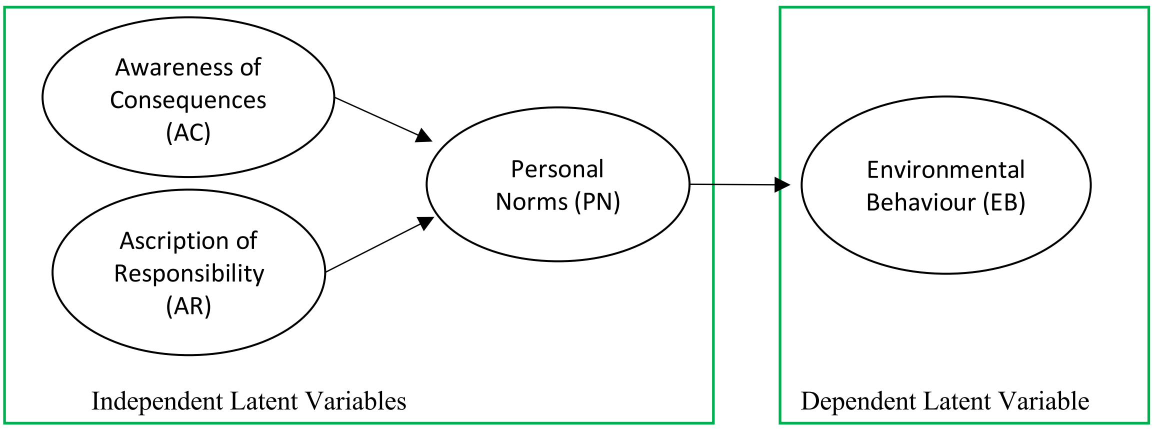

Figure 1: Conceptual model used for this study

Personal Norms (PN) is referred to as the feeling of "moral obligation to perform or refrain from specific actions" (Schwartz and Howard, 1981, p. 191). Thus, the following hypothesis is developed:

H1: Personal Norms significantly and positively affect environmental behaviour.

Awareness of Consequences (AC) is defined as the awareness of negative consequences for others when not taking pro-social actions (De Groot and Steg, 2009). Thus, the following hypothesis is developed:

H2: Awareness of consequences significantly and positively affect personal norms.

Ascription of Responsibility (AR) is described as the feeling of responsibility when not acting pro-socially for the negative consequences (De Groot and Steg, 2009). Thus, the following hypothesis is developed:

H3: Ascription of responsibility significantly and positively affects personal norms.

4. RESEARCH METHOD

A survey is a systematic way of collecting primary data, which can be efficiently utilized to suggest possible reasons for relationships in a model comprised of key variables (Saunders *et al*., 2009).

4.1 PROCEDURE

The questionnaire survey expects to investigate the environmental behaviour of construction workers towards noise pollution control in construction sites. The sample was selected from the SC1- and SC2-graded registered contracting firms in Construction Industry Development Authority (CIDA) in Sri Lanka, using purposive convenience sampling technique. The respondents consisted of tradesmen, plant operators, and unskilled workers. When selecting the sample size, the study considered the rules of thumb of Partial Least Squares Structural Equation Modelling (PLS-SEM). For the application of analysing tool of PLS-SEM, the minimum sample size should be equal to ten times the largest number of formative indicators used to measure one latent construct. Thus, 100 respondents were determined for the sample. Table 2 presents the response rates of each worker category. Female representation of the sample was around 2% of the total respondents.

Table 2: Profile of the construction workers according to the role and work experience

		Profession			Number of respondents	Experience of respondents
		Tradesmen	*Plant operator*	*Unskilled workers*		
Working Experience (years)	Less than 5	6	12	5	23	24%
	5 to 10	14	4	12	30	32%
	11 to 20	12	2	17	31	33%
	More than 20	4	-	6	10	11%
Number of respondents		36	18	40	94	94%
Response rate		38%	19%	43%	94%	

The mean of the descriptive analysis helped to analyse perceptions with a scale that has been employed in the study of Kazaz and Ulubeyli (2007). Accordingly, a difference of 1(strongly disagree) - 5 (strongly agree) of the Likert scale and intervals with 0.8 was developed to determine the degree of central tendency based on following categorizations; 1.00 ≤ "Strongly disagree" ≤ 1.80; 1.80 < "Disagree" ≤ 2.60; 2.60 < "Neutral" ≤ 3.40; 3.40 < "Agree" ≤ 4.20; and 4.20 < "Strongly agree" ≤ 5.00.

