



21ST ANNUAL  
**PAQS**  
2017  
VANCOUVER

21ST ANNUAL  
**PAQS2017**  
VANCOUVER, BC CANADA

**CONGRESS  
PROCEEDINGS**



21<sup>ST</sup> ANNUAL  
**PAQS2017**  
VANCOUVER, BC CANADA

*Green Developments:  
The New Era*



# CONGRESS PROCEEDINGS

FOR THE

## 21<sup>ST</sup> ANNUAL PACIFIC ASSOCIATION OF QUANTITY SURVEYORS CONGRESS

July 24 & 25, 2017

Vancouver, BC, Canada

Westin Bayshore Vancouver Hotel

[www.paqs2017.com](http://www.paqs2017.com)



## Proceedings for the 21<sup>st</sup> Annual Pacific Association of Quantity Surveyors Congress (PAQS 2017)

### Congress Theme: **Green Developments: The New Era**

Subtheme 1: **Living within Planetary Boundaries**

Subtheme 2: **Delivering High Performance Buildings Cost-Effectively**

Subtheme 3: **Working Smarter with Nature and Green Infrastructure**

Subtheme 4: **Fifty Shades of Green (Assessing Building Performance)**

### Congress Organizers:

Canadian Institute of Quantity Surveyors

90 Nolan Court, Unit 19

Markham, ON L3R 4L9

Toll free. +1 (866) 345-1168

Tel: (905) 477-0008

Fax: (905) 477-6774

Email: [execdir@ciqs.org](mailto:execdir@ciqs.org)

[www.ciqs.org](http://www.ciqs.org)

Published online by the Canadian Institute of Quantity Surveyors, December 2017

ISBN: 978-1-896606-33-0

*Disclaimer: The authors, editors, and publisher (CIQS), will not accept any legal responsibility for any errors or omissions that may be made in this online publication. CIQS makes no warranty, express or implied, with respect to the material contained herein. All papers published in these congress proceedings solely reflect the views and/or opinions of the respective author(s).*



## Introduction

**The Pacific Association of Quantity Surveyors (PAQS)** is an international association of national organizations representing Quantity Surveyors in the Asia and Western Pacific region.

### PAQS Mission:

- The promotion of the practice of quantity Surveying (QS) in the region.
- The promotion of “best practice” for QS in the region.
- The promotion of dialogue between member organizations.
- Encouragement of regional co-operation in the practice of QS.
- Fostering of research appropriate to the better understanding of building practice in the region.
- Rendering of assistance to members of member organizations working in each other's countries.

The 1st PAQS Congress was held in Singapore in June 1997 and this included the PAQS annual Board meeting and a technical and social program. The Congress was opened to delegates from all the PAQS member countries and approximately 160 attended the program. At this meeting the Institution of Surveyors Malaysia attended officially for the first time as a full member and Mr. Edward Tang from the SISV was elected as the PAQS Chairman and he assumed the Chair at the conclusion of the Congress. At this meeting the member countries agreed to support a research project by the HKIS into Professional Ethics in the Region and also established the annual rotation of the PAQS Congress between the member countries.

In May 1996 another PAQS meeting and professional seminar were held in Hong Kong, during which the Chairman was appointed and a draft Constitution prepared by the NZIQS was formally accepted for the establishment of the Pacific Association of Quantity Surveyors (PAQS). Professor Dennis Lenard from the AIQS, who had chaired the meeting in 1995, was confirmed as the first Chairman of the PAQS and the AIQS accepted the role of the PAQS Secretariat.

The 21<sup>st</sup> annual PAQS Congress was hosted by the Canadian Institute of Quantity Surveyors (CIQS). CIQS is the premier professional association, governing professional quantity surveying in Canada. CIQS is also a functional part of various other professional Quantity Surveying organizations around the world such as the International Cost Engineering Council (ICEC) and the European Council of Construction Economists (CEEC).

The PAQS2017 program included 4 keynote speakers, 4 plenary feature panels, 16 technical presentations, a PechaKucha Fair with 23 presentations, multiple poster presentations, an exhibit & poster hall and several networking social functions. A total of 56 abstracts were received with 27 being accepted for oral presentation and another 22 as poster presentations. All abstracts were reviewed by a minimum of two reviewers of the abstract review committee, who are experts in the field of Quantity Surveying, through an independent peer review process. A consistent evaluation process and set of criteria were applied across the four sub-themes recognized by PAQS. All the results were carefully reviewed and confirmed by the PAQS 2017 Program Committee.

Angela Lai  
Chair Abstract Review Committee PAQS17  
CIQS Board of Directors  
Past President, CIQS, BC





## TABLE OF CONTENTS

### Subtheme 2: Delivering High Performance Buildings Cost-Effectively

#### ALTERNATIVE COMPOSITE BUILDING SYSTEMS

*J.J.A Jansen, Mikail Jordaan and PAS Bowmman, University Of Pretoria, South Africa* Pages 7-16

#### AN INQUIRY INTO THE CONTROL OF DISPUTES IN INTEGRATED TRANSPORTATION HUB PROJECT

*Yin Yu, Tianjin University of Technology, China* Pages 17-23

#### BARRIERS IN IMPLEMENTING BUILDING INFORMATION MODELLING (BIM) IN QUANTITY SURVEYING FIRMS

*Sing-Sing Wong and Yew Zek-Ung, University College of Technology Sarawak, Malaysia* Pages 24-29

#### COST CERTAINTY: A LEAD DRIVER FOR 5D BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION

*Tochukwu Moses and Glynis Hampton, University of Wolverhampton, United Kingdom* Pages 30-53

#### COST OVERRUN OF ICONIC BUILDINGS: MANAGING CONSTRUCTION COST THROUGH BIM (A CONCEPTUAL PAPER)

*May Chuan Theong and Lee Xia Sheng, University of Reading Malaysia, Malaysia* Pages 54-63

#### DELIVERING COST EFFECTIVE SUSTAINABLE PUBLIC RENTAL HOUSING DEVELOPMENTS – THE HONG KONG EXPERIENCE

*Sr T T Cheung, J.P. and Sr Sunny S L Choi, Hong Kong Housing Authority, Hong Kong* Pages 64-73

#### EXPANED POLYSTYRENE BUILDING SYSTEM VERSUS BRICK AND MORTAR BUILDING SYSTEM

*J.J.A. Jansen, G. Du Plessis, A. Oosthuizen and S. Jansen van Rensburg, University of Pretoria, South Africa* Pages 74-83

#### GREEN COSTS MORE? AN EMPIRICAL STUDY ON THE COSTING OF GREEN BUILDING PROJECTS WORLDWIDE

*Mei-yung Leung, City University of Hong Kong, Hong Kong and Isabelle Y.S. Chan, University of Hong Kong, Honk Kong* Pages 84-92

#### HONG KONG'S BUILDING ENERGY SAVING PLANS IN RESPONSE TO CLIMATE CHANGE

*Paul HK Ho, City University of Hong Kong, Hong Kong* Pages 93-107

#### INTERNAL PROJECT COST AUDIT FOR MITIGATION OF RISKS AND REDUCTION OF CONSTRUCTION COSTS OF HIGH PERFORMANCE BUILDINGS IN HONG KONG PROPERTY DEVELOPERS

*Joseph H.C. Chong, Hong Kong Institute of Surveyors, Honk Kong* Pages 108-127



SOUTH AFRICAN PERSPECTIVES ON THE BUSINESS CASE FOR GREEN BUILDING <i>DJ Hoffman, C Coetzee and E Farmer, University of Pretoria, South Africa</i>	Pages 128-138
STAKEHOLDER PARTICIPATION TRENDS IN GREEN BUILDINGS DURING 2009-2016 <i>D J Hoffman, J Cloete, L van der Schijff and L Wagner, University of Pretoria, South Africa</i>	Pages 139-149
SUSTAINABLE DEVELOPMENT & BIM – THE ROLE OF THE 5D QUANTITY SURVEYOR <i>Dr. Peter Smith, University of Technology Sydney, Australia</i>	Pages 150-160
THE VIABILITY AND SUSTAINABILITY OF AERATED AUTOCLAVED CONCRETE IN SOUTH AFRICAN CONSTRUCTION <i>Mr. J.J.A. Jansen , Mr. U. Erasmus , Mr. M. Gomes , Mr. Z. Pelzer and Mr. A. Yared, University of Pretoria, South Africa</i>	Pages 161-171
THE VIABILITY OF USING ALTERNATIVE BUILDING SYSTEMS IN THE GOVERNMENT SUBSIDISED HOUSING ENVIRONMENT <i>Mr. J.J.A. Jansen and Mr. A.C. Fourie, University of Pretoria, South Africa</i>	Pages 172-180
WHOLE LIFE CYCLE COSTING FOR SUSTAINABLE FACILITY MANAGEMENT <i>Noor Azeyah Khiyon, University of Reading Malaysia, Malaysia</i>	Pages 181-190

#### **SUB-THEME 4 - Fifty Shades of Green (Assessing Building Performance)**

A COMPARATIVE STUDY OF THE PERFORMANCE OF GREEN BUILDINGS IN HONG KONG AND SINGAPORE <i>Ellen Lau and Lo Chung Hay, Haywood, Birmingham City University, United Kingdom</i>	Pages 191-205
SUSTAINABLE RETROFITTING – GLOBAL STRATEGIES & IMPLEMENTATION ISSUES <i>Dr Peter Smith, University of Technology Sydney, Australia</i>	Pages 206-216
THE INFINITE EVOLUTION OF GREEN BUILDING AND SUSTAINABILITY <i>Dr. Alexia Nalewaik, QS Requin Corporation, United States</i>	Pages 217-224

# ALTERNATIVE COMPOSITE BUILDING SYSTEMS

Mr. J.J.A. Jansen <sup>1</sup>, Mr. M. Jordaan <sup>2</sup> and Mr. P.A.S. Bornman

<sup>1</sup> Lecturer, [riaan.jansen@up.ac.za](mailto:riaan.jansen@up.ac.za)

<sup>2</sup> Post Graduate Student, [mikailtuks@gmail.com](mailto:mikailtuks@gmail.com)

<sup>3</sup> Post Graduate Student, [albert.bornman@me.com](mailto:albert.bornman@me.com)

*Department of Construction Economics, Engineering, Built Environment and Information  
Technology Faculty, University of Pretoria, Corner Lynnwood and University Road,  
Hatfield, Gauteng, South Africa, 0002*

## ABSTRACT

Conventional building systems such as brick and mortar, although proven not to be the best in terms of embodied energy and life cycle costing, are still used for the majority of construction work in South Africa. Although a number of composite building systems have been certified by Agrément South Africa (ASA), very few are implemented commercially. A variety of data collection methods were used to compare the conventional brick and mortar systems with the composite building systems. Detailed observations were made at a site that makes use of a specific composite system (Green Crete) to identify the challenges and benefits of this system. A comparison on the thermal resistance values, compression strength and fire-rating was done between the two systems by using data from the South African Bureau of Standards and Agrément South Africa. A case-study was used to compare the construction costs of a specific composite system and a conventional brick and mortar system for a pre-primary school and a residential house. The study found that the composite system outperformed the conventional brick system in terms of quality and costs. Further, in terms of the identified challenges it was found that the market is more comfortable with known building systems.

Keywords: Alternative Building Technologies, Conventional Building Systems, Construction costs, Composite Systems, Thermal Resistance

## INTRODUCTION

Innovation is critical to ensure a sustainable built environment. Scarce resources, climate change and an increasing population challenges the way the built environment currently operates. Only 70% of the current building resources will still be available in 2030, therefore it is important to rethink how one will build future buildings and with which sustainable resources (Bristow, 2012). Various alternative building technologies (ABTs) are registered and approved by Agrément South Africa, an independent agency which evaluates the fitness-for-purpose of non-standardised construction products. Despite the fact that a lot of these ABTs with known advantages exist, they are not used to its fullest capacity. With Agrément South Africa it is possible to find approved alternative building systems. The Construction Management profession revolves around building methods and the materials being used to construct a building while the Quantity Surveying profession revolves around the cost of buildings and the cost implications when different building methods are used. As professionals, the construction managers and quantity surveyors should therefor focus on innovation.

## MAIN BODY

Africa is the second largest continent in the world and is also the second largest populated continent. As estimated by the World Review Population Organization, Africa will reach 1.9 billion people by the year 2050 (ConstructionSA, 2015). Many African countries face severe realization of economic

circumstances with infrastructural and construction development, which is vital but economically demanding (ConstructionSA, 2015). In Africa many materials used in conventional building methods are regarded as expensive and not always accessible. According to Joe Odhiambo, “new cutting edge ideas and innovation in the construction industry happen constantly and the pace of the change is bound to escalate with time. With technology growing in leaps and bounds, so does the potential for innovation within the construction industry” (ConstructionSA, 2015).

Skillicorn (2014), defines innovation as, “making changes in something that has been established, especially by introducing new methods, ideas, or products”. If one looks at the definition of innovation and what it holds in regards to the built environment it clearly follows a different approach to the conventional methods, products and ideas already established in the built environment. Innovation is also the act of coming up with new methods, products and ideas that have never been done before and that are in some ways more advantageous.

There are several definitions to explain what innovation is. Slaughter (1998) explained that “innovation is any significant change and improvement in a product, system or process that is new to the institution developing it.” Stewart and Fenn (2006) defined innovation as “exposing profitable ideas to get a competitive advantage over the competition.” In summary, innovation in construction can be thought of as new ideas and practices and also products or processes that are designed to help to better the performance and efficiency of a company or institution (Egbu, 1998).

Innovative products are new, and therefore are not yet standardized in full by the South African Bureau of Standards (SABS) or the code of practice known as the South African National Standards (SANS). Agrément South Africa (ASA) is the only body recognized in South Africa that evaluates innovative construction products and systems (ConstructionSA, 2015). It provides alternative solutions to conventional building products and methods, which are regarded as expensive and also associated with long completion times and acknowledges the objectives for assessment of these innovative and construction products, systems, processes, materials and components. ASA promotes the social economic development in South Africa by introducing, applying and utilizing satisfactory innovative development (Agrément, 2014).

The SABS is a statutory body that regulates standardization and quality throughout the rendering of services according to the Standards Act, 2008 (Act no. 29 of 2008). It develops and amends new standards and remove standards that are not required. The SABS tests products against the required SANS and then offers system certification to these products and systems (SABS, 2015).

The purpose of the SABS and ASA is different to one another. The SABS only standardizes conventional systems that are being used by manufacturers and contractors. Agrément South Africa however steps in where methods, products, process of production or innovative use of materials are developed which fall outside the scope of the SABS. In these cases, Agrément South Africa can test such subjects and produce certification. Although the certification offered by Agrément South Africa is not an SABS standard, it provides assurance of use for the end user. An Agrément South Africa certified system can however become a SABS approved standard, for example solar-powered geysers (Agrément, 2014).

Composite building systems is one of many types of ABTs available in the market. A composite building system is an alternative building system where two or more separate elements are combined to form one new element (Ashland, 2012). Different kinds of composite building systems exist, for example structured insulated panels (SIPS) and wet work composites. SIPS are composites where the panels acts as a permanent formwork for aggregate infill, often referred to as a sandwich system (SIPS, 2013). The aggregate infill, also known as the core, mostly consists of the insulation for the SIPS system. The wet work composites comprises of materials mixed in a paste or sludge form that hardens within a set time. An example of a conventional wet work composite system is concrete that comprises of a mixture of aggregates, water and cement. The wet work composites can be pre-casted into modular building blocks and are referred to as composite blocks. In some cases, like with composite concrete,



the alternative composite can be casted in situ on site. Composites may be casted in temporary or permanent formwork.

A composite panel system is generally manufactured in a factory environment. This means that the skilled labourers can manufacture year round without any natural interruptions (Ashland, 2012). Manufacturing in a controlled environment saves time. This directly saves costs which is one of the main objectives of alternative building systems (Chan, 1996). Compared to the conventional brick systems, both the SIP and the block system is easier to transport and to handle which saves time and costs.

According to Ashland (2012) the advantages of composite panel systems are:

- It is manufactured to be durable.
- Manufacturing of the system is done in a controlled environment.
- It is lightweight compared to conventional brick systems.
- It has greater energy saving properties.
- Its lightweight provides greater workability.
- It is easier to transport.
- Easier construction on site.
- Done at reduced costs.
- Installation of services are easier.
- Electric wiring can be laid in-between steel frames.

Ashland (2012) further identified the following disadvantages of composite panel systems:

- Limited to certain suppliers only.
- Can't purchase from any construction store / company.
- Need trained labourers.
- Long lead times from ordering to delivery of systems due to manufacturing time of products.

## **Key influences on construction innovation**

There are a variety of influences that play a role in construction innovation. Stewart and Fenn (2006) recognized three main categories of innovation in the built environment - organizational, process and product innovation. In the built environment, innovation is mostly characterized in terms of physical products and processes, especially material improvements. Organizational innovation which entails aspects such as managing the firm and the application of new developed business strategies are becoming more pertinent. Blayse and Manley (2004) also acknowledge six main elements that may influence innovation in the built environment, such as:

- Client and manufacturers.
- The nature and excellence of the organizational resources.
- Individuals' relationships with firms in the specific industry.
- Procurement systems.
- Structure of production.
- Regulations / standards.

### ***Client and manufacturers***

The key industry participants in the development of innovation is the client and the manufacturing companies. Clients have an enormous influence on manufacturers and individuals. Clients therefore influence construction in a way that encourages innovation (Barlow, 2000).

### ***The nature and excellence of the organizational resources***

Firms and individuals should have a culture (including attitudes as well as processes) that is favourable towards innovation. These attitudes and processes are both part of organizational resources. Other parts of organizational resources include the skills that are necessary to embrace innovations that were created somewhere else; the presence of specifically chosen individuals who champion innovation; processes that assist in the preservation of attained knowledge and a strategy for innovation (Barlow, 2000). It is extremely important to have champions of innovation within a firm. These champions are needed to carry out the innovations. Ideas need to originate somewhere and champions are the ones who need to mobilize these ideas.

### ***Individuals' relationships with firms in the specific industry***

The relationships that are present within an industry have a very important influence on construction innovation (Anderson and Manseau, 1999). Relationships allow interactions as well as a flow of knowledge between individuals and firms. These interactions may entail a variety of characteristics including processes that allow the integration of products, processes related to project organization and synchronization, distribution of technologies and practices, an improved flow of work, and also information flow from a selection of sources (Anderson and Manseau, 1999).

### ***Procurement systems***

When procurement systems discourage construction firms to make use of non-traditional processes, it has a negative effect on innovation. Procurement systems that have this effect are those that add competition on the base of price only. Those that create inflexible roles and responsibilities while others encourage oppositional and self-protective behavior (Kumaraswamy and Dulaimi, 2001).

### ***Structure of production***

There may be harmful consequences of innovation within production in the built environment. Some of these consequences are avoidable whereas others are not. Because of the once off nature of construction projects, it is a difficult feature to manage. One of the challenges in innovation is a lack of knowledge development and also a lack in transferring this knowledge within a company or organization. The once off nature of projects hinder the use of certain innovations to be relevant to projects, therefore decreasing these benefits of innovation (Barlow, 2000).

### ***Regulations / standards***

Gann and Salter (2000) argue that government regulations have a strong influence on demand. These regulations also affect the course in which technological changes take place. Internationally, government regulations have also negatively affected innovation. In order to improve the built environment through innovation in products and processes, it is necessary to examine the current best practice and determine areas that are lacking (Egan, 1998). Testing of a new emerging system is very important to protect the user. There are certain tests that a system must pass before being granted a clearance certificate (Agrément, 2014).

There are numerous certified alternative composite building systems available that a client can make use of according to his / her needs. By doing comparisons in specific areas, a client can make an informed decision on which system to make use of (Agrément, 2014).

### ***Some notable areas:***

- Lack of research, development and investment are damaging the built environment's ability to maintain innovation in products, processes and technologies.

- Clients may be dissatisfied with the performance of professional consultants because of their inability to form teams to design innovations, to provide a quick and efficient service and deliver cost effective service.
- Wasted talent in failing to see that suppliers can also contribute significantly towards innovation.
- Repeated selection of new project teams restrain the development of skilled and experienced teams that can learn from each other about innovative methods and prevent the built environment from developing products and processes that the client can understand.
- Product development needs continuity from the product development team by requiring design skills that are closely related to the supply chain where the suppliers' skills can be assessed.
- Supply chain is very important in excelling innovation and increasing performance improvements.
- Project implementation demands the organization of supply chain to maximize innovation in order to learn more about efficiency.
- Component production asks for a commitment to innovation in the design of components.
- Continuous learning is not in the current built environments vocabulary and suppliers are frustrated that their current innovation cannot be used, because current labourers cannot cope with new technologies. This needs to change.
- If contractors, suppliers and clients cooperate with one another instead of competing against each other, an increased amount of improvements can be achieved in innovation.
- Long-term partnering arrangements need to be encouraged between suppliers and clients to secure value for money, consistency, innovation and continuous development.
- Develop knowledge centers where data can be stored about good practice, innovations and performances in the built environment where the whole built environment and its clients can access such data.
- Training in new technologies and techniques.
- Learn from other industries other than the built environment how new innovations are introduced.
- Change in culture can lead to increasing of quality and efficiency in the built environment.
- Improving project processes by accepting that one can learn from people that did it elsewhere.
- It is important to apply product development of innovative products with suppliers because it will improve the product and reliability.
- Enabling improvement in culture and structure in the built environment will drive towards a modern industry. These changes are in the skills, working conditions, design approach and relationships towards companies and training.
- New technology, as a useful tool, can be used to retrieve data and distribute it to the professional team which can be used later to rework the design in a more innovative way. This will allow companies to minimize waste of resources and improve such technologies (Environment and ecology, 2011).

## **Product description of alternative composite system**

In the construction industry there are numerous alternative building systems that a client can make use of according to their needs. This paper discusses the use of composite systems as an ABT with more specific reference to a specific product from a case study. This system is an example of an alternative composite system. The alternative composite system is a building system consisting amongst other materials of recycled polystyrene and fly-ash. Making use of recyclable material is one of the characteristics of a green building system. The specific alternative composite system can be found in two different composite forms namely the block composite system and the panel composite system. The two composite systems are combined to construct a building to optimise the building strength. Generally, internal walls are constructed by the composite block system and the external walls are constructed by the composite panel system when constructing a multi-storey building. Impact strength tests were conducted and ASA found the results to be satisfactory. The composite panel system has

greater compression strength compared to the composite block system. The panel system has a light steel frame that makes the panel system substantially stronger than the block system in comparison. The frame transfers the load evenly over each panel. Unskilled labourers need to attend a 4-week training course to be able to build a house entirely with the alternative composite system (Snyman, 2016).

The composite block system resides under wet work composites and consists of a mixture of recycled polystyrene amongst others, cement (only 20% of the mixture), fibre, slag and a special chemical. It consists of tong and groove joints which are joined together with an adhesive. The composite panel system makes use of a light steel frame filled with the above mixture as an infill walling material. The mixture is casted in the light steel frame which acts as a permanent formwork and increases the strength of the wall. The light steel frames are also manufactured in a factory and assembled before the mixture is casted. The light steel frame system makes use of triple joints to form a wall (Snyman, 2016). The light steel frame makes the composite panel system substantially stronger than the composite block system. The frame transfers the load evenly over each composite panel (Agrément, 2014).

The strength of the 'Polly wall' (wet work mixture) was originally 75Mpa, but was reduced to 12Mpa to make it easier to work with - especially in the drilling of additional holes. According to Snyman (2016) a chemical reaction occurs between the block and the adhesive, that "chemically welds" the components to one another.

## **IMPORTANCE OF THE RESEARCH**

In South Africa, not a lot of alternative building systems are currently being used. Traditional systems are more commonly used and generate a lot of waste and greenhouse gases that affect the environment negatively. Alternative building systems can reduce these negative effects. Composite building systems are less costly, more time efficient and reduces waste and greenhouse gases, which are important aspects to consider when deciding to build (Agrément, 2014). Further, some composite systems make use of waste stream products reducing the impact on the environment. The specific composite system used in the case study, consists of polystyrene and fly ash as a waste product. In fact, the composite system is the only system certified to make use of contaminated polystyrene. Contaminated polystyrene is polystyrene packaging that was exposed to meat products (Snyman, 2016). The findings from the case study where this specific composite system was compared to the traditional (brick and mortar) building system, favoured the use of the composite system.

## **THE RESEARCH METHOD**

Collecting of data was achieved by making use of a mixed research approach. Qualitative research was done by collecting information from relevant professionals from industry as well as through an observation method. The observation method was used to determine the challenges that ABTs experience. The observation method involved a natural setting being used by the researcher to make observations. One of the strengths of the observation method is that the bigger picture can be seen of the organization and what is happening in the observation area. Two of the techniques that was used to collect data through the observation method were written descriptions and photographs. Quantitative research was also done through interviews with professionals from industry and through the use of case-studies- one being a 252m<sup>2</sup> pre-primary school and another a 52m<sup>2</sup> house.

## **RESULTS**

### **Advantages of using the ABT composite systems**

#### ***Reduction in costs***

There are multiple advantages of using ABT composite systems. Some of these systems makes use of recycled material, reducing the impact on the environment and also reducing manufacturing costs

(Agrément, 2014). Further, due to the advantages of pre-manufacturing as well as mass production, the composite system are less costly than the conventional building systems (House Energy, 2014).

### ***Reduction in delivery time***

Delivery time is a big issue in the construction industry. The reduced delivery time of ABT systems is a result from a variety of elements including pre-assembly, manufactured in a factory environment and load-bearing capacity in terms of transport. Since most alternative systems can be pre-assembled and are manufactured in a controlled environment, a lot of time is saved which ensure earlier delivery. Making use of pre-manufacturing reduces overall construction time on site and provide a better quality product manufactured in a controlled quality environment which also reduces waste, more so than the onsite construction environment (SABS, 2015).

### **Challenges that alternative building systems face in the built environment**

Challenges in innovation is the lack of knowledge development and also a lack in transferring this knowledge within a company or organization. People are more comfortable with known systems like conventional brick systems. As discussed, the method used to answer this problem was the observation method which involved a natural setting being used by the researcher to make observations. A site located near Hartbeespoort Dam, North West Province, South Africa have been visited multiple times to make extensive observations. This site contains both a school as well as houses that are built with the specific composite building system. Extensive notes have been taken in observing the building process and all the challenges experienced by labourers, the construction manager, and the organization in general and the implications of this on the built environment have been noted.

In brief the following were observed. The fitness for purpose of materials used, met with the ASA requirements. The external walls consisted of the composite panel system and the internal walls of the composite block system. The composite panel systems are joint to one another by making use of triple joints and the composite block system has male and female joints glued with an adhesive. The contractor made use of a raft foundation with only 80mm thickness which reduced 50% of the concrete in the raft foundation. The soil conditions allowed this. Services were laid inside the light steel frame of the panel system and was cut into the block system. The block size is 900 mm wide x 1200mm high and 90mm thick and the panel size is 600mm wide x 2400mm high and 90 mm thick.

### **A quality comparison between a composite and conventional building system**

ASA and the SABS both conducted tests that tested the quality of the alternative composite system as well as the conventional brick and mortar system. The graph below compares the thermal resistance value (R-value), the compression strength and the fire rating.

Table 1: Quality comparison between the Alternative Composite System and the Brick and Mortar System

	Unit	220 mm brick wall	90 mm composite wall
Compression strength test	kg	125	350
R-Value	m <sup>2</sup> k/w	0.38	1.0096
Fire rating	Minutes	90	120

### **A cost comparison between a composite and conventional building system**

Finances play a significant role when choosing a building system. A quantitative case-study method through the use of bills of quantities was used to do a comparison of building costs between the alternative composite system and the conventional brick and mortar system for a 252 m<sup>2</sup> (outside veranda excluded) pre-primary school and a 52m<sup>2</sup> house. The costs for the alternative composite system



was supplied by the product certificate holder, Mr. H. Snyman (2016). The above saving is possible due to the use of waste stream products such as fly-ash and polystyrene which are supplied at no cost. It is also important to note that there is no relationship between the authors and the product certificate holder.

### ***52 m<sup>2</sup> Residential House***

The superstructure (walls) of the building, consisting of only clay bricks, was measured. By making use of clay brick, no finishes will be measured. The rate per square meter for the brick work is at market average and brick force have been measured for every 5th course.

Table 2: Costing walls for 52 m<sup>2</sup> residential house with brick and mortar system

Building components	Quantities	Unit Price	Total
Conventional half brick wall system:	26.05 m <sup>2</sup>	x R185.00	R 4 819.25
Conventional one brick wall system:	79.84 m <sup>2</sup>	x R320.00	R 25 548.80
Brick force for half brick walls:	26.05 x 2.94 m	x R4.00	R 306.45
Brick force for one brick walls:	79.84 x 2.94 m	x R5.20	R 1 220.59
Total conventional brick system cost:			R 31 895.09

The superstructure (walls) of the building, consisting of only the specific alternative composite systems, was measured. The external walls being only the composite panel system and the internal walls being a combination of the composite block and panel system. The rate / m<sup>2</sup> was collected from the certificate holder of the specific building system.

Table 3: Costing walls for 52 m<sup>2</sup> residential house with the alternative composite system.

Building components	Quantities	Unit Price	Total
Block system cost:	26.05 m <sup>2</sup>	x R 118.80	R 5 012.17
Panel system cost:	79.84 m <sup>2</sup>	x R 208.80	R 13 237.92
Total alternative wall system cost:			R 18 250.09

### ***252 m<sup>2</sup> Pre-primary school***

The superstructure (walls) of the building, consisting of only clay bricks, was measured. By making use of clay brick, no finishes will be measured. The rate per square meter for the brick work is at market average and brick force have been measured for every 5th course.

Table 4: Costing walls for 252 m<sup>2</sup> Pre-primary school with brick and mortar system.

Building components	Quantities	Unit Price	Total
Conventional half brick wall system cost:	115.20 m <sup>2</sup>	x R185.00	R 21 312.00
Conventional one brick wall system cost:	251.78 m <sup>2</sup>	x R320.00	R 80 569.60
Brick force for half brick walls:	115.2 x 2.94 m	x R4.00	R 1 354.75
Brick force for one brick walls:	251.78 x 2.94 m	x R5.20	R 3 849.21
Total conventional brick system cost:			R 107 085.56

The superstructure (walls) of the building, consisting of only the specific alternative composite systems, was measured. The external walls being only the composite panel system and the internal walls being a combination of the composite block and panel system. The rate / m<sup>2</sup> was collected from the certificate holder of the specific building system.

Table 5: Costing walls for 252 m<sup>2</sup> Pre-primary school with the alternative composite system.

Building components	Quantities	Unit Price	Total
Block system cost:	115.20 m <sup>2</sup>	x R118.80	R 13 685.76
Panel system cost:	251.78 m <sup>2</sup>	x R208.80	R 52 571.66
Total alternative wall system cost:			R 66 257.42

Table 6: Cost comparison between the alternative composite system the conventional Brick and Mortar building systems:

Building Type	Brick & mortar	Composite system
Residential house	R 31 895.09	R 18 250.09
Pre-primary school	R 107 085.56	R 66 257.42

## CONCLUSION

Conventional building systems have proven to be reliable in the built environment but may not be the best and only way to construct buildings in the built environment in the future. Looking at the research one can observe a pattern emerging with regard to the different systems. The advantages and disadvantages provide a clear indication to the potential of making use of alternative composite building systems.

A major advantage that the conventional brick and mortar system has over the alternative composite system is that bricks are easily available and procured in the construction industry. The current built environment workforce is skilled and used to building with the conventional building system. With regard to the alternative composite system, only the certificate holder and possible franchisees are allowed to build with the alternative composite system. In analysing the performance and costing data it was found that the alternative composite system outperformed the conventional system, thus providing a product that has a compression strength of more than double the brick and mortar system, a thermal resistance value of 2.66 times that of a brick and mortar system and a fire rating of 1.33 times that of a brick and mortar system. In terms of the thermal resistance value, the life cycle costs will definitely be less than the conventional brick and mortar system. Further in terms of initial material costs, the alternative composite system is 43 % less for the residential house and 38 % less for the pre-primary school. The above saving is possible due to the use of waste stream products such as fly-ash and polystyrene which are supplied at no cost. All the above information indicates that the alternative composite system outperforms the conventional brick and mortar system.

## BIBLIOGRAPHY

1. Agrement, 2014. [Online] Available at: [http://www.agrement.co.za/uploads/cms/document/ASA\\_&\\_SABSx.pdg](http://www.agrement.co.za/uploads/cms/document/ASA_&_SABSx.pdg) [Accessed 22/05/2016].
2. Anderson, F. and Manseau, A. 1999. A systematic approach to the generation/transmission/use of innovation in construction activities. Influences on Construction Innovation: A brief overview of recent literature.
3. Ashland, Inc. 2012. Composite building materials for green building. [Online] Available at: [http://s3.amazonaws.com/cms\\_assets/accounts/e71720bd-3b0a-4f93-9733-a17364748c8a/site-34700/cms-assets/documents/55872-956197.moffit.greenbuilding.pdf](http://s3.amazonaws.com/cms_assets/accounts/e71720bd-3b0a-4f93-9733-a17364748c8a/site-34700/cms-assets/documents/55872-956197.moffit.greenbuilding.pdf) [Accessed 29/06/2016].
4. Barlow, J. 2000. Innovation and learning in complex offshore construction projects. Research Policy. Issues 7-8, pp. 973-989.
5. Blayse, A.M. and Manley, K. 2004. Key influences on construction innovation, pp. 3-14.

6. Bristow, R. 2012. Future of built environment innovation. [Online] Available at: [www.theguardian.com/sustainable-business/future-of-built-environment-innovation](http://www.theguardian.com/sustainable-business/future-of-built-environment-innovation) [Accessed 29/06/2016].
7. Chan, K.H. 1996. Positive management strategy for materials lead time. [Online] Available at: <https://www.instituteforsupplymanagement.org/pubs/Proceedings/confproceedingsdetail.cfm?ItemNumber=10047&SSO=1> [Accessed 29/06/2016].
8. ConstructionSA, 2015. SA construction news. [Online] Available at: <https://www.saconstructionnews.co.za/11-construction-industry/16156-innovation-within-construction-industry-hastens-development-on-african-continent> [Accessed 22/05/2016].
9. Egan, J. 1998. Rethinking construction [Online] Available at: [https://www.mosaicprojects.com.au/PDF/rethinking\\_construction.pdf](https://www.mosaicprojects.com.au/PDF/rethinking_construction.pdf) [Accessed 22/09/2016].
10. Egbu, C.O. 1998 Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: an examination of critical success factors. [Online] Available at: <http://www.crossingboundaries.eu/wp-content/uploads/2014/02/Egbu-2004.pdf> [Accessed 20/09/2016].
11. Environment and ecology. 2011. Environment and ecology. [Online] Available at: <http://environment-ecology.com/environment-and-architecture/80-green-building.html> [Accessed 11/08/2016].
12. Gann, D.M. and Salter, A.J. 2000. Innovation in project-based, service-enhanced firms: the construction of complex products and systems, *Research Policy*, 29: pp.955-972.
13. House Energy. 2014. SIP Advantages. [Online] Available at: <http://www.house-energy.com/Walls/SIP-Advantages.html> [Accessed 20/07/2016].
14. Kumaraswamy, M. and Dulaimi, M. 2001. Empowering innovative improvements through creative construction procurement, *Engineering, Construction and Architectural Management*, 8 (5/6), pp.325-330.
15. SABS. 2015. SABS. [Online] Available at: [https://www.sabs.co.za/About-SABS/about\\_vision.asp](https://www.sabs.co.za/About-SABS/about_vision.asp) [Accessed 13/09/2016].
16. SABS, 2015. Mandate. [Online] Available at: <https://www.sabs.co.za/About-SABS/index.asp> [Accessed 03 11 2016].
17. SIPS. 2013. Advantages of SIPS. [Online] Available at: <http://www.sips.org> [Accessed 28/08/2016].
17. Skillicorn, N. 2014. Idea to value. [Online] Available at: [https://www.ideatovalue.com/inno/nickskillicorn/2016/03/innovation-15-experts-share-innovation-definition/gclid=CjwKEAjw\\_e7BRDs97mdpJzXwh0SJABSdUH0BHxHOJGubIaWadKdsmBrwrWcxtUIDbpkwy3GzJ-Q0xoC427w\\_wcB](https://www.ideatovalue.com/inno/nickskillicorn/2016/03/innovation-15-experts-share-innovation-definition/gclid=CjwKEAjw_e7BRDs97mdpJzXwh0SJABSdUH0BHxHOJGubIaWadKdsmBrwrWcxtUIDbpkwy3GzJ-Q0xoC427w_wcB) [Accessed 22/5/2016].
18. Slaughter E.S. 1998. Models of construction innovation. *Journal of Construction Engineering and Management*, 124, pp. 226-231.
18. Snyman, H. 2016. Interview. [20/05/2016].
22. Stewart, I. and Fenn, P. 2006. Strategy: the motivation for innovation: *Information Process Management. Construction Innovation*, 6(3), pp. 173-185.

# AN INQUIRY INTO THE CONTROL OF DISPUTES IN INTEGRATED TRANSPORTATION HUB PROJECT

Yin Yue

*Post-graduate, School of Management, Tianjin University of Technology, Tianjin, China  
Room 403, Building Number 25, Main Campus of Tianjin University of Technology, Hongqi South Road,  
Xiqing District, Tianjin, China, 342067231@qq.com*

**Abstract:** Based on that the management of integrated transportation hub is one off and disputes in project involve various stakeholders, adopting nothing more than traditional feedback control to manage disputes will weaken the performance of management. From the perspective of integrating quantitative and qualitative analysis, to improve the management of disputes in integrated transportation needs plural model to support. In the process of explicating the control of disputes and analyzing its application, according to the degree of perceiving disputes in integrated transportation hub, we concluded that the whole process control model includes dispute identification model, dispute intensity analysis model and dispute responding model and proposed the blueprint for resolving the disputes in integrated transportation hub. The research findings have theoretical significance and practical value on guiding dispute management in integrated transportation hub.

**Key words:** dispute management process, fuzzy set theory, integrated transportation hub, stakeholders.

## I. INTRODUCTION

The improper treat with the disputes between the function design of transportation hub will make the final performance lower than the expectation(Sampo et al., 2010). In recent years, the broadening scope of stakeholder leads the disputes among different stakeholders to be various and complicated, with construction scale of integrated transportation hub expanding. Therefore, more and more attention of scholar has been paid to dispute management in integrated transportation hub. The purpose is to find approaches for dispute resolution to guarantee the desirable project performance, which undoubtedly is a changeling task for the dispute managers(Mei-yung et al., 2005).

However, the studies on dispute analysis and resolution mainly focused on deepening the research on mathematical methodology in dispute management area rather than establishing dispute resolution process(Lo,2010; Power,2011; Xu et al., 2010). The process from dispute analysis to dispute resolution was broken. The integrated transportation hub is a complicated and large-scale public project which involves numerous stakeholders. Consequently, the dispute analysis of stakeholders should be the beginning of dispute analysis while establishing the dispute resolution process is the key to study the dispute management in integrated transportation hub.

In regard to the issue mentioned, the paper put forward the whole dispute management process comprising “dispute identification- dispute analysis- dispute resolution” by integrating dispute management methods at every stage. The finding of the study would make

the dispute manager build the blueprint for resolving disputes from global perspective and will provide application value in practice.

## **II. CONCEPT AND CLASSIFICATION OF DISPUTE IN INTEGRATED TRANSPORTATION HUB PROJECT**

### **A. The Concept of Dispute in Integrated Transportation Hub Project**

Disputes in project is opposition or friction caused by the conflicts among different objectives in the complicated interpersonal relationship(Barnes and Erickson,2005), which have the common features of general dispute. Before the stakeholder theory was invented, disputes in project were mainly on the disputes among “time, quality and cost”. This dispute analysis structure could not deal with the benefit dispute among stakeholders in the project, hence there exists the limitation. In 2004, PMI emphasized that “It is important to identify and manage stakeholders in the project for guaranteeing the successful completion of the project.” Therefore, identifying and managing stakeholders correspond to the characteristics of strong externality of stakeholders in the integrated transportation hub.

In integrated transportation hub project, the different requirements of stakeholders at different stages enhance the complicity of project completion, and increase the possibility of dispute happening. Based on the analysis above, the disputes in integrated transportation hub project can be identified as the frictions between the stakeholders’ requirement because internal and external stakeholders with vested interest has different requirements in integrated transportation hub project.

### **B. Classification of Dispute in Integrated Transportation Hub Project**

The classification of disputes in integrated transportation hub project is usually determined by distinctions among different objectives of different stakeholders in the integrated transportation hub project(Yin and Hu,2006). Sutterfield et al.,(2007) pointed out that disputes are divergence which includes interpersonal divergence, task divergence and process divergence. Ding(2010) divided disputes into disputes between personal benefits and project benefits, disputes among different organizations in the project and disputes between project benefits and social benefits.

Based on the conclusion of literature review, the paper classified the disputes as disputes on expected utility, disputes on investment and cost, and disputes on expected function among the stakeholders in the integrated transportation hub.

## **III. IDENTIFICATION OF DISPUTES IN INTEGRATED TRANSPORTATION HUB PROJECT**

The paper found three main stakeholders in the intricate relationship network in integrated transportation hub project by literature review. They are government, passengers and hub operation company(Yin and Wang,2008; Yin and Wang,2009). The relationship of the three main stakeholders is as shown in figure 1.



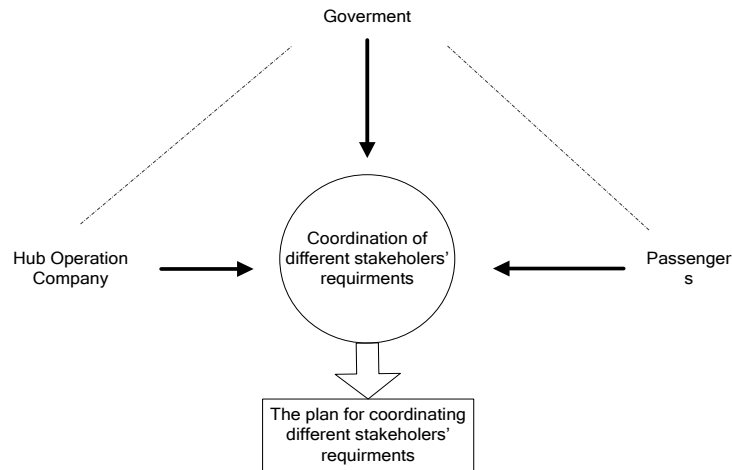


Figure1 The Relationship of The Three Main Stakeholders

According to the field survey and analysis of stakeholder's requirements, the study found three kinds of disputes among the main stakeholders. They are the disputes between government and passengers, the disputes between operation company and passengers, as well as the disputes between operation company and government. The following passages will elaborate the three kinds of interest disputes between different stakeholders.