Kazaz and Ulubeyli (2007) have also used a similar approach that comprises intervals of the study for investigating the drivers of productivity among construction workers. The rank defined, when there are two or more variables, having same mean values, the priority is assigned for the variables according to the descending order of standard deviation or coefficient of variation (COV) (Kumaraswamy and Chan, 1998).

4.2 MEASURE OF CONSTRUCT

The questionnaire comprised of general information, demographics, and variables of environmental behaviour. The items were developed using literature and variable definitions to ensure content validity. Three items were developed to measure the awareness of consequences, one for ascription of responsibility, four for personal norms, and two for environmental behaviour of construction workers regarding the noise pollution on construction sites.

5. RESULTS

5.1 WORKERS' VIEW ON THEIR RESPONSIBLE BEHAVIOUR

As shown in Table 3, the overall mean scores for the ten (10) constructs used to measure the latent variables affecting noise pollution control behaviour ranges from 4.00 to 5.00. Out of them, six (06) constructs were rated as 'strongly agree', which consists of one each from awareness of consequences, personal norms, and environmental behaviour. The rest of the constructs were rated as 'agreed'.

Table 3: Statistical measures of the items of noise pollution

Code	Items	Min	Max	Mean	Std. Dev	COV (%)
AC-1	The noise pollution in construction sites causes serious health impacts to workers	1	5	4.64	0.80	17.24
AC-2	I am aware of the negative influence of noise pollution on my site on the society	1	5	4.25	0.85	20.00
AC-3	The noise pollution in construction sites causes nuisance and discomfort to the neighbourhood	1	5	4.15	1.03	24.82
AR-1	I feel I am jointly responsible for the consequences of noise pollution of my site on workers' health and safety	1	5	4.18	0.92	22.01
PN-1	It would be against my moral principles not to act against noise pollution issues in my site	1	5	4.49	0.87	19.38
PN-2	I have a moral obligation to protect the environment from noise pollution arising from my site	1	5	4.61	0.83	18.00
PN-3	I would feel guilty about not acting against noise pollution arising from my site	1	5	4.01	0.97	24.19
PN-4	I feel obliged to protect the environment from noise pollution from my site	1	5	4.19	0.72	17.18

Code	Items	Min	Max	Mean	Std. Dev	COV (%)
EB-1	I help reduce noise pollution in my site	2	5	4.45	0.74	16.63
EB-2	I am very concerned not to generate noise in my work; If it is unavoidable, I take precautions to minimize it	1	5	4.55	0.69	15.16

5.2 MODEL VALIDATION

Past studies have employed Structural Equation Modelling (SEM) (e.g., Zailani *et al.*, 2015; Abdullah *et al.*, 2016) considering its capability to perform a full test of concepts and theories (Rigdon, 1998). Two techniques have been used under SEM that are variance-based partial least squares (PLS-SEM) and covariance-based techniques (CB-SEM). However, the technique will depend on the research objectives, characteristics of data, and model structure (Gefen *et al*., 2011). Hair *et al*. (2013) suggested that PLS-SEM is superior to CB-SEM for exploratory studies. Thus, PLS-SEM was selected for this study since the study is exploratory in nature as the effect of awareness of consequences and ascription of responsibility on the environmental behaviour of construction workers has not previously tested. Notably, this technique was employed using the software SmartPLS 3.0. The model testing involved a two-step approach followed by Hair *et al*. (2013) to evaluate the reliability and validity of the indicators before validating the structural relationship of the model. The first step was analysing measurement model, followed by analysing structural relationships among the latent constructs using the structural model as the second step.

5.2.1 Evaluation of Measurement Model

The internal consistency reliability and validity of constructs were assessed. Table 4 presents a summary of factor loadings, Composite Reliability (CR), and Average Variance Extracted (AVE) of all indicators.