#### **A. The Disputes between Government and Passengers**

During the construction of integrated transportation hub, major passengers concentrated on the hub function, such as convenient ticket selling system, facilitating transfer, the relaxed environments of transit and so on. However, the government considers that the construction of the integrated transport hub should not only satisfy the transport function, but also should drive the economic development in the surrounding area. That is, the government considers more on the construction of integrated transportation hub from the perspective of the urban development strategy. Therefore, the interest difference above formed dispute between the passengers' function requirement and government's urban development strategy.

#### **B. The Dispute between Operation Company and Passengers**

The key indicator for passengers' to evaluate the transportation capability of integrated hub system is transfer efficiency. The improvement of transfer efficiency requires operation company to improve the equipment and services. However, the improvement of equipment and services would inevitably enhance operation company's cost and difficulty of management, which would induce the incentive to the operation company to promote the service level. The dispute between passengers' function requirement and operation company's budget constraint should be tackled.

#### **C. The Dispute between Government and Operation Company**

Integrated transportation hub is quasi-profit infrastructure which led to that operating income cannot meet the expenditure of day-to-day operational activities. Under this condition, if

effective government cannot give enough subsidy to the operation company of integrated transportation hub in time, the operation company will not be able to get enough operating fund to maintain normal hub operation, resulting in lower operational efficiency. As a result, the operation company will try his best to strive for the subsidy from the government. However, government is also afraid that operation company would ask for more than the real needs of the subsidies, which would result in waste of resources. Therefore, how to ensure the subsidy satisfying the need for operation and to avoid the subsidy wasting is the game between government and operation company.

#### IV. ANALYSIS OF DISPUTES IN INTEGRATED TRANSPORTATION HUB PROJECT

In the paper, set  $U(1,2,3)$  represented the stakeholders, while 1 represented government and 2 represented passengers and 3 represented operation company. Set  $A(a,b,c)$  represented the disputes, while  $a$  represented the dispute in allowance, and  $b$  represented dispute in transfer space, and  $c$  represented dispute in transfer inefficiency. By holding 3-time meetings (90 Mins per time) with the representatives of the main stakeholders, the opinion of the stakeholders about the disputes were collected which formed the disputes situation. The disputes situation is as shown in Table 1.

Table 1 Disputes Situation

Stakeholders	Disputes			
		$a$	$b$	$c$
1		-1	0	+1
2		0	-1	+1
3		+1	+1	-1

+1 represented agreement, -1 represented disagreement, 0 represented waiver

According to the fuzzy set theory(Pawlak, 1998), dispute among stakeholders can be considered as a distance. The greater the distance is, the more intense the dispute is. The paper established a function for calculating the distance and set a threshold for the intensity of dispute which can identify the relationship of the stakeholders.  $distance(a, x, y)$  can be identified as:

$$distance(a, x, y) = \begin{cases} 0 & a(x)=a(y)=0 \text{ or } x=y \\ 1 & a(x)a(y)=0 \text{ and } a(x) \neq a(y) \\ 2 & a(x)a(y)=-1 \text{ and } x \neq y \end{cases} \quad (1)$$

$a(x)$  and  $a(y)$  represented the stakeholders' opinion about the disputes.

Therefore, the distance sum of dispute A between X and Y can be identified as

$$\gamma B(x, y) = \left\{ \sum d_a(x, y) | distance(a, x, y) \right\} \quad (2)$$

The dispute function of dispute A between x and y can be identified as

$$\rho_B(x, y) = \frac{\sum_{a \in B} d_a(x, y)}{2|B|}$$

(3)

According to the formula (3), we can obtain

$$\rho(1, 2) = 0.5, \rho(1, 3) = 0.83, \rho(2, 3) = 0.67$$

The dispute matrix is as shown as Table 2.

Table 2 Dispute Matrix

U	1	2	3
1			
2	0.5		
3	0.83	0.67	

In this study, the threshold was set as 0.5. Therefore, the relationship between government and passenger is neutral and the relationship between government and operation company as well as the relationship between operation company and passenger are dispute.

## V. RESOLUTION OF DISPUTES IN INTEGRATED TRANSPORTATION HUB PROJECT

Third party consultant approach was adopted in the study for dispute resolution. Based on the relationship of main stakeholders in integrated transportation hub project, the paper provided three dispute resolution schemes after several meeting among delegates of stakeholders and the third party consultant.

### A. The resolution scheme for dispute between government and stakeholders

Under resource constraints, the government should take the shortest distance as the goal to determine the indicators of hub design. The government is requested to design specific units responsible for carrying out the hub transfer design. So that, the design could not only satisfy the passengers' requests for convenience, but also meet the need of government to realize the value of the integrated transport hub project, which make both parties reach consensus.

### B. The resolution scheme for dispute between operation company and passengers

According to the third party' evaluation for the hub, the operation company should take transfer efficiency at the first place and implement measures for promote stakeholders' convenience. The action of operation company could ultimately coordinate the interests of the hub operators and passengers.

### C. The resolution scheme for dispute between government and operation company

The paper suggested that the government should combine direct subsidies, indirect subsidies and cross subsidies for the hub operation company to provide finance guarantee for sustaining operation of integrated transportation hub. The scheme resolved the interest dispute between government and operation company.

## VI. CONCLUSION

According to the trait of Integrated Transportation Hub that it involves amount of stakeholders, and in accordance with the perceived level of the conflicts in Integrated Transportation Hub, dispute management system was established. Integrated transport hub project dispute management process is a dispute management framework including dispute-related factors at all stages. In this process, a variety of different approaches integrated with each other, which constitute a system comprising dispute identification, dispute analysis and dispute resolution. The system could support the integration process from qualitative analysis to quantitative analysis more effectively. The use of quantitative and qualitative analysis provided an accurate basis for the dispute control decision-making, so that the requirements of the stakeholders can arrive at consensus, which would help achieve the goal of minimizing the possibility of dispute. Based on the finding of this research, the further study should focus on the analysis of dispute in Integrated Transportation Hub to find approach for analyzing the data about the disputes more accurate, which will help the manager make more pertinent dispute management strategy.

## REFERENCE

- Barnes G., Erickson S. (2005). Developing a Simple System for Dispute Management of Public Involvement. *Journal of the Transportation Research Board*.109-113.
- Ding Jie (2010). A Study of Construction Project Dispute Management Based on Evolutionary Game Theory. Modeling Risk Management in Sustainable Construction. 321-326.
- Lo ChihYao, Chang YuTeng, Hsies HsiuYu (2010). Analysis of Negotiation Strategies on Dispute Resolution with Action Game". *International Conference on Intelligent Control and Information Processing*. Dalian, China., August, pp. 13-15.
- Mei-yung, Leung, Anita M.M., Liu, S. Thomas Ng(2005). Is there a relationship between construction disputes and participants' satisfaction? *Engineering, Construction and Architectural Management*,2,149-167.
- Pawlak, Z(1998). An inquiry into anatomy of disputes. *Journal of Information Sciences*, 109, 65-78.
- Power S. A. (2011). Towards a Dialogical Model of Dispute Resolution. *Psychology & Society*, 1,53 – 66.
- Sampo, Tukiainen, Kirsi Aaltonen, Mervi Murtonen(2010). Coping with an unexpected event-Project managers' contrasting sensemaking in a stakeholder conflict in China. *International Journal of Managing Projects in Business*,3, pp.526-543.
- Sutterfield J. S., et.al (2007). How NOT to Manage a Project: Dispute Management Lessons Learned from a DOD Case Study. *Institute of Behavioral and Applied Management*, 3, 218-230.
- Xu Haiyan, Hipel KeithW., Kilgour D. Marc, Chen Ye (2010). Combining strength and

uncertainty for preferences in the graph model for conflict resolution with multiple decision makers. *Theory and Decision*, 4, 497-521.

Yin Yilin, Hu Jie(2006). Study on the Success Criteria of Public Project Based on the Core Value of the Stakeholders. *China Soft Science*, 5, 149 – 155.

Yin Yilin, Wang Wenxue (2008). On Management of the Stakeholders of Tianjin Transportation Hub Project. *Urban Mass Transit*, 9, 4-6.

Yin Yilin, Wang Yao (2009). Research on Facility Optimization Design of City Transport Hub Project Based on Stakeholders Requirement. *Journal of Beijing Institute of Technology(Social Sciences Edition)*, 3, 53-57.



# BARRIERS IN IMPLEMENTING BUILDING INFORMATION MODELLING (BIM) IN QUANTITY SURVEYING FIRMS

Wong, Sing-Sing<sup>1</sup> and Yew, Zek-Ung<sup>2</sup>

*<sup>1</sup>Associate Professor, <sup>2</sup>Undergraduate Student, University College of Technology Sarawak, Sibu, Sarawak, Malaysia,*

*<sup>1</sup>drwong@ucts.edu.my, <sup>2</sup>yewzekung@gmail.com*

## **Abstract:**

Building Information Modelling (BIM) is a revolutionary technology involving the usage of Information Technology (IT) that has transformed the construction procurement via collaboration between different industry players. In Malaysia, the industry players are encouraged by the Construction Industry Development Board (CIDB) adopting BIM for cost efficiency and waste reduction. Even though several studies were conducted in West Malaysia exploring barriers in BIM implementation, there is lack of study in Sarawak, East Malaysia. Thus, this study aims to fill the gap via examining the barriers in implementing BIM in Sarawak from the perspective of Quantity Surveying (QS) firms. A questionnaire survey was sent to all QS firms in Sarawak. Relative Importance Index (RII) was used to analyze the findings. This study revealed that main barriers of BIM implementation are high initial cost of BIM, lack of training on BIM software, lack of knowledge about BIM, lack of data of Return on Investment of BIM and unaware of BIM. This study concludes that most of these barriers are related to the lack of BIM information. Hence, this study recommends that the government should organize BIM seminars providing more information to the QS firms in Sarawak.

**Keywords:** Barriers, Building Information Modelling (BIM), Quantity Surveying Firms.

## **INTRODUCTION**

Building Information Modelling (BIM) is a revolutionary technology involving the usage of Information Technology (IT) in the construction industry. BIM has transformed the construction procurement via collaboration between different industry players. In Malaysia, private sectors started to implement BIM in their projects since 2009. One year later, Malaysian government appreciated the ability of BIM and decided to use BIM in the National Cancer Institute (NCI), the first government project (CREAM, 2014). In 2013, two projects were chosen as pilot projects for BIM, namely Healthcare Center at Sri Jaya Maran, Pahang and Administration Complex for Malaysian Anti-Corruption Commission (MACC) at Shah Alam, Selangor (PWD, 2013). Since then, the industry players are encouraged by the Malaysian Construction Industry Development Board (CIDB) adopting BIM for cost efficiency and waste reduction (CIDB, 2013). Furthermore, the Malaysian government as the major property holder has decided to implement BIM for projects in public sector in 2016 (CREAM, 2014). Several studies in BIM were conducted in West Malaysia in relation to BIM implementation (Ahmad Latiffi et al., 2013; Memon et al., 2014; Zahrizan et al., 2013), BIM as conflict resolution tool (Gardezi et al., 2013), government's initiatives (Ahmad Latiffi et al., 2014), barriers (Memon et al., 2014; Zahrizan et al., 2014), driving factors (Zahrizan et al., 2014), and advantages and disadvantages (Memon et al., 2014). At the time of this study, there is lack of study in BIM in Sarawak, East Malaysia. Hence, this study aims to fill the gap via investigating the barriers in implementing BIM in Quantity Surveying (QS) firms in Sarawak.

## **LITERATURE REVIEW**

Previous studies showed that the implementation of BIM in construction facing numerous barriers as the industry players use to the conventional approach. This study adopted various barriers from studies conducted by Memon et al. (2014) and Zahrizan et al. (2014). These barriers are lack of knowledge about BIM, lack of demand from client, resistance to change, unawareness of BIM, lack of data of Return on Investment of BIM, legal or contract issue, high initial cost of BIM, application of BIM will affect the current process practice and productivity, BIM does not reduce the time used on drafting compared with the current drawing approach, BIM lacks of features or flexibility to create a building model or drawing and lack of training on BIM software.

Lack of knowledge about BIM causes the industry players feeling lack of competence when operating the software (Memon et al., 2014). Furthermore, none of the industry players wants to take the initiative to implement BIM due to lack of knowledge. They perceive that it is too difficult to learn BIM leading to the increase of operating cost (Zahrizan et al., 2014). Lack of demand from client pulls back the implementation of BIM in the construction project. Client does not request BIM as part of the project's requirements (Zahrizan et al., 2014). This may due to the unawareness of BIM's benefits as well as the negative perceptions (Memon et al., 2014). The majority of clients in the construction industry have used to the conventional approach. They refuse to change as there is lack of success record of BIM in the operation and maintenance phase in the life cycle of construction project (Zahrizan et al., 2014). The level of awareness of BIM is still low in the construction industry and it is regarded as the infant stage by the industry players who have implemented BIM in their projects (Zahrizan et al., 2013). Unawareness of BIM retreats the industry players, especially the contractors and consultants, implementing BIM in their projects (Memon et al., 2014). Furthermore, lack of data of Return on Investment of BIM, especially the investment in information technologies, pushes the industry players continuing practicing conventional approach in their projects (Zahrizan et al., 2014). The implementation of BIM incurs the legal or contract issues. These issues are not addressed by the traditional contacts that been used in the construction industry (Foster, 2008). High initial cost of BIM, involving both software and hardware, is another barrier that cause the industry players not keen in implementing BIM in their construction projects (Memon et al., 2014). Due to the failure experience in Industrialised Building System (IBS) in the past, the industry players are not willing to venture into BIM. They worry that the application of BIM will affect the current process practice and productivity (Zahrizan et al., 2013). BIM does not reduce the time used on drafting compared with the current drawing approach and BIM lacks of features or flexibility to create a building model or drawing are two barriers that cause the industry players, especially design consultants, not keen in replacing current tool with BIM (Tse et al., 2005). Lack of training on BIM software is another barrier of BIM implementation. The industry players are not willing to invest in BIM training for their staff (Baba, 2010).

## **RESEARCH METHOD**

As suggested by Kumar (2014), this study adopted the questionnaire survey as data collecting technique because the respondents were located over wider geographical areas. The questionnaire consisted of close-ended questions with five-point Likert scale (i.e. 1 = unimportant, 2 = less important, 3 = moderately important, 4 = important, and 5 = very important). The questionnaire was sent via email to all quantity surveying (QS) firms registered under Board of Quantity Surveyors Malaysia (BQSM) in Sarawak. Out of 30, 6 respondents returned the questionnaire. The response rate was 20%. It was higher than the typical response rate (i.e. 5-15%) of the questionnaire survey conducted in the Malaysian construction industry (Idrus, et al., 2008). The data received in the questionnaire was analysed by

Relative Importance Index (RII) method to determine the relative importance of barriers in implementing Building Information Modelling (BIM) in the Malaysian construction industry from the perception of QS firms.

RII was calculated using the following formula:

$$RII = \frac{\sum P_i U_i}{N(n)}$$

Where:

RII = Relative Importance Index

$P_i$  = Respondents' rating

$U_i$  = Number of respondents placing an identical weighting/rating

$N$  = Sample size

$n$  = Highest attainable score (in this study  $n$  is 5)

## FINDINGS AND DISCUSSION

Table 1 illustrates the relative importance indices and the rank for barriers in implementing BIM in QS firms in Sarawak. This study reveals that the top 3 barriers are high initial cost of BIM (RII = 0.933), lack of training on BIM software (RII = 0.833), lack of knowledge about BIM (RII = 0.800), and lack of data of Return in Investment of BIM (0.800). This study challenges Memon et al. (2014) and Zahrizan et al. (2014) that high initial cost of BIM is the most important barriers in implementing BIM in QS firms in Sarawak. At the time of this study, most of the BIM solution providers were located in West Malaysia. Hence, the respondents might perceive that it will involve high initial cost to install BIM hardware and software due to the logistics issue. This opposes the view of respondents in Zahrizan et al. (2014) study who believed that the purchasing cost of BIM is not so expensive. This study challenges Zahrizan et al. (2014) whose study indicated that lack of training on BIM software is not a barrier in implementing BIM. The respondents of this study pointed out their concerns in the training on BIM software. It was not earlier to send their staff for BIM software training compared to those organizations that located in West Malaysia. However, the respondents in Zahrizan et al. (2014) study expressed their willingness to send their employees attending BIM related trainings as majority of these trainings are located at their doorstep.

This study agrees with Zahrizan et al. (2014) that lack of knowledge about BIM is one among the top 3 barriers. Lack of knowledge about BIM is the main barrier because there was no BIM project in Sarawak during the time of this study. The only way that respondents might able to obtain BIM knowledge is reading reports published by CIDB and BQSM. Findings of this study echo findings of Memon et al. (2014) and Zahrizan et al. (2014) that lack of data of Return on Investment of BIM is among the top 5 barriers. Since lack of knowledge about BIM and lack of data of Return on Investment of BIM are ranked at the same level (top 3), this may infer that the respondents regarded lack of data of Return on

Investment of BIM as parts of their knowledge about BIM. Hence, this study proposes that lack of knowledge about BIM should be used in future research in the similar field.

**Table 1: Barriers in implementing BIM in QS firms**

	RII	Rank
High initial cost of BIM	0.933	1
Lack of training on BIM software	0.833	2
Lack of knowledge about BIM	0.800	3
Lack of data of Return on Investment of BIM	0.800	3
Lack of demand from client	0.700	5
Unawareness of BIM	0.633	6
Resistance to change	0.600	7
Application of BIM will affect the current process practice and productivity	0.600	7
BIM does not reduce the time used on drafting compared with the current drawing approach	0.533	9
BIM lacks of features or flexibility to create a building model/drawing	0.533	9
Legal or contract issue	0.467	11

This study found that BIM does not reduce the time used on drafting compared with the current drawing, BIM lacks of features or flexibility to create a building model/drawing and legal or contract issue are located at the bottom of the list as barriers in implementing BIM in QS firms. This study agrees with Memon et al. (2014) and Zahrizan et al. (2014) that BIM does not reduce the time used on drafting compared with the current drawing is not an important barrier in implementing BIM. Even though the respondents of this study complained that more works needed by using BIM in drafting, it would not be an issue for them as they are QS practitioners who do not do drafting works regularly. Findings of this study echo findings of Zahrizan et al. (2014) that BIM lacks of features or flexibility to create a building model/drawing is not an important barrier in implementing BIM. The respondents of Zahrizan et al. (2014) study who were mainly architects and engineers claimed that it is easier for them to create 3D model by using BIM. As mentioned earlier, the respondents of this study consists of QS practitioners who are expert in preparing cost estimate and contract but not in design phase. Hence, it is not an issue whether BIM is useful or not during design phase. This study disagrees with Zahrizan et al. (2014) study that legal or contract issue, which was ranked at 6th, is the least important barrier in implementing BIM in QS firms in Sarawak. As the contract administrator, the quantity surveyor might have less legal liabilities compared to the designer (i.e. architect and engineer) as well as the contractor. The designer needs to bear the legal liabilities on the design while the contractor is responsible for the entire construction work until the completion.

## CONCLUSION

This study concludes that most of top ranked barriers in implementing BIM in QS firms in Sarawak are related to high initial cost, lack of training and knowledge. Hence, this study recommends that the government should provide incentive and financial assistance for the initial purchase of BIM package in QS firms. Furthermore, the government should organize more BIM trainings and seminars providing adequate information to the QS firms in Sarawak. These trainings and seminars could be held in Sarawak as logistics which incurs additional cost is the main concern for the QS firms in Sarawak.

## REFERENCES

- Ahmad Latiffi, A., Mohd, S., Kasim, N. and Fathi, M. S. (2013) Building Information Modeling (BIM) application in Malaysian construction industry. *International Journal of Construction Engineering and Management*, 2, 1-6.
- Ahmad Latiffi, A., Brahim, J., Mohd, S., and Fathi, M. S. (2014) The Malaysian government's initiative in using Building Information Modeling (BIM) in construction projects. In Chantawarangul, K., Suanpaga, W., Yazdani, S., Vimonsatit, V., and Singh, A. (eds.) *Sustainable Solutions in Structural Engineering and Construction*, ISEC Press, USA, pp. 767-772.
- Baba, H. D. (2010) Building information modeling in local construction industry. Unpublished Master Thesis, Faculty of Civil Engineering, Universiti Teknologi Malaysia.
- Construction Industry Development Board (CIDB) (2013) *Building Information Modelling Roadmap for Malaysia's Construction Industry Workshop Report (Series 2)*. CIDB, Kuala Lumpur.
- Construction Research Institute of Malaysia (CREAM) (2014) *Issues and Challenges Implementing Building Information Modelling (BIM) for SME's in the Construction Industry*. CREAM, Kuala Lumpur.
- Foster, L. L. (2008) Legal issues and risks associated with building information modeling technology, Unpublished Master Thesis, Engineering and the Graduate Faculty of the University of Kansas.
- Gardezi, S. S. S., Shafiq, N. and Khamidi, M. F. B. (2013) Prospects of Building Information Modeling (BIM) in Malaysian construction industry as conflict resolution tool. *Journal of Energy Technologies and Policy*, 3, 346-350.
- Idrus, A., Hashim, K., and Farah, A. M. (2008) Towards development of a database civil and structural construction works' production rates. In *the International Conference on Construction and Building Technology (ICCBT)*, Kuala Lumpur, Malaysia, June.
- Kumar, R. (2014) *Research Methodology: A Step By Step Guide for Beginners*. 4<sup>th</sup> edn, Sage Publications Ltd, California.
- Memon, A. M., Abdul Rahman, I., Memon, I., and Azman, N. I. A. (2014). BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level. *Research Journal of Applied Sciences, Engineering and Technology*, 8, 606-614.
- Public Work Department (PWD) (2013) *BIM Pilot Projects*. Available from <www.jkr.gov.my>. [28 September 2015].
- Tse, K. T., Wong, A. K., and Wong, F. K. (2005) The utilisation of building information models in nD modelling: a study of data interfacing and adoption barriers. *ITcon*, 10, 85-110.
- Zahrizan, Z., Mohamed Ali, N., Haron, A. T., Marshall-Ponting, A. and Abd Hamid, Z. (2013)

Exploring The Adoption of Building Information Modelling (Bim) in the Malaysian Construction Industry: A Qualitative Approach. *International Journal of Research in Engineering and Technology*, 2, 384-395.