Table 4: The factor loadings, CR, and AVE of the PLS algorithm

Construct	Indicators	Factor Loadings	CR	AVE
Awareness of Consequences	AC-1	0.640	0.815	0.598
	AC-2	0.811		
	AC-3	0.852		
Ascription of Responsibility	AR-4	1.000	1.000	1.000
Personal Norms	PN-5	0.844	0.931	0.773
	PN-6	0.955		
	PN-7	0.872		
	PN-8	0.841		
Environmental Behaviour	EB-9	0.972	0.971	0.944
	EB-10	0.972		

The loadings of all indicators were above 0.7, signifying satisfactory indicator reliability (Hair *et al*., 2011). The AC-Noise 1 was retained, based on the contribution to content validity. The internal consistency reliability of all constructs, which were evaluated using CR, was above 0.7, and the convergent validity of constructs, evaluated using AVE was above 0.5; thus, the results satisfy a sufficient degree of rule-of-thumb according to Hair *et al*. (2011). The discriminant validity was assessed using two approaches. First, the cross-loadings were examined to validate that the opposing constructs are higher than loads of indicators. Second, Table 5 shows, in accordance with the Fornell and Larcker criteria, the discriminant validity of each latent construct is higher than the construct's highest squared correlation with other constructs of the model.

Table 5: Construct correlations versus square root of AVE

	AR	AC	EB	PN
AR	**1.000**			
AC	0.533	**0.773**		
EB	0.438	0.291	**0.972**	
PN	0.678	0.723	0.384	**0.879**

Note: Diagonals represent the square root of the AVE.

Thus, both analyses confirm the discriminant validity of all constructs.

5.2.2 Evaluation of Structural Model

The explanatory power of the research model was assessed using the Coefficient of determination (R2). The predictive relevance (Q2) value (0.127), larger than zero, indicates that the model has satisfactory predictive relevance (Hair *et al*., 2011). The bootstrapping with 5,000 bootstrap samples were applied to assess the path coefficients' significance. Table 6 represents the path coefficient and bootstrapping results of the structural model. The results indicate that the effect of AR ($\beta=0.409$, $p<0.001$) and AC ($\beta=0.505$, $p<0.001$) on PN and PN ($\beta=0.384$, $p<0.001$) on EB are significant and positive, thereby supporting H1, H2, and H3.

6. DISCUSSION

The model was conceptualised to ascertain whether the awareness of consequences, the ascription of responsibility, and personal norms influence the environmental behaviour of construction employees when making decisions about their behaviour towards the environmental impacts. Three (03) hypothesis were tested, as depicted in Table 6. From the first hypothesis, the results established that the relationship between PN and EB is positive and significant. This proves PN is a latent variable of EB and, workers who have high altruistic PN are more likely to control noise in their sites. Thus, an increase in EB can happen while increasing PN of a person. It further indicates that employees tend to control noise emission in their work as personal norm dictates that it is the right thing to do.

Table 6: The path coefficients and bootstrapping results of the structural model

Hypothesis	Relationship	Path coefficient	Decision
H1	Personal Norms → environmental behaviour	0.384^{***}	Supported
H2	Awareness of consequences → personal norms	0.505^{***}	Supported
H3	Ascription of responsibility → personal norms	0.409^{***}	Supported