Zahrizan, Z., Mohamed Ali, N., Haron, A. T., Marshall-Ponting, A., and Abd Hamid, Z. (2014). Exploring the Barriers and Driving Factors in Implementing Building Information Modelling (BIM) in the Malaysian Construction Industry: A Preliminary Study. *Journal – The Institution of Engineers Malaysia*, 75, 1-10.

# **COST CERTAINTY: A LEAD DRIVER FOR 5D BUILDING INFORMATION MODELLING (BIM) IMPLEMENTATION**

Tochukwu Moses<sup>1\*</sup> and Glynis Hampton<sup>2</sup>

<sup>1</sup>*Lecturer/Senior Lecturer in Quantity Surveying, School of Architecture and Built Environment, University of Wolverhampton, United Kingdom*

*\*Corresponding author's e-mail: [t.moses@wlv.ac.uk](mailto:t.moses@wlv.ac.uk)*

<sup>2</sup>*Senior Lecturer in Quantity Surveying, School of Architecture and Built Environment, University of Wolverhampton, United Kingdom*

*e-mail: [g.e.hampton@wlv.ac.uk](mailto:g.e.hampton@wlv.ac.uk)*

## **ABSTRACT**

Challenging economic times inspire innovative abilities, capabilities and solutions in the construction industry particularly with the existing dichotomy of either building for a low cost or high quality performance buildings. The challenge of creating a balance in delivering high performance construction projects and cost-effectiveness providing value for money is a key drive towards the UK Government Construction Strategy for Level 2 Building Information Modelling (BIM) implementation on all public sector projects. This initiative is with a requirement for 25% reduction in overall cost of a project establishing the most cost-effective means. Further key considerations within the strategy includes reduction in overall project time, early contractor involvement, high quality product performance, improved sustainability and integration of process information (automated processes). This allows integrated team to gain good understanding that promotes requirements, mitigate cost uncertainties, develop innovative solutions, plan and mobilise resources, managing risks to accelerate delivery and reduce costs.

Integrated project delivery and collaborative workflow is fundamental to the Level 2 BIM strategy yet the Quantity Surveyors, Cost Consultants and Cost Managers tasked with these deliverables are far from the innovative awareness required being bound by inefficiencies integrated within the traditional cost estimating approaches. Using a phenomenological investigative approach informed by research and a case study inquiry, this paper proposes a paradigm shift from a fragmented traditional costing approach to early contractor involvement and the resulting automation protocols for integration of process information leading to cost certainty. It discusses a methodological solution from a practitioner's perspective for implementing 5D BIM to the whole lifecycle of a project with the objective of delivering a better building performance with cost certainty.

**KEYWORDS:** *Automated quantification, BIM, 5D BIM, ECI, Level 2 BIM.*

## **INTRODUCTION**

Building Information Modelling (BIM) as one of the process and technological development in the architecture and built environment, has progressed from assuming the position of another research output into a commercial reality given its growing rate of adoption and implementation till date. Industry-wide adoption of construction digitisation through BIM enabled platforms is predicated on collaboration. An increasing collaboration amongst multi-construction professionals has positioned BIM as the most promising emerging technology leading a significant revolution on building designs, constructions, maintenance and operations (SCSI, 2017).

Digital capabilities of BIM deploy potentialities that virtually represents the physical and functional characteristics of a built facility providing a shared source of information among project parties thereby

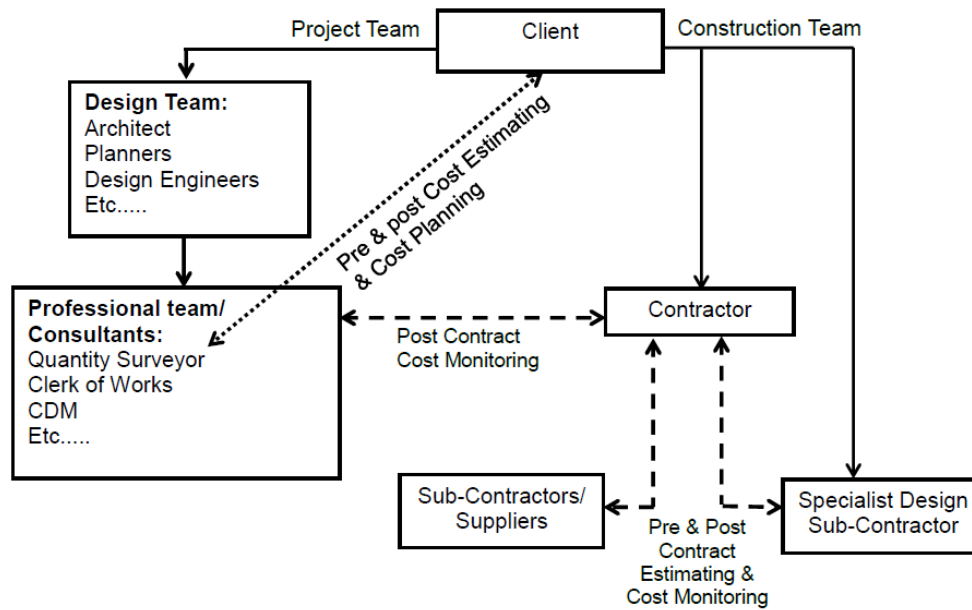
forming reliable bases for decision making process throughout the whole life cycle of a facility (Eastman et al, 2011). It is co-opting a paradigm shift in the industry from Quantity Surveying conventional practice (paper based information management process) which is time consuming, error-ridden, cost ineffective to automated digitisation process through advanced technologies providing more value for money regarding time, cost, quality and scope. Traditional estimating and measurement process is accelerated through BIM's capability of automated processes. It brings further benefits which includes extracting quantities directly from BIM model, exporting measurements to spreadsheet through linking modelling tools with estimating plug-ins, increased visualisation at concept stage, virtual reality (VR) designs and optimises facility management through life cycle. BIM as a database of components in the design and construction of a building, can quantify accurately using relevant software tools all the necessary materials required for construction while reducing greatly the margin for error (Haque and Mishra, 2007). At present, industry capacity to deliver cost effective and high performance construction projects providing value for money is challenged due to lack of 5D digital approach as required during costing functions, therefore innovative technological process which puts BIM as prime catalyst needs urgent consideration. The traditional QS status quo currently engaged by the cost practitioners needs to evolve into a digital function to keep track of technological benefits.

## **TRADITIONAL COSTING APPROACH**

There is a worldwide paradigm shift in construction practices and buildings are becoming more complex with diverse procurement approaches. Clients are beginning to demand facilities that are built on time, within budget and provide 'value for money' for the complete lifecycle of the facility. Due to integrated complexities from the outset to post commissioning of large projects, there is an urgent prompt from industry for a digital planning approach of costing activities, time schedules and ultimately what Ashworth and Perera (2015) allude to as 'getting it right the first time' meaning 'build it twice' once virtually and once physically. To meet this collaborative obligation, early project collaboration of the developers, design team, contractors and their supply chain, end users and facility managers involved throughout whole lifecycle of projects are required to work in tandem, communicating visually to facilitate target cost design rather costing an already completed design (RICS, 2015). Hence project design, work activities, cost estimation and cost planning must be undertaken together and start right at the beginning during the feasibility planning stage and continue throughout the whole lifecycle of the project to monitor the cost budgets acting as a live document consistently interrogating the geometric BIM model. Certainly, this enables better cost benchmarking and cost analysis framework (Benge, 2014) as shown in Table 1.

Considering the Royal Institute of British Architects (RIBA) key activity tasks identified in the RIBA Outline Plan of Works 2007 (RIBA, 2007) showcasing a traditional approach – Figure 2; the existing nature of construction is such that often the cost of a project is not known until after the final design decisions (Stage C - Concept Design) has been made and in some cases may even be after the construction itself has been completed (Ashworth and Perera, 2015). Following this linear process, the prime characteristics of this procurement route as suggested by Cartlidge (2013) is that there is "little or no parallel working, resulting in a sometimes lengthy and costly procedure". The main contractor whose construction expertise ensures a fully streamlined process if involved early, has no input into the design as they are not appointed until after the drawings and tender drawings have been finalised and fully measured Figure 1. It is seen in same figure below that there is no contractual or collaborative working relationship between the design and construction team during the pre-contract stage. Value engineering cannot be fully adopted or full value added design cost considerations which is critical for 5D BIM costing process and collaborative working frameworks to be achieved as highlighted in Table 1 (Schaufelberger and Holm, 2017).





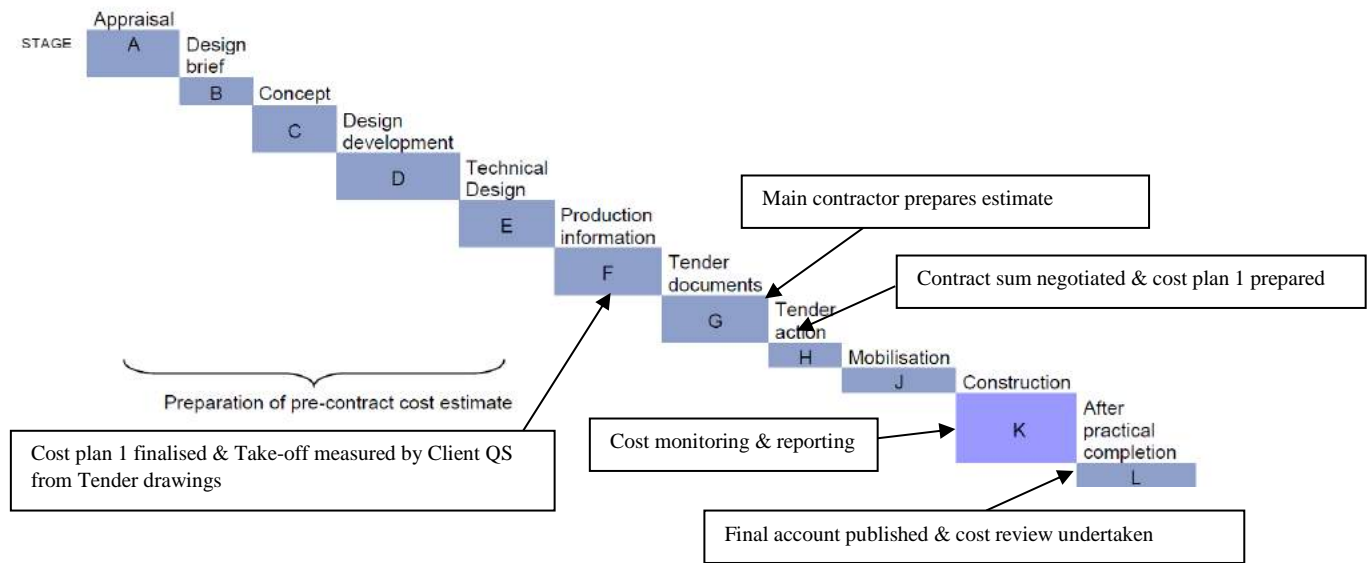
**Figure 1: Traditional Project Delivery and relationship of cost planning activities**

The recurrent traditional construction process is problematic because different design decisions have varying cost implications embedded, and to ensure that the best decisions are made, it is imperative to adopt a reliable mechanism where costs of design options can be established before final design decisions are made and implemented. More importantly, following the good practice guidance of soft-landing to truly assess the functionality of the project and validate the whole life cost implications of the building's operational performance at the project brief and early project inception (Usable Buildings Trust, 2014). The purpose of pre-contract costing is to produce a forecast of the probable cost of a future project before the building has been designed in detail and contract particulars prepared. In this way, the client is able to consider - right at the inception stage - alternative schemes that can achieve similar objectives, and is aware of the projects likely financial commitments even before extensive design work is undertaken to enable developers make arrangements for sourcing finance (Schaufelberger and Hom, 2017). Since 1963, the RIBA have presented the linear planning model (RIBA, 2007), however due to the global changes in the way that projects are delivered and managed, as well as the acknowledgement of BIM integration and collaboration; a new online flexible RIBA Plan of Works 2013 (RIBA, 2013) is provided which is a build-up on 2012 BIM overlay (RIBA, 2012). This can be manipulated to suite the procurement approaches and acknowledging that tendering happens throughout the project not just confined to stages G and H as used in traditional setting (Figure 2).

**Table 1: Outputs required for 5D BIM and collaborative design team activities for Whole life project planning.**

RIBA PoW 2007		RIBA DPoW 2013		COST (5D OUTPUTS)	END TO END JOURNEY	EXPECTED BIM OUTPUTS
Stages	Activity Tasks	Stages	Activity Tasks	Cost Information activities & Cost Data Outputs	Soft Landings Supporting Activities	Core BIM Activities & data drops
		<b>0 Strategic Definition:</b>	<ul style="list-style-type: none"> <li>Produce business case &amp; strategic brief</li> <li>Establish programme</li> <li>Planning pre-application discussion</li> <li>Review previous lessons learnt</li> </ul>	<ul style="list-style-type: none"> <li>Contribute cost information to preparation of Strategic Brief</li> </ul>		<b>Stage 0: Explanation &amp; Stage 1: Definition</b> <ul style="list-style-type: none"> <li>Explain BIM &amp; collaborative working</li> <li>Define information requirements</li> <li>Appoint project information manager</li> <li>Confirm integrated team scope of services, responsibilities &amp; definitions of levels of design for each stage</li> </ul>
<b>A Appraisal</b>	<ul style="list-style-type: none"> <li>Identify client's objectives, business case &amp; constraints.</li> <li>Prepare feasibility studies &amp; assessment of options.</li> </ul>	<b>1 Preparation &amp; brief:</b>	<ul style="list-style-type: none"> <li>Develop project objectives &amp; outcomes</li> <li>Identify roles &amp; responsibilities</li> <li>Review project programme</li> <li>Produce initial project brief</li> <li>Risk assessments &amp; handover strategy</li> <li>Produce project execution plan</li> </ul>	<ul style="list-style-type: none"> <li>Provide cost advice</li> <li>Undertake optional appraisals</li> <li>Produce order of cost estimate using functional estimating measured using NRM1 to set authorised budget</li> <li>Prepare project budget with client</li> </ul>	<b>Stage 1: Briefing:</b> <ul style="list-style-type: none"> <li>Identify all actions needed to support procurement approach</li> <li>Define roles &amp; responsibilities</li> </ul>	<ul style="list-style-type: none"> <li>Define common data environment &amp; ownership of model</li> <li>Confirm BIM inputs &amp; outputs &amp; scope of post occupancy evaluation</li> <li>Confirm scope of surveys &amp; investigations</li> <li>Confirm commissioning requirements</li> <li>Collate available data &amp; identify conditions</li> <li>Issue data drop 1</li> </ul>
<b>B Design Brief</b>	<ul style="list-style-type: none"> <li>Produce design brief</li> <li>Confirm procurement approach, procedures, project &amp; design team</li> </ul>				<ul style="list-style-type: none"> <li>Explain Soft Landings to all participants</li> <li>Identify user champions</li> <li>Identify all processes</li> </ul>	
<b>C Concept</b>	<ul style="list-style-type: none"> <li>Implement Design Brief</li> <li>Prepare Concept Design &amp; outline proposals for structural and building services systems, outline specifications and preliminary cost plan.</li> <li>Review procurement approaches</li> </ul>	<b>2 Concept Design:</b>	<ul style="list-style-type: none"> <li>Prepare concept design</li> <li>Develop outline proposals for structural, building services, outline specs, preliminary cost information, etc., in accordance with the design programme</li> <li>Implement project brief</li> <li>Prepare sustainability strategy, maintenance &amp; operational &amp; handover strategies &amp; risk assessments</li> <li>Update Project Execution Plan</li> <li>review construction &amp; Health &amp; Safety strategies</li> </ul>	<ul style="list-style-type: none"> <li>Produce preliminary Cost information using functional/ area/ elemental estimating methods using NRM1 &amp;/or NRM3</li> <li>Produce Formal Cost Plan 1 using NRM1 measurement rules</li> </ul>	<b>Stage 2: Design Development:</b> <ul style="list-style-type: none"> <li>Promote engagement with all users</li> <li>Support the design as it evolves</li> <li>Review past experience</li> <li>Confirm performance metrics</li> </ul>	<b>Stage 2: Design</b> <ul style="list-style-type: none"> <li>Confirm BIM protocol, access levels &amp; legal obligations</li> <li>Undertake risk analysis</li> <li>Implement project quality plan &amp; procedures</li> <li>Implement BIM implementation plan</li> <li>Communicate model to design team for strategic analysis &amp; options appraisals</li> <li>Undertake environmental performance &amp; area analysis</li> <li>Develop key model elements (e.g. offsite components)</li> <li>Create concept level parametric objects for all major elements</li> <li>Agree performance specified work</li> <li>Data Drop 2</li> </ul>
<b>D Design Development</b>	<ul style="list-style-type: none"> <li>Develop concept designs to include structural and building services systems, updated outline specifications and cost plan.</li> <li>Publish project brief.</li> <li>Apply for detailed planning permission.</li> </ul>	<b>3 Develop Design</b>	<ul style="list-style-type: none"> <li>Prepare developed design</li> <li>Update proposals for structural, building services, outline specs, cost information, etc., in accordance with the design programme</li> <li>Update project programme</li> <li>Review &amp; update sustainability strategy, maintenance &amp; operational &amp; handover strategies &amp; risk assessments</li> <li>Update project execution plan including change control Procedures</li> <li>Review/update construction &amp; H&amp;S strategies</li> </ul>	<ul style="list-style-type: none"> <li>Update preliminary Cost information</li> <li>Prepare Formal Cost Plan 2 using NRM1 &amp;/or NRM3 rules of measurement</li> </ul>	<b>Scheme Design reality-check:</b> <ul style="list-style-type: none"> <li>Review design targets</li> <li>Review usability and manageability</li> <li>Agree design targets</li> </ul>	<b>Stage 3: Integration &amp; analysis</b> <ul style="list-style-type: none"> <li>Design co-ordination &amp; detailed analysis including data links between models</li> <li>Integration/development of generic/ bespoke design component</li> <li>Environmental performance &amp; area analysis</li> <li>Design co-ordination, technical analysis &amp; addition of specification data</li> <li>Export data from planning application</li> <li>Export BoQ &amp; quantity check</li> <li>Spatial co-ordination &amp; clash avoidance control</li> <li>Carbon analysis</li> <li>4D &amp;/or 5D assessment</li> <li>Data Drop 3</li> </ul>

RIBA PoW 2007			RIBA DPoW 2013		COST (5D OUTPUTS)	END TO END JOURNEY	EXPECTED BIM OUTPUTS
Stages		Activity Tasks	Stages	Activity Tasks	Cost Information activities & Cost Data Outputs	Soft Landings(SL) Supporting Activities	Core BIM Activities & data drops
<b>E Technical Design</b>		<ul style="list-style-type: none"> <li>Prepare technical design(s) and specifications, sufficient to co-ordinate components elements of the project and <i>information for statutory standards and construction safety</i>.</li> </ul>	<b>4 Technical Design</b>	<ul style="list-style-type: none"> <li>Prepare technical design in accordance with design responsibility matrices</li> <li>Produce project strategies including architectural, structural &amp; building services information, specialist subcontractor design &amp; specifications in accordance with design programme</li> <li>Review &amp; update support strategies as in Stage 3</li> </ul>	<ul style="list-style-type: none"> <li>Update preliminary Cost information</li> <li>Undertake pre tender estimate using NRM 1 rules of measurement</li> <li>Prepare Formal Cost Plan 3 using NRM1 rules of measurement</li> </ul>	<b>Technical Design reality-check(s):</b> <ul style="list-style-type: none"> <li>Review design targets</li> <li>Involve facilities managers</li> </ul>	<b>Data development:</b> <ul style="list-style-type: none"> <li>Export data for building control reports</li> <li>Confirm design co-ordination &amp; detailed analysis with subcontractor</li> <li>Confirm all design team inputs</li> <li>Commence performance specified work</li> <li>Embed performance specified design work into model</li> </ul>
<b>F Production Information</b>		<ul style="list-style-type: none"> <li>Preparation of production information in sufficient detail to enable a tender or tenders to be obtained.</li> <li>Preparation of further information for construction required under the building contract.</li> <li>Application for statutory approvals.</li> </ul>					
<b>G Tender Documentation</b>		<ul style="list-style-type: none"> <li>Prepare &amp;/or collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project.</li> </ul>		<i>Information exchanges will vary within the project timeline depending on the procurement approach &amp; building contract. However will still follow the tender activities outlined in RIBA PoW 2007</i>	<ul style="list-style-type: none"> <li>Prepare tender documents using NRM2 rules of measurement</li> <li>Appraise &amp; award tenders</li> </ul>	<b>Optional tender stage reality-check:</b> <ul style="list-style-type: none"> <li>Confirm further requirements</li> </ul>	
<b>H Tender action</b>		<ul style="list-style-type: none"> <li>Identify and evaluate potential contractors and/or specialists for the project.</li> <li>appraise &amp; award tenders;</li> </ul>				<b>Tender award stage reality-check</b> <ul style="list-style-type: none"> <li>evaluation SL procedures within tender bids</li> </ul>	
<b>J Mobilisation</b>		<ul style="list-style-type: none"> <li>Appoint contractor.</li> <li>Issue project data to contractor.</li> <li>Arrange site hand over to the contractor.</li> </ul>	<b>5 Construction</b>	<ul style="list-style-type: none"> <li>Offsite manufacturing &amp; on site construction in accordance with construction programme</li> <li>Resolution of design queries from site</li> <li>Administer building contract</li> <li>Regular inspections &amp; review of progress</li> <li>Implement handover strategy</li> <li>Update construction H&amp;S strategies</li> </ul>	<ul style="list-style-type: none"> <li>Prepare valuations in accordance with Building Contract</li> <li>Undertake change assessments</li> <li>Undertake cost monitoring</li> </ul>	<ul style="list-style-type: none"> <li>Confirm roles &amp; responsibilities of all parties in relation to SL Requirements</li> </ul>	<b>Construction Update:</b> <ul style="list-style-type: none"> <li>Embed performance specified design work into model</li> <li>Review BIM information provided by contractors and specialists</li> <li>Update BIM model with “as constructed” information</li> <li>Co-ordinate and release end of construction BIM model</li> <li>4D progress monitoring</li> </ul>
<b>K Construction to Practical Completion</b>		<ul style="list-style-type: none"> <li>Administer building contract to Practical Completion.</li> <li>Provision to the contractor of further Information as and when reasonably required.</li> <li>Review of information provided by contractors and specialists.</li> </ul>					
			<b>6 Handover &amp; close-out</b>	<ul style="list-style-type: none"> <li>Handover of building &amp; conclusion of building Contract</li> <li>Carry out activities listed in Handover strategy</li> <li>Feedback for use to future life of building or on future projects</li> </ul>	<ul style="list-style-type: none"> <li>Agree final account in accordance with Building Contract</li> <li>Undertake tasks listed in Handover Strategy</li> </ul>	<b>Stage 3. Pre-Handover:</b> <ul style="list-style-type: none"> <li>Prepare for building readiness</li> <li>Provide technical guidance</li> <li>Communicate with FM staff &amp;/or contractors</li> <li>Review/ Post- handover sign-off</li> </ul>	<b>Model and Handover Planning</b> <ul style="list-style-type: none"> <li>Receive “as constructed” BIM model including all operation and maintenance data</li> <li>Commissioning and Soft Landings trials</li> <li>Review and monitor building performance</li> </ul>
<b>L1</b>	<b>Post- practical Completion</b>	<ul style="list-style-type: none"> <li>Administer building contract after Practical Completion and making final inspections.</li> </ul>	<b>7 In Use</b>	<ul style="list-style-type: none"> <li>Undertake “in use” services in accordance with schedule of services</li> <li>Conclude handover activities</li> <li>Post occupancy evaluation</li> <li>Review of project performance &amp; project outcomes &amp; research</li> <li>Update project information</li> </ul>	<ul style="list-style-type: none"> <li>Undertake cost analysis</li> </ul>	<b>Stage 4. Aftercare in the initial period:</b> <ul style="list-style-type: none"> <li>Support the first few weeks of occupation</li> <li>Incorporate SL requirements</li> </ul>	<b>Ongoing Maintenance</b> <ul style="list-style-type: none"> <li>Maintain model with changes to build throughout its life</li> <li>Handover BIM model for decommissioning/major refurbishment and/or demolition</li> </ul>
<b>L2</b>		<ul style="list-style-type: none"> <li>Assisting building user during initial occupation period.</li> </ul>				<ul style="list-style-type: none"> <li>Set up home for resident on-site attendance</li> </ul>	
<b>L3</b>		<ul style="list-style-type: none"> <li>Review project performance</li> </ul>				<b>Stage 5. Years 1 to 3 Aftercare:</b> <ul style="list-style-type: none"> <li>Monitor review, fine-tuning &amp; feedback/ review processes/ undertake evaluations</li> </ul>	

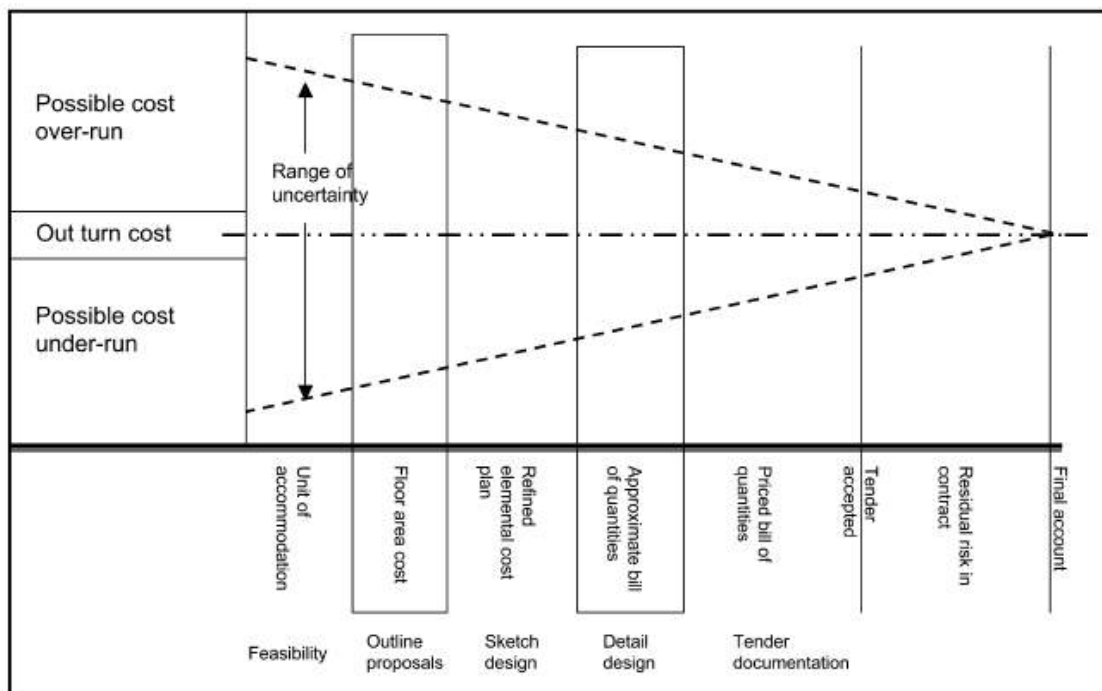


**Figure 2: RIBA Plan of Work 2007 Stages – highlighting cost estimate and cost plan outputs**

Figures 1 and 2 shows a traditional preparation of pre-contract cost functions limited to feasibility and technical design stages. As the scheme design progresses to a more detailed design (from superficial to elemental costing), more information becomes available (data drop increase), therefore initial cost estimates and cost targets need to be reviewed to ensure it is as accurate as possible with subsequent design inputs considered and up to-date. The traditional procurement approach is not value add in terms of value proposition and cost related challenges until the construction stage, invariably causing potential delays as design evolves and affecting accurate cost information in particular when massive changes are required (RICS, 2015; Cartlidge, 2013; RICS, 2014).

## DIFFERENT TRADITIONAL COSTING APPROACHES

Several approaches to preparing pre-contract cost estimates currently exist with embedded weaknesses and strengths in relation to industry best practices. Available data from clients determines the type of cost estimating technique or method considered to be adopted with varying degrees of cost certainties and uncertainties.



**Figure 3: Degree of cost uncertainty and traditional costing approach**

Applicability of some techniques is easier when compared to other approximate costing techniques and the reliability of the cost outputs is dependent on the credibility and quantity of data available.

- Functional Unit method** is a single price rate method based upon cost per functional unit of the building or standard unit of accommodation e.g. cost per bedroom, uses interpolation of cost between buildings of similar nature to obtain a cost range for a ball park figure only as there may be many intangibles - storey height and drawing for a true comparison. The level of cost accuracy in the estimate produced however is directly linked to the information supplied by the client (Kirkham, Brandon and Ferry, 2015; Ashworth and Perera, 2015). This type is ideal when trying to ascertain an approximate cost budget or guide price for a proposed building project without the aid of any detailed plans as expressed in RIBA DPoW 2013 stages 1 & 2 – Table 1 (RIBA, 2007). Cost data is typically sourced from indexed data of past projects where the contract sum is divided into the number of functional unit e.g. cost per bedroom for a hotel. The previous cost data is analysed, compared and then interpolated to allow for changes to specification, basic design as well as making allowance for location, market forces and inflation (Brook, 2017; Cartlidge, 2013; RICS, 2012).
- Superficial method** also known as cost/m<sup>2</sup> is a single price rate method based upon the usage area known as gross internal floor area (GIFA) and uses published analysed cost database e.g. Building Cost Information Services (BCIS), Standard form of contract (Brook, 2017; Elbeltagi et al, 2014; RICS, 2014; Cartlidge, 2013; BCIS, 2012). Appropriate method where an early budget cost is required without any specific details other than approximate size. More accurate than functional unit as the costs can be manipulated to reflect the criteria set by the client brief. This method is based on the fact that there is a close relationship between construction cost and the floor area of a building i.e. the greater the floor area, the greater the construction cost (Brook, 2017; Kirkham, Brandon and Ferry, 2015; Ashworth and Perera, 2015) - RIBA stage 1 and 2. Cost data is typically sourced from previous past projects where the contract sum is divided by the project GIFA and then multiplied by the new GIFA. This floor area is measured between the internal faces of the enclosing walls, and it includes internal walls, partitions, columns, stairs, chimney breasts, lift shafts, corridors etc. All sloping surfaces are measured flat on plan. Care needs to be taken when calculating GIFA and what is classed as usable space e.g. circulation areas are included (Ashworth and Perera, 2015; BCIS, 2012)

- **Approximate quantities** - this method relates to assessing in detail and combining into composite items all associated cost of the actual work to be carried out but requires full drawings and specifications. This is presumed to provide the most accurate form of estimate traditionally. This form is very similar to measuring using detailed rules of measurement: NRM2 (Brook, 2017; Cartlidge, 2013; RICS, 2007)
- **Elemental estimating** - costs are estimated by breaking the building down into its major elements. The rates are calculated by “measuring the size/amount of the element and multiplying by a unit rate” using a combination of the above estimating techniques (Benge, 2014; RICS, 2014; Cartlidge, 2013; BCIS, 2012; March, 2009). This method is excellent for forming cost targets and usually becomes the formal cost plan used throughout projects.

Early cost estimation relies upon the use of quality historic design and cost data and is a forecast of the contract sum to enable a prediction of the future estimated cost as well as the accuracy of the estimate (Brook, 2017; Ashworth and Perera, 2015; CIOB, 2009). Before commencing the detailed design or the construction phase it is essential to consider the associated costs involved in setting the project budget and best practice to review those costs as design develops. When selecting a method to use, a number of factors must be taken into consideration, which includes the information available about the project, the stage of the project cycle, the time available, the experience of the estimator, the form of cost data available and the amount of cost data available (Cartlidge, 2013). The availability of project data therefore dictates the type of estimate required and equates to the stages of the traditional procurement approach where the most accurate estimate is undertaken when full designs have finally been agreed incorporating many revisions (RICS, 2012; Cartlidge, 2013). The practice is to choose the technique which will yield the most accurate estimate within the time available, given available information. Defined costing techniques above has been engaged by industry practitioners for years – the QSs, cost managers, cost consultants, clients and contractors still struggle with the inefficiency and inaccurate tender sum embedded within the process. The challenges of traditional approach like poor data management, changes or alteration by project stakeholders/client, inexperienced QSs/estimators, poor understanding of measurement rules, poor value of products, wrong interpretation of drawing/designs, improper breakdown of building works into measureable items, error filled BoQ and tender sum, missing information, late information, insufficient detail, conflicting information etc still burdens the entire process. Figure 3 shows the input data process of different cost estimating techniques with varying degrees of cost inaccuracies at project milestones. The possibility of cost overrun and cost underrun as a result fluctuates and exists throughout the cost estimating and cost planning processes leaving a residual risk factor even after the tender process has been initiated and completed. This defines further issues and practice challenges both at the design, construction, operation and maintenance phase of any project. The Canadian Construction Association (2012) commissioned a taskforce to assess the degree of accuracy for different estimating technique linked to the RIBA 2007 stages and in the UK, a corresponding stage percentage error was also analysed by RICS (2014). Reported finding is as follows:

*“At concept design, cost variance ranged between 20-30%  
 When 33% of design developed cost variance ranged between 15-20%  
 When 66% of design developed cost variance ranged between 10-15%  
 When 100% tender documentation complete cost variance ranged between 5-10%”*

Expected percentage of errors in the UK:

*“Conceptual estimates during schematic design range between 10-20%  
 Semi detailed during design development range between 5-10%  
 Detailed when plans and specification have been produced between 2-4%”*

Due to the fragmented linear style as shown in Figure 3, quality of early design information with no integration of the design and construction team, accuracy of the cost models will remain compromised

even after the project has started on site. With 5D BIM integrated common data approach, cost certainty is improved as opposed to the substantive range of cost uncertainty embedded traditionally (Elbeltagi et al, 2014; Ashworth et al., 2013). Hence the RIBA DPoW 2013 promoting new procurement routes with early contractor involvement, acknowledging 5D BIM embedded processes, and a more standardised measurement classification (NRM1-3 suite) to be used consistently throughout the lifecycle of the project - enabling better cost control and cost predictability at pre contract – Table 1.

## **TRADITIONAL MEASUREMENT PROCESSES**

Traditionally, the choice of unit of measurement and cost outputs are dictated and still will be on the level of detail available (BCIS, 2012). Construction costing and estimating always uses some form of measurement, whether measuring the material quantity e.g. volume of concrete or counting the number of external doors or if no drawings count the number of bedrooms required by the client. The same rules of measuring or counting apply to any model, diagram or description. However this does not mean that the contractor would use the same measurements as per the standard rule of measurement – they would manipulate the data to contextualise to the quantities of material e.g. ordering of material quantities, this technique is known as ‘builder’s quantities’ hence error filled bill of quantities and rates (Cartlidge, 2013; Ashworth, Hogg and Higgs, 2013).

During tender estimation, detailed project cost in form of bill of quantities (BoQ) is developed using Standard Method of Measurement (SMM) for construction industry practice (Matipa et al., 2010). Measurement standards have been in existence for nearly a century providing set of rules and guidelines for QSs to measure and price building works (RICS, 2014). Due to its limitations on the required procurement variability, different forms of measuring standards were deployed for industry practice especially when employing procurement methods that does not need a detailed BoQ and tender documents. According to Cartlidge (2011), “the format presented in SMM7 is specifically related to the preparation of BoQs but not to cost estimates or cost plans. Therefore SMM7 is unable to support QS in providing cost advice due to its failure to suit the new approach of cost planning, particularly when capturing cost information”. In the absence of a specific set of standards, SMM has been adopted for cost estimating and cost planning (RICS, 2014). Various sets of standards were as a result used for measurement and description of building works by the QS which compromised data integrity and created doubts among the project team members regarding the provision of cost advice. Prior to the publication of the NRM measurement suite, there were no standard measurement rules for cost estimating recognised by the QS profession, causing a lack of consistency and structure towards the production of measurement data or cost planning through the whole life cycle of the project (RICS 2012). Added to this lack of structure is the manual take off process undertaken by the QS where various detailed 2D drawings are required to be interpreted and cross checked for any discrepancies among different professionals, design team and trade suppliers inputs due to lack of joined up integration (Cartlidge, 2014; RICS, 2014; Bylund and Magnusson, 2011). The Royal Institute of Chartered Surveyors (RICS) was moved towards developing a new set of rules for measurement known as New Rules of Measurement (NRM) as a result of the inappropriateness of standards and the compromise of data integrity fuelled by application of differing measuring rules and standards. NRM was developed in three distinct volumes to cover the whole lifecycle of construction process – from initiation of project definitions and strategies through to completion and building occupation supporting the RIBA framework stages for project lifecycle and NBS developed BIM standards.

According to RICS (2012), “NRM 1 provides vital guidance on the quantification of building works for the purpose of preparing cost estimates and cost plans. NRM 2 was prepared to guide the detailed measurement and description of building works for the purpose of obtaining a tender price while NRM3 extends indispensable guidance on the quantification and description of maintenance work for the purpose of preparing initial order of cost estimates during the preparation stages of a building project, cost plans during the design development and pre-construction stages, and detailed, asset-specific cost plans during the pre-construction phases of a building project”. In summary NRM 1 basically identifies information requirement from BIM for cost advice at the project early design stage, NRM 2 is for the production of tender document to obtain tender sum while NRM 3 is for asset maintenance but stretches from initial cost estimate through design development and pre-construction stages to asset specific cost

plans during the preconstruction phase of a building project. NRM if well applied within the cost functions of a BIM project will meet the requirements of RIBA-DPoW 2013 unlocking principles that develop an NRM BIM tender though issues regarding designing to a correct level of detail and object naming conventions need urgent resolution.

## **TRADITIONAL ESTIMATING AND COST PLANNING APPROACHES**

“Cost estimating is the process of collecting, analysing and summarising data to prepare an educated projection of the anticipated cost of a project” (Schaufelberger and Holm, 2017). Estimating is basically at the heart of cost planning of construction work as it allows developers to calculate project budgets controlling and regulating main contractor’s functions as well as being used to form a cost planning tool. This enables the client to make informed decisions on affordability and risks (Schaufelberger and Holm, 2017; Bengé, 2014). The process of cost control begins at the inception of a project particularly where the “guide prices or indicative costs” are required (Ashworth, Hogg and Higgs, 2013) and identifies this as a pre tender estimate or more recently under NRM1 - order of cost estimate (Benge, 2014; RICS, 2012). Conventionally, the QS functions is mainly associated with cost estimating and cost planning, production of bill of quantities (BoQs), interrogation of tender processes and documentation, procurement input, payments, construction cost control advice, valuation preparation, contractual claims and final accounts. However, changes in procurement strategies with the developments in the construction sector in particular Building Information Modelling (BIM), have expanded the role and responsibilities of QS to cover whole lifecycle costing, value management and decision drive, risk analysis and resolution, project and construction management, facilities management, contractual disputes and litigation (Ashworth and Hogg, 2007).

Due to the fragmentation of the construction industry and the linearity of the design process, cost estimating is typically performed traditionally at a time when the conceptual design is quite advanced or even completed, which is much too late in the design process to help the different stakeholders make informed decisions (Forgues & Iordanova, 2010). Very often, this cost feedback highlights potential budget concerns and a cost engineering process will be performed to reduce construction costs, often at the expense of building performance and construction quality. Performing value engineering and cost estimating from the beginning of the design process would potentially enable a faster and more cost-effective project delivery process, higher quality buildings, and increased control and predictability for the owner (Sacks S., et al, 2010). According to literature, variation of over 40% with the initial budget is frequent in these cases (Flyvbjerg, et al., 2003, and Winch 2010). Although BIM-based cost estimating tools have been available for some time, only a handful of large construction firms have been able to fully leverage this functionality. Nowadays, the AEC (Architecture-Engineering and Construction) industry is facing a technological change represented by the transition from CAD-based (Computer Aided Design) documentation to BIM (Building Information Modeling) (Winch, 2010). Unlike the CAD drawings which were limited in information presenting only independent views as plans, elevations, sections etc, BIM opens an expanded range of possibilities due to the immense amount of information which can be encapsulated and later extracted from the digital model. The emergence of BIM presents the opportunity to use the detailed design elements and quantifications needed by today’s estimators and quantity surveyors (Mena, et al., 2010). Designs require earlier validation for more accurate estimates and can be used earlier culminating in improved cost predictability, reducing number of estimates required and making less room for errors filled processes.

## **PARADIGM SHIFT FROM TRADITIONAL ESTIMATING TO AUTOMATED QUANTIFICATION**

Building Information Modeling (BIM), is a 3D, 4D or 5D digital construction design tool used for sharing information between designers, clients, owners, quantity surveyors, builders, estimators and any other stakeholders in a particular project (Howard and Bjork, 2008). It brings with it both great benefits and a few challenges in regards to cost estimation. According to Liu et al (2016) “BIM itself is a purpose-built, product-centric information database”. BIM as a database of components in the design and construction of a building, can quantify accurately all the necessary materials required for construction while reducing greatly the margin for error (Haque and Mishra, 2007). Using the 5D



methodology requires input from the integrated and collaborative design team, the building operators and users from the outset of the project development delivering strategic cost and BIM outputs as identified in Table 1 above – thus mitigating residual risk factors of inherent measurement errors and cost inaccuracy (Usable Buildings Trust, 2014; RICS, 2013; RIBA, 2013). The traditional estimating methods and the estimator would rely solely on the plans and specifications to make the determinations of what is required. With the multi-dimensional aspect of BIM, and the file sharing capabilities, everyone is able to see exactly what is contained in the project from a single dimensional image. This sharing feature is a huge improvement over traditional methods. BIM is capable of providing the detailed design elements and quantifications needed by today's estimators and quantity surveyors (Mena, et al., 2010). Typically, cost estimating done from quantification of components was very time consuming: counting, checking and recounting. The counts from one firm could vary greatly due to human error and would carry over right through to the construction bid. These errors could prove quite costly if a job was awarded to a low bidder with incorrect counts on a high cost item. But with a model of the completed project, these oversights are rare and provide for a more accurate estimate and consistency from one estimator to another.