$^{***}p<0.001$

The second hypothesis of the model claimed that awareness of consequences significantly and positively affects personal norms. The output of the PLS analysis confirmed this hypothesis. This relationship was tested concerning the noise pollution caused from construction sites and could be interpreted as the generation of moral obligation to act towards noise pollution which is influenced by the awareness of negative consequences of noise pollution. Moreover, it illustrates that when workers are aware of the severe health impacts on workers and community due to noise emitted by site activities, a change in behaviour could occur by the activation of personal norms. Similarly, the third hypothesis confirms the relationship between PN and AR being positive and significant. Hence, personal norms can be activated by assigning responsibility of the action. This reveals that when a person feels jointly responsible for the consequences of noise pollution of their site on workers' health and safety, it generates moral obligations to protect the workers from noise pollution. Thus, the model postulating the significant and positive relationship between EB and PN was confirmed from the PLS-SEM statistical analysis. Furthermore, the model confirms this relationship is moderated by both AC and AR. The relationship between PN and EB become positively strong when employees are aware of the seriousness of the negative outcomes of noise pollution for others and feel self-responsible for the consequences of their behaviour. In contrast, employees have successfully neutralised moral obligation on their behaviour while they are less aware of the negative consequences and denying the responsibility of consequences. Hence, well-established altruistic moral norms willingly alter the behaviour of someone, and this concept should be cleverly utilised between sites to obtain a significant reduction in environmental pollution that emerges from many construction activities.

7. CONCLUSIONS

This study aimed to investigate the environmental behaviour of workers towards noise pollution control in the construction industry. The findings confirmed that the awareness of the negative consequences of noise pollutions and a feeling of self-responsibility could affect the environmental behaviour of construction employees via the activation of personal norms. The study revealed a significant fact to the theory that other than the environmental ethics, environmental behaviour could be changed by normative concerns. The study provides several practical implications for construction companies, where some of the worker attributes identified could be used to change worker behaviour and mitigate a considerable portion of noise pollution arising out of construction activities. There are many strategies proposed in the past literature that could be used to enhance pro-environmental attitudes and behaviour of workers. Further research is needed to test which of those strategies are suitable for construction workers, especially regarding attitude and behaviour on noise pollution.

8. REFERENCES

Abdullah, M., Zailani, S., Iranmanesh, M. and Jayaraman, K., 2016. Barriers to green innovation initiatives among manufacturers: the Malaysian case. *Review Managerial Science*, 10(4), pp.683-709.

Ballesteros, M.J., Fernández, M.D., Quintana, S., Ballesteros, J.A. and González, I., 2010. Noise emission evolution on construction sites. Measurement for controlling and assessing its impact on the people and on the environment. *Building and Environment*, *45*(3), pp.711-717.

Braungart, M., 2013. Foreword. In: R. Crocker and S. Lehmann, eds. *Motivating change: sustainable design and behaviour in the built environment*. Routledge, pp. xxii-xxiii.

Cordano, M., Welcomer, S., Scherer, R.F., Pradenas, L. and Parada, V., 2011. A cross-cultural assessment of three theories of pro-environmental behavior: A comparison between business students of Chile and the United States. *Environment and Behavior*, *43*(5), pp.634-657.

De Groot, J. I. M. and Steg, L., 2009. Morality and Prosocial Behavior: The Role Morality and Prosocial Behavior: The Role in the Norm Activation Model. *The Journal of Social Psychology*, 149(4), pp.425–449.

Fang, J., Zhou, Y., Hu, X. and Wang, L., 2009. Measurement and analysis of exhaust noise from muffler on an excavator. *International Journal of Precision Engineering and Manufacturing*, 10(5), pp.59–66.

Fernandez, M., Quintana, S., Chavarria, N. and Ballesteros, J., 2009. Noise exposure of workers of the construction sector. *Applied Acoustics*, 70, pp.753–760.

Fuertes, A., Casals, M., Gangolells, M., Forcada, N., Macarulla, M. and Roca, X., 2013. An environmental impact causal model for improving the environmental performance of construction processes. *Journal of Cleaner Production*, *52*, pp.425-437.

Geetha, M. and Ambika, D., 2015. Study on noise pollution at construction site. *International Journal of Research in Engineering and Technology (IJRET),* 4(2), pp.420-421.

Gefen, D., Rigdon, E.E. and Straub, D., 2011. Editor's comments: an update and extension to SEM guidelines for administrative and social science research. *MIS Quarterly*, pp.iii-xiv.

Golmohammadi, R., Mohammadi, H., Bayat, H., Habibi Mohraz, M. and Soltanian, A.R., 2013. Noise annoyance due to construction worksites. *Journal of Research in Health Sciences*, *13*(2), pp.201-207.

Hair, J., Hult, G., Ringle, C. and Sarstedt, M., 2013. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM*). Sage, Thousand Oaks.