BIM provides the estimator the ability to generate material surveys and cost estimates from conception through completion, with accuracy that can only be gained through a dimensional model (Kraus, et al., 2007). Building information modeling takes into consideration the overall life of the building as well its future maintenance and use. This is helpful in preventing the equivalent product being accepted as a substitution for specified materials in the estimation, when the properties are actually different and building integrity would be compromised. BIM is an asset to the world of estimating as well as a landmark innovation in the building industry. Professional estimators know there is more to cost estimating in BIM than simple automation of estimating from objects to spreadsheets. 'Building Information Models are formed of intelligent and multi-dimensional objects; these being objects containing information about the element they are representing, such as quantity and specification details (Azhar and Brown, 2009). Through this, BIM enables automatic quantification (Deutsch, 2011) and the production of schedules (Woo, 2007), which will largely eliminate the need for manual take-off of buildings during estimating. In addition, design data is interrelated, and therefore an alteration of one element instantly updates anything affected by the change (Sylvester and Dietrich, 2010)' (Thurairajah N., et al 2013). Cost estimators also understand the challenges and obstacles beyond the technology that must be overcome if cost estimating is to become a viable dimension of BIM

One convention deployed by estimators in the traditional process is in identifying the expected accuracy range of an estimate based on the level of project definition or available data. In the traditional process, the project plans and specifications are the primary means by which this is determined, and as such, there was a direct correlation between the project's level of definition and the expected accuracy of an estimate (Figure 3). It is reasonable to expect a similar convention exists in BIM, and that as BIM contains more project definition or increase in data drop, it also impacts the potential accuracy of an estimate. The difference in BIM, though, is in how a designer creates the objects for project 'plans,' and specifications now have an impact on the estimate.

The method or sequence by which a designer created plans and specs in the traditional formats did not impact the estimate because the information relevant to an estimate was an overlay by the estimator and external to the graphical representation. In the traditional process, the estimator managed the information from these documents and extracted, organized, and used the information as best suited to accomplish the task of estimating. However, with BIM the point of organizing information shifts as more of it begins in the design model phase. Model objects are rich with the information estimators need to create a cost estimate, and if this information is to be used by estimators, then there is a point where the estimator's process should filter into the information management during design (Pennanen et al., 2011).

The development of a model includes the graphical representation of data-rich objects. The primary purpose of the design model is to convey design intent. However, each of the objects inserted are available now for future extraction by other stakeholders. The difference in BIM is that from an estimator's perspective, the development of a model is about the information associated with the objects and the input process for this information. This aspect of BIM is a significant shift in paradigm from which the estimator previously worked. 'Woo (2007) points out, it will be essential that design

information is correct in the first place because information extracted from the model is only ever as good as that inputted. According to McCuen (2008) estimators with an adequate BIM understanding can benefit from the 5D BIM function and automated quantification, by creating quicker estimates. This should lead to increased client satisfaction as they are receiving earlier real time economic feedback on the alternatives available (Pennanen et al., 2011), whilst having a greater understanding of the likely cost influences of design decisions (Deutsch, 2011)' (Thurairajah N., et al 2013). It is crucial that the estimator has confidence that the information is a valid representation of the object beyond the model to physical reality. This is new in the world of estimating and is challenging estimators as they work within this new paradigm.

## **RESEARCH METHODOLOGY**

This is a qualitative research strategy informed by research, particularly phenomenological investigation. Phenomenological research is a qualitative method of inquiring a given concept, which involves exploring an in-depth understanding of a phenomenal experienced by different individuals (Creswell, 2007). Data was collected using semi-structured open ended interview from key industry practitioners with relevant experience and skills in BIM projects across a spectrum of construction organisations involved with virtual and built environment. A total of 21 (twenty one) individually semi-structured open ended interviews across a spectrum of construction supply chain with virtual environment experiences and BIM backgrounds were conducted. Organisational roles such as design managers, heads of BIM, BIM directors, traditional quantity surveyors (QSs), 5D BIM quantity surveyors (QSs), traditional QS/5D BIM, cost managers, BIM software managers, BIM systems integrator and support, BIM strategy manager, BIM integration manager, BIM programme and project manager, 5D BIM information managers, graduate QS, cost estimators, BIM project planners etc were interviewed and recorded. Scope was intentionally provided for extensive discussion to identify issues beyond the literature findings and that which is conceived by the researcher. The interviews supported an in-depth interrogation and apprehension of the challenges and issues surrounding a seamless 5D BIM implementation than could be obtained using quantitative questionnaire surveys. The reason being that questionnaire survey approach would not offer a one on one in-depth interrogation on the issue under investigation and again there is no guarantee that the responses will be from the targeted individuals or job roles. Collected data as audio recorded was transcribed, analysed, interpreted; identifying significant statements and advancing textural and structural descriptions into an exhaustive description of the invariant structure called "essence" of that which is experienced. Discussions from the findings are as follow:

## **DISCUSSIONS**

### **EARLY CONTRACTOR INVOLVEMENT (ECI)**

Early Contractor Involvement (ECI) is an aspect of the growing trend for early project collaboration across the industry allowing contractor's early involvement within the project team at the outset of a scheme bringing expertise in planning, buildability, cost estimating and value engineering (Garlick, 2016). ECI allows the contractor to be engaged in a project under a two-stage Engineering and Construction Contract (ECC) before project details regarding what are to be constructed is fully developed and priced. This enables the contractor to be involved and integrated within the design development and construction planning stages of a project early enough to make a valuable expertise input. This approach promotes team working, collaboration, innovation and good construction planning through the whole project and sharing benefits gained through such team working. NEC has recently developed an additional clause to be used with the NEC3 Engineering and Construction Contract (ECC), options C and E where ECI approach is required. The traditional approach within the construction industry using single-stage procurement and contractual model has only involved the contractor and its subcontractors at the construction phase. However, such a model is not likely to obtain the best contributions from all parties to deliver a successful project due to the exclusion of the main contractor and subcontractors from the early design and project planning. As a result innovative solutions, constructability, cost saving benefits, overall project timescale, health and safety planning into the design has been adversely affected. Experience has shown that value for money is not achieved in either the final cost of construction or the whole life and operational costs (Pittard and Sell, 2016).

One of the interview questions was on the respondent's perspective on contractor's involvement in a design phase or design model development of a BIM process. Respondents from various organisational categories – sub-contractors/fabricators, main contractors, client organisation, cost consultants (SMEs), cost consultants (multinationals) and majority of the respondents had the opinion that getting the contractor involved early in the project has a huge cost benefit impact on the overall cost of the project and also generates a better value for money. One of the respondents, a 5D BIM Information Manager from a cost consultancy firm had this to say regarding contractor's involvement on projects. The respondents view was the following:

*“Currently in a D&B project, the contractor comes in at stage 4 which is the last stage of design in RIBA Plan of Work stages and carries it to completion which is not good enough. I would rather see contractors coming in earlier than stage 4 in a two stage D&B tender - having a contractor involved with the project earlier than stage 4 has benefits in terms of earlier buildability analysis, earlier supply chain sub-contractor procurement solutions, advice on buildability, advice on value engineering, the whole supply chain of sub-contractors and their solutions, health and safety issues, early advice on costing and programme etc; I would rather see the contractor on board at stage 2 or 3, rather than 4. So rather than the architect coming up with some solutions that won't actually work when it comes down to build; you've got your sub-contractor very early saying 'actually, that's not the way it's going to work, I've got my solution, here it is. The biggest advantage of an early contractor involvement in the project is the transfer of risk from the designer and the client over to the contractor. The advantage will reduce the design errors passed to sub-contractors”*

Another respondent from a cost consultancy firm – a 5D BIM QS also agrees with early contractor involvement and said;

*“I tend to think that getting a contractor involved as early as you can is generally a good idea. It's not something that's necessarily done in the industry and I guess it depends on the type of contract as well; if you're using a traditional type of contract, in theory, the contractor wouldn't need to have any input until post-tender. D&B would be slightly different, particularly if you've got Value Engineering (VE) items where you want to get the contractor's input to try and drive down costs, or make things simpler. So I would say as early as possible”.*

A BIM Information Manager from a sub-contracting firm was also in agreement and has this to say when asked the same question;

*“Every project should be like a joint venture almost, like an integrated project delivery (IPD). Nobody's there at the moment, but that approach where the contractors or the sub-contractors are brought in early for their design knowledge is as soon as possible. I've always asked the question 'why aren't we there earlier?' Is that not going to be the thing that increases the advantages, having our expertise at the outset stops them designing something incorrectly. So if we're talking 'where do they come in initially? It should be right at the very outset; I'd say even once the brief has been given, that's where contractors should come in. I think for it to work well, you have to involve the contractor straight away, at the end of stage 1/start of stage 2”.*

Another participant reiterated this perspective further - *“We've got a transition to move from silos activities still into a shared environment and federated models and so on; the benefits will be for a 5D QS, you would be involved a lot earlier in the process, you would have more opportunity to add value to the process because your valued cost advice would be able to influence the project at the earlier stage and everyone understands the earlier in the process, the bigger changes you can make and I think it will just integrate the cost into the early stages of project development from where it had been relegated to, traditionally”.*

Early Contractor Involvement and the supply chain is exclusively a management decision with positive impact on project outcome. The strategic protocol on project initiation should be such that supports design process to be linked to contractors cost and schedules reflecting contractor's BIM Execution Plan. Contractors initial design response to the client if involved early in the project development should

integrate the clients agreed programme of schedule and cost to their internal programme linking design cost and schedules. 5D BIM cost protocol as developed using the key findings of this research framework should be part of the competency assessment for generation of accurate cost information and should be submitted alongside BEP. Leveraging on the contractors professional input at the early stages supports a 5D BIM costing approach rather than the late stage traditionally led approach that is error prone. It supports the 5D BIM QS to interrogate a 3D model for early cost estimate and cost planning advice and strengthens the internal gateway processes of the client to achieve design stage cost targets. It is an early decision that empowers the clients with knowledge, skill and appropriate exposure to streamline design and construction processes. The respondents' views on ECI are very clear regarding the early project benefit of getting the contractor very early on board.

One of the respondents who is a BIM Strategy Manager from a client organisation gave this response when asked same question;

*“Right from the start, it has to be done from the conception, or from planning stage because from a client perspective, we need to make sure we've got clarity on data, so it's not just about the physical assets, but also about what information, or what digital data we need in order to design that asset, build it and operate and maintain it at the end, especially because I worked in TfL as well, from an operator's and owner's perspective, that clarity on requirements and communicating it right from the start is key”.*

At the moment contractors are involved at a later stage during design model development, and at this stage the benefits of contractor's vast experience and inputs within the design processes is lost. Late stage involvement reverts the entire digital initiation to a traditional costing approach and destroys client's feasibility studies. The procurement strategy chosen by the client for the project largely affects what input and benefits could be realised from the vast experience of the contractor and the supply chain as flagged by the respondents. Contractor's inputs and benefits in terms of buildability analysis, procurement solutions, health and safety advice, building systems performances, engineering systems performances, supply chain input and assessment on supply chain competences, sustainability aspirations and checkpoints, performance criteria, and energy conservation are positively impacted. Stage design checks with respect to elemental cost limits, performances, project objectives and varied strategies are carried out, design data verified and validated before passing on to the next stage. Late involvement creates lots of myriad cost issues within the construction phase where opportunity to design changes are very minimal and even if it occurs, the high impact cost of change at a later project stage affects the overall project budget. But early contractor involvement does not only provide benefits within the design development, basically the contractor takes the risk for all of the design early on which is great for the client and the design team, it is one of the biggest advantage. This both challenges and mitigates the impact of design errors that is passed to the sub-contractors.

A design manager from a subcontracting firm also subscribed to the same views as above and also cited a case study;

*“So most of our projects that we get involved with are extremely complicated and we are only looking at maybe 10 per cent of the overall project. Most projects are design and build of a whole facility, we don't do whole facilities, we provide ventilation systems. Complicated ventilation systems probably only equate for about 10 per cent for the cost of an overall project. So most of our projects, there is a main contractor and he will do a concept design, he may do a detailed design. When he's finished the detailed design, he may produce a technical specification and go out to tender to ductwork manufacturers like our groups. So at that point, you're given a model, it could be in any software that's available, it could be Solidworks, it could be PDMS, it could be Revit, it could be anything and the client, all he wants you to do is add a level of manufacture design, so you're not responsible for the design, i.e. will those fans work? Will those air handling units work? Is the size of the ductwork correct? That's all his responsibility and our responsibility is to turn that into a manufacture design, manufacture and install it and then he will commission it and make sure that his design works. Then you have the total opposite contract of where we do the concept design, so all the way through. So we come into these contracts in any of the phases from the beginning of the design until almost the end of the design and it's up to the individual, main contractors to determine where the cut-off point is and where we add value to their scope. We're trying to convince them that we can add value earlier on because quite a lot of the time, if they do a model in PDMS, we can't convert PDSM, so they spend three*

*years doing a design and it arrives in a software that we can't convert, so we almost have to trace over that information and re-draw that information, to put it into a software that we can use, so that's not adding value, you're repeating the work all over again. So what we try to encourage clients and demonstrate to them is that we can add value by getting involved sooner on some of these projects”.*

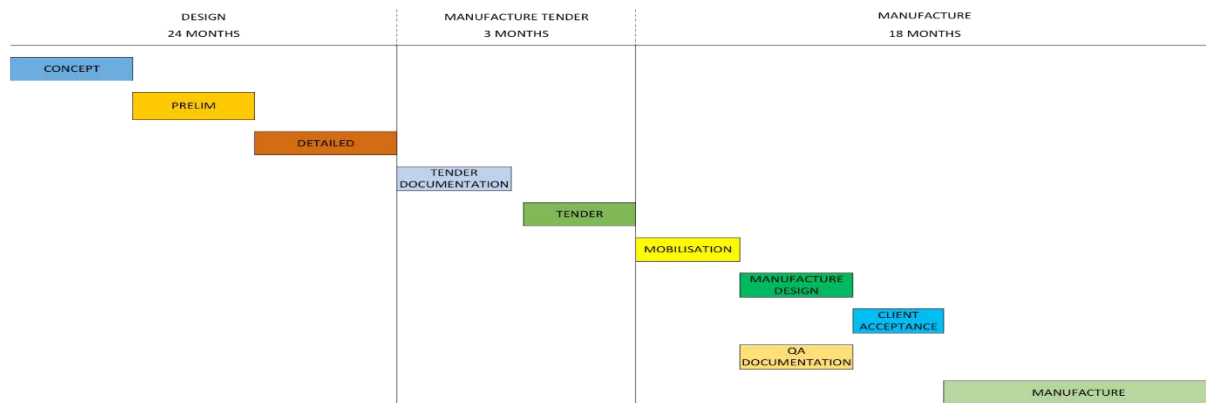
The respondent cited a case study where early contractor involvement had impact on cost efficiency, collaboration, and information sharing and time savings. The below case study further consolidates the positive impact of early contractor involvement in achieving project cost limit, process efficiency and overall timescale.

## **CASE STUDY FROM SME ORGANIZATION**

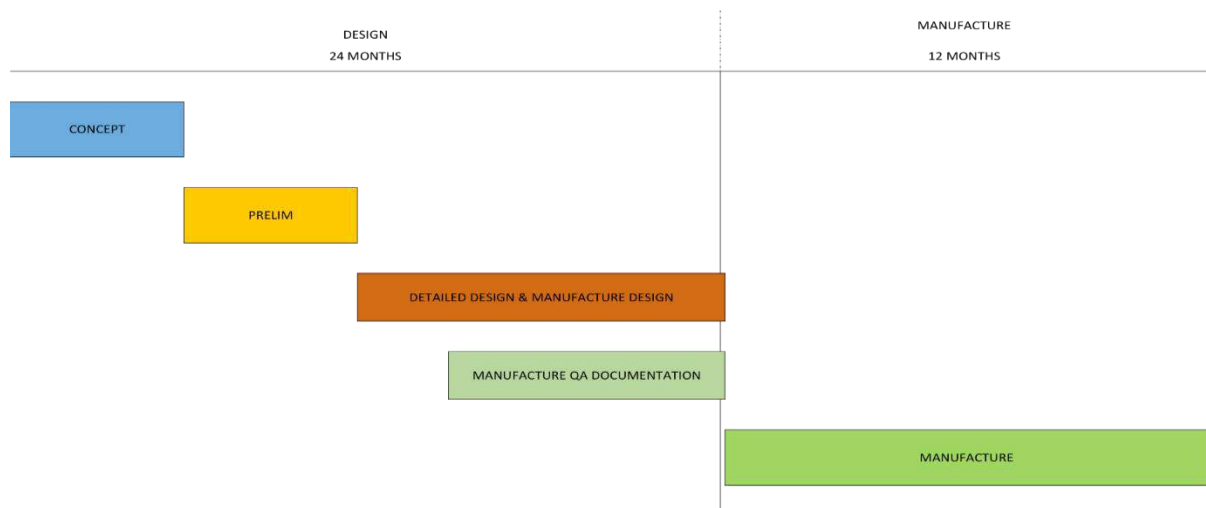
The case study cited focused on a single high value project within the host organization where the client's design consultant had identified early within detailed design, that their traditional design team had little experience in coordinating traditional building services and ventilation systems. The design consultant was using BIM clash reports to manage the detailed design layouts, but was not controlling coordination or access requirements which can then move the problem further down the programme and into manufacture design. This approach would have brought about considerable reworks of the HVAC systems after the coordinated model for detailed design had been approved. In embracing the manufacture design team early and embedding the team with a digital common data approach into the traditional detailed design, enhanced the teams overall capabilities to deliver a rounded solution. The manufacture design teams brought practicality into the routing, coordinated support structure, which improved installation time and saved overall project cost.

The value transition point for this project was much earlier than the traditional methodology, as the drawing and routing design works was led by the manufacturer rather than the clients design consultant, due to the manufacturer's practicality in digitization and knowledge of the product. The early involvement of the manufacture designers added 5D cost value to the design scope at that early point of entry, challenging design liabilities, estimating errors and design details that come in excess of what's required at that design phase. Again receiving a completed design model in a file format that cannot be converted or interrogated (like solidworks, PDMS) by the manufacture designers is not value add, it means retracing that design information and redesigning it for appropriate use – meaning a massive additional cost. 5D BIM automated processes with this approach brings confidence in the detailed design output and cost information; this confidence allows the project to move directly into manufacture once the detailed design gate has been achieved. Having a huge cost and time savings on the normal costly tender exercise / contract placement and quality assurance documentation/ manufacturer familiarization period as could be seen in Figure... and.... below. The study highlighted exemplar usage of 5D BIM and ECI leading to integration of process information. The early contractor involvement of the design-manufacture company eliminated the tendering process completely with the benefit of a reduced quality assurance documentation process since the stage cost is being derived in collaboration with the client design consultants alongside the manufacture designers. Commencement of the quality assurance documentation can only commence in manufacture design, this documentation process within the traditional process is quite likely to take longer than the manufacture design and in some instances delays product manufacture.

The case study highlights ECI supported the client's design consultants in designing to a correct level of detail for use in the manufacture and positively impacting on the overall project cost.



**Figure 4: Traditional Costing QS Approach**



**Figure 5: Early Contractor Involvement/Integration of Process Information**

The traditional approach involved the team much too late in the project development and therefore providing limited scope for innovation, cost considerations, knowledgeable inputs into the design phase and the consideration of constructability issues. It is expected that the design team, consultants and contractor's team work together from the very beginning upon which the premise of the ECI is based. ECI supported through the BIM processes is a credible means for cost savings and rewards cost-benefit ratio with respect to initial process investment for the product manufacturers. It offers potential project merits in avoiding and managing project risks, predicting cost and project time, encouraging innovations and better project. As a consequence, the industry should embark on a sustained campaign to cushion the effect of performance problems through a number of initiatives in particular 5D BIM automated quantification/integration of process information and radically different approaches to the procurement and management of construction projects to enable ECI. Employers should leverage on the valuable expertise of contractors from the brief definition stage right through commissioning to ensure a maximised streamlined process and a support for automated quantification process in order to deliver a reduction in overall project cost. Emerging project delivery methods should increasingly rely on a strong collaborative relationship between the client, design team and the contractor (multidisciplinary project parties) together with their supply chain, and are aimed at developing longer term positive project impact for the benefit of all involved parties.

## **Benefits of Early Contractor Involvement and 5D BIM**

- Removes the normal costly time consuming mid-term tendering process.
- Knowledge retention through-out the whole project delivery.
- Visualisation of cost information by all parties involved
- Ability to interact with the design model with reference to cost and programme schedule
- Enhancement of project team collaboration through modelling of 5D information and generating the suitability of 3D design information.
- Project conceptualisation as 3D design information facilitated the costing of design options through ECI
- Efficient generation of quantities for cost planning as compared to the traditional QS processes during the design detailed cost plan stage
- Contract arrangement more likely to encourage a fit for purpose solution.
- Increased ability to resolve RFI's in real time, potential risks identification and clash detection possibilities
- Substantial time and cost saving exist for the project, as the quality assurance documentation and manufacture design detail can be completed earlier - during the detailed design phase, further enhancing the benefits identified in item one above.

ECI is very beneficial because the contractors build the facility. Project feasibility should be protected by constraining any design decision or input that triggers cost overrun using BIM integrated functions. When people bring in contractors, infrastructure projects and clients, contractors and the supply chain should be on board from stage 1 of the RIBA Plan of Work 2013 (the very project outset) to make sure that the 5D cost information generated is accurate with design progression and buildability is assured. Designers sometimes do not have an oversight in what can actually be built and this is the reason early engagement model of involving contractors very early on to inform and influence buildability is critical at the moment. They construct the facility and therefore having a decision from the management for early contractor involvement and getting the contractor and the supply chain on board early makes sure that there are no surprises. When the contractor do not get involved until very late in project stages, they get to site and flag non-buildability, extended design errors and clashes - thus the reason for a shift in procurement approaches. The buildability and option appraisals, contractors and supply chain coming up with project delivery solutions they are certain will be able to build and that would then feed into the estimating process and aligned to what can be built.

## **AUTOMATED QUANTIFICATION/INTEGRATION OF PROCESS INFORMATION**

Quantity measurement and classification has evolved from the traditional processes into the digital age, taking off quantities against multiple measurements digitally. This is requiring early project collaboration across the whole spectrum of construction professionals bringing in expertise in planning, cost estimation, constructability and value engineering - hence the obvious need for early contractor involvement (ECI) in delivering projects. The conventional manual interventions or interpretation of data breeds risks of inconsistency and error in costing activities whereas BIM has capabilities to quantify accurately while reducing error margins. BIM with a multi-dimensional capabilities and the information sharing abilities enables all parties involved in a construction project to visualise the model content from a single dimensional image and provides detailed designed elements and quantification for QS use (Mena *et al.*, 2010). To import quantities from a model into a costing software in a BIM enabled data environment, elements are selected either individually or as a group. Correct classification of elements in the model for automated BIM process are considered extremely important and names for different material/object types is to be shared for correct interpretation as appropriate naming convention is currently a challenge. One of the key findings of literature was the inability of the traditional measurement approach to correctly classify elements while undertaken measurement, hence an error prone measurement process. This problem was extensively engaged while conducting interviews to know how the industry practitioners deal with the issue of elemental classifications and

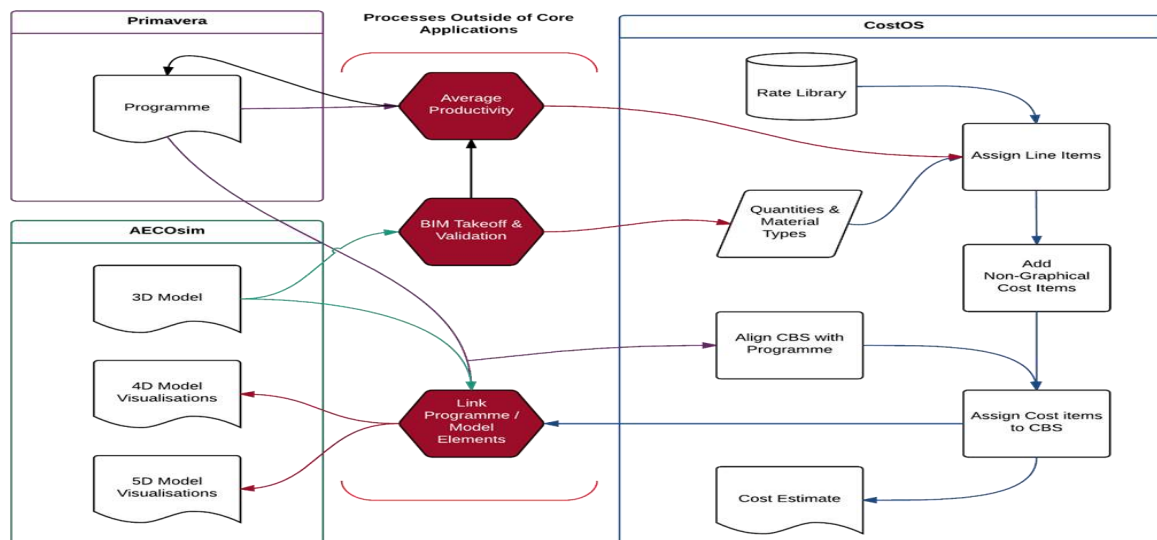
naming of objects within virtual or digital environments. A respondent who is a cost consultant explained further with the following;

*“Here's the thing, it entirely relies on the information given to us by the designers, so if it's the same designer working on different projects and he uses always the same naming convention for his objects, then we can set up our template on it. If he changes the name, it's going to change the links, the clever links that we have put inside of our system to put in the rate which is why it's incredibly frustrating for us to work with designers who do not have a naming convention in place because it will screw up our automatic rate up system. It's already named. If you go on Revit and you want to put a table in that room and you've used always the same table, it's got a name, but sometimes because they chose to be annoying, or because they don't know what they're doing, they will change the name; so sometimes it will be called a wooden table and the next project, it's going to be called Table 1 and the next time around, it's going to be called table 001 etc., so we rely on the naming convention of Revit, or whatever system. So whatever comes in, that's the name, that's what we rely on; it might be the same table, or if it's not, if it doesn't have the same name, then we lose the clever link, so we can re-establish it, but that's a waste of time. So for us, the critical thing for the design of information in models is the naming convention, it's got to be one and it's got to be respected. So the BIM library has to be in place and a name convention has to be respected. If you have a naming convention in place, admittedly, you've got to have two pieces of information and they've got to be linked somehow, you need to have a common denominator that attaches this to that, A to B, there's got to be a point that says, you're linked into it. That to us, at the moment is the naming convention. So if “A” has a proper name, then “B” is automatically attached to it because it recognises that name, therefore it's that rate. So right now, we rely entirely on the naming convention which BIM addresses, so theoretically, that works. In practice, when the naming convention is butchered by the designers, we lose the link, but BIM should have that link in place”*

Design information that gets to the QS or the cost consultants and the format of that information is critical to the accurate measurement process in a digital BIM environment. According to the respondents, designers do not like QSs controlling their design concepts and ideas and there's also lack of QS understanding of different design software and therefore cannot dictate naming conventions for QS functions. Elements are defined by intelligent data-rich objects within the model and these objects contain quantities and specification details enabling automated quantification. BIM based estimating tools vary in their functionality and working processes. It is the responsibility of the QSs at the operational level in collaboration with the strategic management to select and engage these tools to be part of BIM based projects and also benefit from the merits of BIM technology. Choice of costing software with abilities to interrogate product models - the responsibility of testing and validating the use of that tool adapted to suit the types of model manufacturers produce is vital in evaluating organisations software need for process automation in 5D BIM quantification. QSs/Cost Consultants have the responsibility to improve their internal business processes by choosing appropriately the estimating tools (liaison with software vendors), looking at the potentials and performance of these tools in handling product data, ability to challenge design programme input, speedy dimensional quantity data extraction and ensuring alignment in their business goal and objectives.

The Figure... below shows a typical 5D BIM automated process demonstrating an interaction between software products, processes and data required to create 5D on mass in an efficient manner. The diagram demonstrates an automated tested process with a model assembly produced by a costing software 'CostOS' designed to price works according to the RICS NRM 2 method of measurement for capital building works (Craven, 2016). It should be noted that this automated process mirrors what is possible with 'CostOS' and would apparently work differently with other costing software like CostX, Vico, Bentley AECOSim, Solibri Model Viewer/Checker 8, BIM Measure 16.4, Vectorworks etc.





**Figure 6: 5D BIM Automated Process (LBA/HS2, 2016)**

In this ‘CostOS’ process an IFC file is used as input and subsequently elements to price on the basis of their BIM Classification for example “Wall” are selected. From this subset the structural elements are grouped by thickness and a new Bill of Quantities (BoQ) item added for the sum of those elements with matching thickness. The unit rate library provided alongside the IFC has matching Unit Rates for the groupings which the assembly produces and allocates them accordingly. This process is repeated for all the classification types the assembly is programmed to interpret. Parametric factors are set in the assembly run interface to allow estimation of non-graphical items such as rebar content, formwork and soffits for the new line items. Non-graphical items are added automatically to the BoQ and there are pre-programmed cost line items for each of the items the assembly can import to apply prices. If elements in the model are misclassified, the assembly will not function as intended. Data could be passed into the assembly through a coding sequence to define how items are added to the BoQ or what automated non-graphical items would be added’ (Craven, 2016). Accurate classification of elements and correct naming of objects in a 5D automated process offers a better data interpretation and mitigates cost estimation risks when used in pricing. A knowledgeable QS is still required though an automated process to guide the software as in the semi-automated process while engaging ‘CostOS’ procedure for efficient cost 5D output. This is because the Qs will apply professional judgment to determine the suitability of measurement standards (eg NRM 1, NRM 2 and NRM 3) applicable to level of details and level of information (increase in data drops at various stages). An experienced QS with a digital costing exposure will know when model cost estimation is area rate based, object/elemental rate based or a mix between both when design stages overlap and will further determine which formal cost plan applies to changes in data drops. Additions of non-graphical items like site logistics and traffic control logistics not directly relating to the actual physical construction, would need to be added to the cost breakdown manually, or as function of total cost by a QS. Data availability and open relationships in regards to individual product data remains a big challenge facing 5D seamless automation in the built industry (Kirkham, 2015). However, database/data integration supporting applications to draw data from each other’s databases (multi-disciplinary database) freely will eliminate the manual import/export of data and will enhance 5D automation processes in the built environment (Craven, 2016).

Manual interventions are still required for an efficient automated process to work well due to few element classification and IFC issues (Pittard and Sell, 2016). Defining the granularity of information produced during design phase supports 5D process to be fully automated and thus the very reason for early contractor involvement as elaborated above. The accuracy range of an estimate is based on the level of project definition in the traditional process using plans and specifications as a primary means to define a correlation between projects definition and the expected accuracy of an estimate. Traditional QS managed, organised, extracted and used cost information in the best means suited however that process shifted in BIM through early contractor involvement (ECI) as more of the functions and cost

saving advice begins in the design model phase (Garlick, 2016). This research has found out iterative design outputs (self-imposed design increments, client commentary, external advice on design criteria etc) currently has an overlapping consequence on the early generated 5D cost estimate. However, identifying clearly the key cost drivers, inclusions and exclusions, and ensuring the lead designer and architect understand cost criteria supports design process to 'design to cost' rather than 'costing a design'. Secondly, a well-reviewed procurement strategy and a defined Design Responsibility Matrix (DRM) reduces complexities and making deliverables clear with an early agreement of how cost information will be dealt with as design develops. Thirdly, a robust and informative early cost plan will strengthen clients and contractors understanding of the relationship between design programme and cost and will trigger relevant questions on associated risks with cost plan and programme component if need be.

## **CULTURAL ISSUES AS BARRIERS TOWARDS 5D SEAMLESS IMPLEMENTATION**

To exploit full 5D BIM capabilities and benefits towards a more accurate and quicker cost information generation, contractors and the supply chain, QS practices and cost consultants are required to re-evaluate and re-engineer their business processes. As BIM evolves, industry practice in many construction organisations will typically rebrand to meet the changing requirements of clients. An emerging trend of larger scale businesses and operations are gradually developing alliance and synergy to enable a maximum delivery of 5D BIM offers (Smith, 2014). However, the biggest barrier facing QS and cost consultancy practice in the construction market is 'cultural conservatism' or strong resistant to change as uncovered by research. Systematic structures in different organisations linked to cost coding, payroll systems and supply chains would need total or partial alteration with appropriate interventions to cushion the change impact on their business processes. Organisations with mostly 'dinosaurs' workforce will find it even more difficult to adapt to the 5D process evolving trend. Either because of the initial up-front investment on relevant software/hardware technologies and training of staff or the fear of compromising basic QS required analytical and checking skills to automated BIM competencies. Narrow profit margin and down time for upskilling is also part of a prime concern. Digital technological competencies acquired by younger QSs and cost consultants is perceived as threats by senior QS practice personnel in construction organisations and this is constituting even more stronger barrier towards 5D BIM adaptation (Smith, 2014).

According to Smith (2014), "the added complication is that the technology is always evolving, lots of time and expense could be spent on software and training with uncertain outcomes. The pioneering path can be high risk as firms become 'test pilots' for certain technology whilst their competitors wait in the wings to see if the 'testing' will result in commercial value and competitive advantage". Secondly, clients and contractors have an existing bespoke cost model, specific cost coding system of design elements/objects and lots of other existing intelligent database that drives their business processes. This in practice is already a strong hitch and impedes collaborative working in 5D digital environment. Construction practitioners insist on familiar approaches, processes and standards making them unamenable to evolving BIM practices. The industry at the moment is still grappling with the challenges and complications of working with varying existing cost database and standards as effort is made towards collaborative assembling of project party members. Presently contractors and the supply chain with varying details of existing cost model for cost estimation and cost planning purposes in nearly every project complicate efforts to benchmark digital cost performance and drive efficiency as interoperability is literally unachievable. Best procurement considerations for successive work stages with potentials to offer myriad BIM benefits towards integrating 5D processes are challenged by these variances. With widespread recognition to improve productivity, reduce waste and achieve 25% cost savings on centrally procured public sector projects (Cabinet Office, 2016), construction industry leadership should embrace developed industry common standards for BIM projects – initiating collaborative performance benchmark for generating 5D cost information. Efforts are encouraged to engage all project parties particularly the 5D BIM QS, cost managers and cost consultants to function within a Common Data Environment. This will advance the understanding of the stages in projects where cost efficiencies and cost benchmarking can be achieved, improve cost estimation and functional capabilities across projects and alliances; deploy collaborative procurement techniques, embed and

increase the use of digital technology for BIM Level 2, enhance process implementation while driving or enhancing whole-life cycle costing (WLCC) approach.

## CONCLUSION

The comparative details of the various traditional QS cost estimation, cost planning and measurement approaches with the digitization process of cost functions supporting cost effectiveness of whole life cycle of a facility has demonstrated a practice gap particularly with respect to costing activities. The case study cited within the work showed a strong need for early contractor involvement which will ensure design information within the model is complete and structured correctly as poorly designed models deter the QSs from using BIM model for cost functions purposes. Early stage involvement of the QS will influence the accuracy of the input design information and will consequently impact the construction workflow because the more accurate the information the greater accuracy of the outcome.

Traditional approach has varying cost implications embedded as design evolves and does not offer reliable mechanism to establish cost of design options before final design decisions are made. On the contrary model objects are rich with design information the QS needs for cost activities and therefore a point where the QS process should integrate with information management during design stages should be established as best practice. Clients objective or project outcome relative to cost can only gain active collaboration of the supply chain if data is integrated through common data environment. It is also important to understand how increased efficiency and speed using 5D BIM automated process in cost estimation can enhance the function of a QS rather than threaten it. Time saved using a digitised process can allow cost professionals to provide additional value adding services such as value engineering, life cycle costing and carbon costing. Therefore, integration of process information and automated process is the most promising intervention to delivering cost effectiveness and high performance construction building projects.

## REFERENCES

Ashworth, A., & Hogg, K. (2007). *Willis's Practice and Procedure for the Quantity Surveyor* (12th ed.). Oxford: Blackwell Publishing Ltd.

Ashworth, A. and Perera, S. (2015). *Cost studies of buildings*. 6th ed. Florence: Routledge Ltd, pp.121, 530.

Ashworth, A., Hogg, K. and Higgs, C. (2013). *Willis's practice and procedure for the quantity surveyor*. 13th ed. Chichester: John Wiley & Sons Ltd.

Azhar, S. and Brown, J. (2009) BIM for Sustainability Analyses. *International Journal of Construction Education and Research*, 5, 276-292.

BCIS, (2012). *Elemental Standard Form of Cost Analysis Principles, Instructions, Elements and Definitions*. 4th ed. London: RICS.

Benge, D. (2014). *NRM1 cost management handbook*. 1st ed. London: Routledge.

Brook, M. (2017). *Estimating and tendering for construction work*. 5th ed. Oxon: Routledge.

Bylund, C. and Magnusson, A. (2011). *Model based cost estimations—an international comparison*. 1st ed. [ebook] Lund: Lund University. Available at: [http://www.bekon.lth.se/fileadmin/byggnadsekonomi/CarlBylund\\_AMagnusson\\_Model\\_Based\\_Cost\\_Estimations\\_-\\_An\\_International\\_Comparison\\_\\_2\\_.pdf](http://www.bekon.lth.se/fileadmin/byggnadsekonomi/CarlBylund_AMagnusson_Model_Based_Cost_Estimations_-_An_International_Comparison__2_.pdf) [Accessed 9 Apr. 2016].

Cartlidge, D. (2011). *New Aspects of Quantity Surveying Practice*. Oxon: Spon Press

Cartlidge, D. (2013). *Quantity surveyor's pocket book*. 1st ed. Abingdon, Oxon: Routledge, p.213.

Chartered Institute of Building (CIOB), (2009). *Code of estimating practice, seventh edition*. 1st ed. Chichester, U.K.: Wiley-Blackwell.

Craven, D. (2016). *BIM 5D Process and Prototype Development*. London Bridge Associates.

Creswell J. (2007) *Qualitative Inquiry and Research Design: Choosing among five approaches* (2nd Ed)

Deutsch, R., (2011) *BIM and Integrated Design: Strategies for architectural practice*, John Wiley and Sons

Eastman, C., Teicholz, P., Sachs, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors* (Second ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Elbeltagi, E., Hosny, O., Dawood, M. and Elhakeem, M. (2014). A. BIM-based cost estimation/ monitoring for building construction. *International Journal of Engineering Research and Applications*, 4(7), pp.56-66.

Winch, G. M. (2010). *Managing Construction Projects* (Second ed.). Oxford, UK: Blackwell Publishing

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W. (2003). *Megaprojects and risk: an anatomy of ambition*. Cambridge, Angelterre: Cambridge University Press.

Forgues, D., and Iordanova, I. (2010). An IDP-BIM framework for reshaping professional design practices. Paper presented at the Construction Research Congress 2010 (CRC 2010), 8-11 mai, Banff, Canada.

Garlick, P. (2016). Early Contractor Involvement. *The Journal of the Chattered Institution of Civil Engineering Surveyors – Civil Engineering Surveyor*. Pages 31-33.

Haque, M. E. & Mishra, R. (2007) 5D virtual constructions: Designer/constructor's perspective. In: 10th international conference on Computer and information technology, 27-29 Dec. 2007 2007 Dhaka, Bangladesh. 1-4.

Howard R., and Bjork B. C., (2008) *Building Information Modelling – expert views on standardization and Industry development*. *Advanced Engineering Information*, 22, 271-280.

Kirkham, R., Brandon, P. and Ferry, D. (2015). *Ferry and Brandon's Cost Planning of Buildings*. 9th ed. Chichester: Wiley Blackwell.

Kirkham, R. (2015). *Ferry and Brandon's Cost Planning of Buildings; with contributions from Anas Bataw, Brian Greenhalgh and Anthony Waterman*. Ninth edition. Wiley Blackwell

Kraus, W. E., Watt, S. & Larson, P. D. (2007) Challenges in Estimating Costs Using Building Information Modeling. AACE International Transactions, 01.1-01.3.

Liu, H., Lu, M. and Al-Hussein, M. (2016). Ontology-based semantic approach for construction-oriented quantity take-off from BIM models in the light-frame building industry. *Advanced Engineering Informatics*, 30(2), p.190.

March, C. (2009). *Finance and Control for Construction*. 1st ed. Abingdon: Spon Press, p.57.  
Mena, Á., López, F., Framiñan, J. M., Flores, F. & Gallego, J. M. (2010) XPDL project: Improving the project documentation quality in the Spanish architectural, engineering and construction sector. *Automation in Construction*, 19, 270-282.

McCuen, T. L. (2008) Scheduling, Estimating, and BIM: a Profitable Combination. AACE International Transactions, 1-8.

Mena, Á., López, F., Framiñan, J. M., Flores, F. & Gallego, J. M. (2010) XPDL project: Improving the project documentation quality in the Spanish architectural, engineering and construction sector. *Automation in Construction*, 19, 270-282.

Ostrowski, S. (2013). *Estimating and Cost Planning Using the New Rules of Measurement*. 1st ed. Hoboken: Wiley.

Pennanen, A., Ballard, G. & Haahtela, Y. (2011) Target costing and designing to targets in construction. *Journal of Financial Management of Property and Construction*, 16, 52- 63.

Royal Institute of British Architects (RIBA), (2007). *RIBA Outline Plan Of Work 2007.pdf*. 1st ed. [ebook] London: RIBA, p.1. Available at: <https://www.architecture.com/Files/RIBAProfessionalServices/ClientServices/RIBAOOutlinePlanOfWork2008Amend.pdf> [Accessed 7 Jun. 2017].

Royal Institute of British Architects (RIBA), (2012). *BIM Outlay to the RIBA Outline Plan of Works*. London: RIBA Publishing.

Royal Institute of British Architects (RIBA), (2013). *RIBA Plan of Work 2013*. [online] Ribaplanofwork.com. Available at: <https://www.ribaplanofwork.com/> [Accessed 3 Apr. 2017].

Royal Institute of Chartered Surveyor (RICS), (2012). *NRM1 RICS new rules of measurement order of cost estimating and cost planning for capital building works*. 1st ed. Coventry: RICS, p.48.

Royal Institute of Chartered Surveyors (RICS), (2013). *RICS new rules of measurement NRM 3: Order of cost estimating and cost planning for building maintenance works*. 1st ed. London: RICS.