Hair, J., Ringle, C. and Sarstedt, M., 2011. PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice,* 19(2), pp.139-151.

Hamoda, M., 2008. Modeling of Construction Noise for Environmental Impact Assessment. *Journal of Construction in Developing Countries,* 13(1), pp.79-89.

Haron, Z., Noh, H.M., Yahya, K., Omar, W. and Majid, Z.A., 2012. Assessing noise emission levels from earthwork construction equipment. *Malaysian Journal of Civil Engineering*, *24*(1), pp.13-28.

ISO, 1996. International standard: Acoustics – Recommended practice for the design of low-noise workplaces containing machinery, ISO 11690-1:1996.

Kazaz, A. and Ulubeyli, S., 2007. Drivers of productivity among construction workers: a study in a developing country. *Building and Environment*, 42(5), pp.2132-2140.

Kumaraswamy, M. and Chan, D., 1998. Contributors to construction delays. *Construction Management and Economics*, 16(1), pp.17-29.

Kurisu, K., 2015. *Pro-environmental Behaviors*. Tokyo: Department of Urban Engineering, The University of Tokyo.

Mora, E., 2007. Life cycle, sustainability and the transcendent quality of building materials. *Building Environment,* 42(3), pp.1329-1334.

Murray, P., 2013. Leading by design: Cultivating self-leadership for sustainability. In *Motivating Change: Sustainable Design and Behaviour in the Built Environment* (pp.159-184). Routledge.

National Institute for Occupational Safety and Health (NIOSH), 1990. National Occupational Exposure Survey. Report No. 29 CFR 1926.52., Washington D.C., USA: National Institute for Occupational Safety and Health.

Park, J. and Ha, S., 2014. Understanding consumer recycling behavior: Combining the theory of planned behavior and the norm activation model. *Family and Consumer Sciences Research Journal*, *42*(3), pp.278-291.

Rigdon, E., 1998. Structural equation modeling. *In: G. Marcoulides, ed. Modern Methods for Business Research. Erlbaum, Mahwah*, pp.251-294.

Robin, C. and Poon, C., 2009. Cultural shift towards sustainability in the construction industry of Hong Kong. *Journal of Environmental Management*, 90, pp.3616–3628.

Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. 5th ed. Edinburgh Gate, England: Pearson Education.

Schwartz, S. H. and Howard, J. A., 1981. A normative decision-making model of altruism. *Altruism and Helping Behaviour*, pp.89-211.

Shen, L., Wu, Y. and Zhang, X., 2011. Key assessment indicators for the sustainability of infrastructure projects. *Journal of Construction Engineering and Management,* 137(6), pp.441-451.

Thalheimer, E., 2000. Construction noise control program and mitigation strategy at the Central Artery/Tunnel Project. Noise Control Engineering Journal, 48 (5), pp.157–165.

Thomas, N.I.R. and Costa, D.B., 2017. Adoption of environmental practices on construction sites. *Ambiente Construído*, *17*(4), pp.9-24.

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G., 2015. Attitudinal and behavioural approaches to improving waste management on construction projects in Australia: benefits and limitations. *International Journal of Construction Management,* 15(2), pp.137-147.

Waddington, D., Lewis, J., Oldham, D. and Gibbs B.M., 2000. Acoustic emission from construction equipments. *Building Acoustics,* 7(3), pp.201–215.

Weston, J., 2011. Screening for environmental impact assessment projects in England: what screening? Impact Assess. *Project Appraisal,* 29(2), pp.90-98.

Wong, E.O. and Yip, R.C., 2004. Promoting sustainable construction waste management in Hong Kong. *Construction Management and Economics*, *22*(6), pp.563-566.

Yusof, N., Iranmanesh, M. and Awang, H., 2015. Pro-environmental practices among Malaysian construction practitioners. *Advances in Environmental Biology*, 9(5), pp.117-119.

Zailani, S., Kanapathy, K., Iranmanesh, M. and Tieman, M., 2015. Drivers of halal orientation strategy among halal food firms. *British Food Journal,* 117(8), pp.2143-2160.

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