Royal Institute of Chartered Surveyors (RICS), (2014). *How can Building Information Modelling (BIM) Support the New Rules of Measurement (NRM1)*. London: RICS, p.23.

Royal Institute of Chartered Surveyors (RICS), (2015). *BIM for cost manager: requirements from the BIM model*. 1st ed. London: RICS.

Schaufelberger, J. and Holm, L. (2017). *Management of construction projects A Constructor's Prospective*. 2nd ed. Oxon: Routledge.

Usable Buildings Trust, (2014). *The Soft Landings Framework for better briefing, design handover and building performance in use*. BSRIA BG 54/2014. BSRIA.

Pittard, S., and Sell, P. (2016). *BIM and Quantity Surveying*. Routledge: Taylor and Francis Group. London and New York

Sacks, S., L., Koskela, B.A., Dave & R. Owen (2010). Integration of Lean and Building Information Modeling in Construction. In: *Journal of Construction Engineering and Management*.

Smith, P., (2014). BIM & the 5D project cost manager. *Procedia-Social and Behavioral Sciences*, 119, pp. 475-484.

Sylvester, K. E. & Dietrich, C. (2010) Evaluation of Building Information Modelling (BIM) Estimating Methods in Construction Education. In: International conference of the 46th Annual ASC Conference, April 7-10, 2010 2010 Omaha, Nebraska, US. ASC.

Thurairajah, N., and Goucher, D., (2013). Advantages and Challenges of Using BIM: a Cost Consultancy's Perspective. 49th ASC Annual International Conference Proceedings.

Usable Buildings Trust, (2014). *The Soft Landings Framework for better briefing, design handover and building performance in use*. BSRIA BG 54/2014. BSRIA.

Woo, J. H. (2007) BIM (Building Information Modeling) and Pedagogical Challenges. In: International Proceedings of the 43rd Annual ASC Conference, April 12 - 14, 2007 2007 Flagstaff, Arizona, US. ASC

# **COST OVERRUN OF ICONIC BUILDINGS: MANAGING CONSTRUCTION COST THROUGH BUILDING INFORMATION MODELLING – A CONCEPTUAL PAPER**

Theong May Chuan<sup>1</sup> and Lee Xia Sheng<sup>2</sup>

<sup>1</sup>Lecturer, University of Reading Malaysia  
Iskandar Puteri, Malaysia, [t.m.chuan@reading.edu.my](mailto:t.m.chuan@reading.edu.my)

<sup>2</sup>Lecturer, University of Reading Malaysia  
Iskandar Puteri, Malaysia, [x.s.lee@reading.edu.my](mailto:x.s.lee@reading.edu.my)

## **ABSTRACT**

Most construction projects fail to achieve effective cost performance that results in tremendous cost overruns due to various reasons. Lately, Building Information Modelling (BIM) is widely acknowledged with its potential to revolutionise the current practice in the construction industry. It has adopted on many high profile large scale projects. BIM is frequently championed for its technology in the process of generating and managing digital information to create a more efficient construction industry. Thus, this conceptual paper aims to highlight the severity of cost overruns in iconic projects and serves to provide context on BIM's role in relation to costing with a view to developing a methodology that can be adopted within a BIM execution plan in order to deliver cost-effective projects. A fundamental of the methodology is to adopt review method that reveals significant errors associated with construction cost that exist in remarkable projects around the world, then relate the features of BIM to cost management. It is recommended that the practitioners devote more efforts towards the use of BIM in their practice to tackle challenges faced in the traditional working method.

Keywords: building information modelling, cost overrun, iconic buildings, quantity surveyors

## **INTRODUCTION**

In the recent years, construction projects has evolved to become intricate and difficult to manage due to increasingly and varying demands from the clients for more sophisticated end products at minimum cost and maximum speed. As a global phenomenon, cost overruns in the construction industry is common, particularly in massive construction projects. Abdul Rahman *et al* (2013) stated that it is rare to have projects completed within the budgeted cost. This is evidenced by a study carried out by Flyvbjerg *et al* (2003) that revealed 9 of 10 projects faced cost overrun problems in the range of 50 to 100%.

Ineffective cost performance in construction projects has been a serious concern within the industry since last decade, thus, needs stern attention and efforts to address the problem. Apparently, many previous studies focused very much on assessing significant causes contributing to the issue while several researchers mentioned a few ways to mitigate the problem. In spite of these, cost overruns persist as a severe problem. This is due to the use of conventional methods in cost estimation and management of construction projects that are based on 2D models, which acquires a lot of effort and time from the quantity surveyors (QS) because the processes are carried out manually.

Way back in 1989, Mitsutaka acknowledged that innovation and advanced technologies potentially increase competitive advantages within the construction industry by providing opportunities and lowering costs. Evolutionary developments brought in a remarkable change to the construction industry when Building Information Modelling (BIM) is currently the most common denomination for a new approach of design, construction, management and maintenance of buildings (Bryde *et al*, 2013).

BIM is holistically defined as “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life cycle” (Succar, 2009). It has been adopted on several high profile large scale projects, such as 2012 Olympic 6,000 seating velodrome cycle track at London, Miami Science Museum, Coca-Cola Place at north Sydney, Walt Disney Concert Hall, etc. This is due to anticipated benefits with regards to decrease in transaction cost and reduction of opportunity for errors made from the use of BIM (Bryde *et al*, 2013).

Many studies explored on BIM and its application to construction projects, from practitioners’ perspective. A few researches were carried out to highlight the use of BIM that promotes cooperation among designers, engineers, and contractors to provide an efficient way for cost estimating. Limited studies explore the potential methodology in managing cost with the use of BIM (Mitchell, 2012). Besides, Harris (2011) asserted that BIM is a new paradigm as a result of tremendous change for every professional involved in the construction industry. With the support of The Royal Institution of Chartered Surveyors (RICS), Wu *et al* (2014) also assured that BIM enhances the role of QS in managing cost of construction projects. Hence, this paper aims to reiterate the severity of cost overruns problems in several international remarkable buildings, then reveal the revolution of cost management in construction projects with the implementation of BIM.

## **BUILDING INFORMATION MODELLING**

In general, BIM is not merely a software but it is both a technology and a process. Azhar *et al* (2012) observed that in the respect of technology, BIM assists stakeholders to visualise product to be built through simulation for early identification of any possible design, construction or operational issues, while enhancing the process of a project via close collaborations and integrations of the roles of all stakeholders. A simplified technical definition has been brought by Schwegler *et al* (2001) who described BIM as a process of creating an information database for a project in which life cycle information is expressed in an interoperable manner to create, engineer, estimate, illustrate and construct a construction project.

BIM needs to be clearly distinguished from the traditional Computer Aided Design (CAD) that stores and manipulates 2D or 3D geometry. As mentioned by Watson (2010), it is able to define parametric constraints to enforce relationship between relative geometry of objects. It models the functions and behaviour of building systems and components (Sacks, *et al*, 2004).

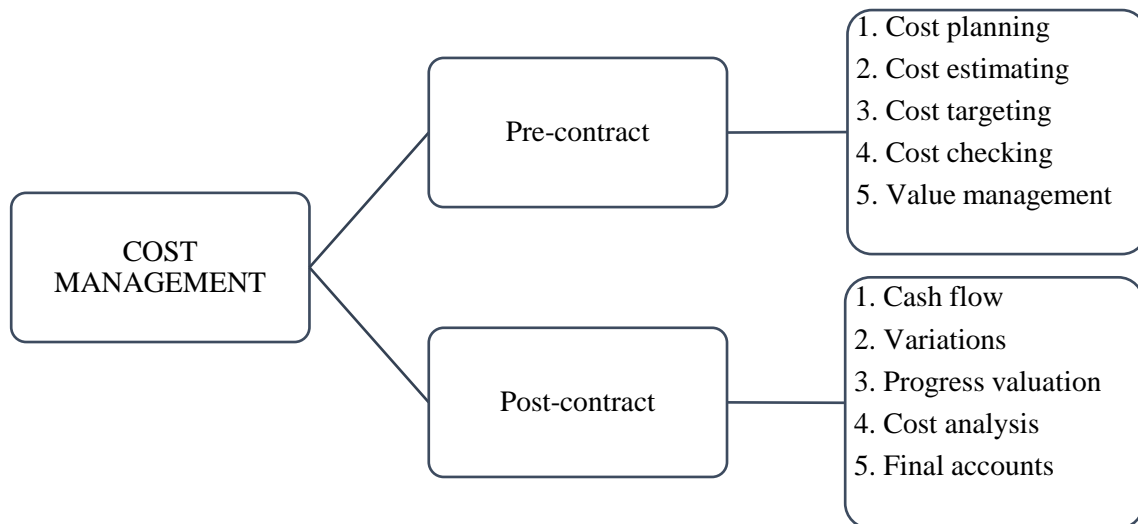
Besides its capabilities as a design visualisation tool, BIM has multidimensional capacity such as specialist analysis, detailed design, simulation, 4D animation of the construction program against time and 5D evaluation of expenditure against program. Stanley and Thurnell (2014) stressed that 5D or the 5<sup>th</sup> dimension of BIM incorporate cost which is related to quantification, modification and extraction of data within the model and these serve the major information for QS services.

BIM as a sophisticated technology, it eases comprehension of the digital representation for designs and contributes to every phase in project delivery. However, it is also perceived to be complex (Eastman *et al*, 2011). The BIM tool pledges from design stage, to documentation, realization and operation of the building; starting with conceptual design through design development, construction documentation to construction administration and management and ultimately to facility management (Graphisoft, 2015).

## **COST MANAGEMENT**

According to RICS, cost management is referred to the delivery of best value in building and infrastructure. To achieve this purpose, responsibilities in managing construction project costs are basically categorised into pre-contract and post-contract stages (Towey, 2013). To ease understanding, the elements covered for cost management is exemplified in Figure 1. As a professional who is responsible to provide the most meaningful advice in relation to construction cost, a QS needs to carry out numerous tasks to ensure the final cost of a project is within the budgeted amount.





**Figure 1:** Elements of cost management

## CHALLENGES FACED IN MANAGING COST BY THE QS

It is noticeable that the process in computing and documenting construction costs, including cost estimates, cost plan, cost comparison, cost control, pricing, progress payment monitoring, cost analysis and other cost related responsibilities, are perceived as tedious and susceptible to errors. Nagalingam *et al* (2013) pointed out that challenges, such as prone to errors and very time consuming are faced when the duties of managing cost are to be carried out through manual process. Similarly, Wong *et al* (2014) also indicated that tasks of cost management are laborious, inefficient, time consuming and always prone to errors. This situation is evidenced when Thomas (2010) reported that 30% of projects do not meet original budget. These led to clients' dissatisfactions on the output of services provided by the profession (Fortune, 2006).

Nani and Adjei-Kumi (2007) suggested that the most severe problem faced in managing cost is poor quality of drawings. O'Brien *et al* (2014) reiterated that poor quality of design documentation - both drawings and specifications is one of the key challenges faced for cost planning and estimating during pre-contract stage. In many cases, ambiguousness and discrepancies are found in design drawings and specifications as they contain errors or lack of sufficient details for providing accurate cost advice and carrying out measurements and pricing. When designs are too complex or fraught with constructability problems, it is difficult to understand the method and approach of construction in practice. Furthermore, designs of a project changed frequently in the construction industry, therefore there are difficulties in updating the cost plan (Wong *et al*, 2014). It was reported that 92% of the designers' drawings were insufficient for construction while 10% of the extra cost incurred were due to change orders (Thomas, 2010).

Mitchell (2012) pointed out that costs are always uncertain as a 2D design is not tested for functional efficiency against known elemental cost during the early phase of a project. As a result, there is lack of connection between the designs and cost plans that real-time cost feedbacks are unable to be provided as the design progresses and changes.

The impact of the challenges mentioned pose highest effect on cost control for a construction project (Nani and Adjei-Kumi, 2007). Several estimating software were available but yet to gain efficiency as the elements were still captured based on manual operations from the drawings and measurement (Jiang, 2011). Nevertheless, BIM is able to automate measurement and facilitate the preparation of accurate estimates (Ashworth *et al*, 2007). It is believed by Mitchell (2012) when collaborations exist among different design partners, costing process will be made easier.

## **RESEARCH METHODOLOGY**

Majority of the researches carried out by the academics, professional groups and software vendors revolved around the future benefits of BIM in construction projects, particularly the functions of BIM that facilitate the technical skill of the design profession, such as the architects, engineers and designers. Due to the fear that BIM is disruptive technology which creates a threat to the QS profession, very little studies focused on one of the QS's main responsibilities, i.e. managing cost.

Exceptionally, this paper explores the frequent occurrence of austere errors in terms of costing made in many large scaled projects around the world, then uncover how BIM-based project aids to lessen the mistakes. Considering that a constructed building is produced based on the project management triangle which consists of cost, time and quality, this study focuses on the cost dimension as construction has bad reputation for budget accuracy (Ijeh, 2015). Vast variations between estimated and actual cost occurred due to various reasons.

It is worth noting that this study deployed review approach via content analysis process. The first phase is to examine preferably errors in respect to construction costs existed over several international significant construction projects. Reviews of remarkable buildings or structures have been gathered through secondary data documentations. Thorough reviews on a number of literatures in the built environment area documenting completed prominent buildings around the world enable the identification of severe cost-related problems occurred during the conceptual design stage. The sources of data were case studies, write-ups and forums featured in construction or building related magazines and professional bodies in the public domain. Through this, factors contributed to the cost overrun issue for these projects are identified.

In the second phase, capabilities of BIM in enhancing the process of construction cost management are ascertained through reviews of books, academic journals, reports, conference proceedings and BIM system providers specifications that closely related to the cost aspect. In the search and identification of literature, the focus is placed on the ability of BIM in addressing issues faced during managing construction project cost.

All data are analysed to establish in which specific ways the process of managing cost are revolutionised from the use of BIM. Analysis is carried out by deriving errors occurred from cost planning during the pre-contract stage up to the final accounts preparation during the post-contract stage of globally famous projects, then linked the mistakes to demonstrate the influence of BIM on managing buildings and constructions costs.

## **FINDINGS AND DISCUSSIONS**

### **Cost overruns**

The world is amassing a long list of iconic projects marred by vast cost overrun. This issue is caused by several reasons that will be discussed through cases as follows.

The Port Authority of New York and New Jersey (PATH) transportation hub, costed USD 4 billion was twice the original budget. Its complicated design which encompasses a vast underground chamber and surrounding buildings that house all the station's mechanical components called for hugely difficult construction which required time-consuming manual coordination. As a result, the conceptual design used for early budget estimation was unrealistic (Daley, 2013).



**Figure 2:** Port Authority of New York and New Jersey (PATH) transportation hub

A 30-years of construction of The British Library next to the busy St Pancras station costs more than £500 million, three times the original expectations. The significant time and cost overrun were due to mistakes and delays in information feeding, constant changes to the design that plagued the project (Building, 2005).



**Figure 3:** The British Library

Due to a low level of details of the designs and minimal degree of precision (Daley, 2013), the City of Arts and Sciences Complex in Valencia ultimately cost around €900 million, almost triple what was originally budgeted, over a 20-year period.



**Figure 4:** City of Arts and Sciences Complex, Valencia

The cost of the Constitution Bridge over the Grand Canal in Venice was three times the original estimate, mainly due to excessive maintenance costs and absence of timely information as drawings were not supplied promptly (Vitucci, 2007).



**Figure 5:** Constitution Bridge, Venice

A vastly complex highway project, the Big Dig was initially budgeted at USD2.6 billion. It has to be noted that the cost was estimated based on a preliminary concept before undertaking detailed technical studies. Led by one of the world's largest engineering firms, numerous problems that beset the project began with incomplete and error-filled designs, failure in identifying errors in the drawings, crucial information such as verification of the locations of utility lines and buildings were not properly disseminated, use of incorrect materials, multitude of interfaces without systematic communication of information and uncertain construction method. These had greatly amounted to approximately USD19.5 billion, which attributed to an increased cost at 685% (Wilks, 2015).



**Figure 6:** Downtown Boston, before and after the Big Dig

Being the most iconic landmark in Australia, The Sydney Opera House, is as famous for its runaway budget. The project was originally budgeted at AUD 7 million based on a series of schematic concept sketches. As a result of minimal technical studies conducted and lack of details in the designs, the podium columns were unable to support the roof and required to rebuild. The geometric complexity of the rooftop shells and lack of structural precedent caused the consultants to redesign to achieve an economic solution. These had led the estimated cost to rise exponentially to AUD102 million, which is more than 1350% (Building, 2015).



**Figure 7:** The Sydney Opera House

The Scottish Parliament Building at Edinburgh was estimated at £10 million but it ended up exceeding £410 million, which overran more than 4000%. Such a hefty difference between original and actual

cost was due to the woefully inadequate specifications on materials and construction methods. Besides, there was insufficient information, such as required size, accommodation and facilities which led to a vast cost underestimation (Ijeh, 2015).



**Figure 8:** The Scottish Parliament Building

These discussed cases had obviously depicted that erratic estimates expose project owners to significant risk for the substantially increase overall cost. Nevertheless, Hooper (2012) suggested that BIM offers a solution to the deficiency while Nagalingam *et al* (2013) conferred that efficiency and accuracy in exchanging building design information creates great certainty in construction projects deliveries.

### **BIM Capabilities and Cost Management**

Stanley and Thurnell (2013) realised that the current use of BIM in cost modelling is limited and restricted to quantity take offs by the quantity surveyors. Hence, this section uncovers how BIM enhance the roles of the QS profession in managing cost, particularly focuses on Level 3 BIM, which represents full collaboration among players from all disciplines by means of using a single, shared project model which is held in a centralized repository.

Thurairajah and Goucher (2013) indicated that ability to view a building or structure from various perspective in 3D this allows better understanding on the projects involved (Samphaongoen, 2010). Missing items are therefore easily identified during the time of extraction (Boon and Prigg, 2012). As a result, queries are forwarded to the design team and thus reducing the reliability towards assumptions made for cost estimation and budget preparation. Even with sophisticated designs, maximum extraction of geometric data is possible with the implementation of BIM system (Cheung *et al*, 2012) to comprehensively include breakdowns of elements and components during early budget preparation.

Variations and changes to design are common in the construction industry. As a result, early cost estimates are often inaccurate or unreliable. However, implementation of BIM is able to minimise the gap between budgetary estimates and final cost as models assembled by the various design teams, i.e. architect, structural and MEP engineers are dynamically linked with the project elemental areas which results in an automated update (Mitchell, 2012). Then, cost implication towards changes in design and specifications is easily identified and presented (Thurairajah and Goucher, 2013). Therefore, cost overflows are detected earlier and easier and steps to rectify can be taken to minimise the consequences.

Researchers such as Olantuji *et al* (2010), Boon and Prigg (2012) and Mitchell (2012) agreed that BIM enable cost comparisons of alternative design options available. The most accurate economic advice can be provided to optimise the client's budget in order to speed up decision making process.

Act as a database, 5D BIM provides high level of cost detail, enabling the profession to developed thorough cost plans by linking the model to the cost library (Thurairajah and Goucher, 2013). At the same time, cost information is integrated with the models designed and they are completely stored in one location (Samphaongoen, 2010). Due to this, massive data can be processed quickly and efficiently. Thus, it leads to reduction in errors and time taken to produce cost related documents (Shen and Issa, 2010).



According to Mitchell (2012), the awarded contractor's price and rates can be attached to the executable file to be presented based on trades or zones or elements, depending on the needs. This information is also accompanied by a complete construction material specifications. As a result, visualisation of all relevant information improves understanding on complex designs, construction method, contract price, quantities and required material and equipment of all key players of the project, including the builders.

BIM encourages collaborations on projects (Won *et al*, 2011) in which the software used consists of 3D designs, models and cost information. This can be achieved because of the inter-operability and compatibility of BIM that enable information exchangeable (Thurairajah and Goucher, 2013) between the key players of each project, such as the decision making, design, costing and construction teams. Therefore, clash detection is permitted and real time changes are allowed to be made electronically at any stage of the project (Thurairajah and Goucher, 2013).

As all revisions of drawings are automatically updated and identified by all users within the project, myriads of contractors involved within a project are able to receive latest design documents and change order which incorporate accurate quantities and material specifications (Lee *et al*, 2003). The variations can be calculated reliably, easily and quickly (Mitchell, 2012) by the quantity surveyors since dynamic links between work items, quantities and rates are created during pre-construction stage. Besides, Mitchell (2012) also suggested that progress payments calculation becomes easier and transparent. Consequently, project cost is always up-to-date and budget performance can always be easily tracked and controlled by the profession when cost information is interrogated.

Besides, BIM has the ability in connecting and synchronising the as-built model (Mitchell, 2012). This capacity enables indication of cost information relating to maintenance of the building or structure to provide the best economic feedback and prepare reliable operating budget to the owners based on several replacement costs, life span and running costs.

## CONCLUSION

Effective financial decisions are one of the utmost important criteria for successful construction projects. However, it is obvious that unreliable cost estimates or budget overrun issue persist over the years that is caused by poor documentation and communication problems. This is mainly due to conventional means of working method and the fears that advanced technologies or automations create threats to the costing profession. This paper looks critically at the opportunities that arise for construction cost management process by the implementation of BIM. Findings show that accurate and computable nature of BIM enable better performance in estimating and feedback on design changes. The technology compliments traditional costing techniques by setting strategies from pre-contract to post contract stages with an aim to prevent cost overruns. This paper serves to provide context of the role of BIM in enhancing the practice in relation to managing construction cost. A further study focuses on the adoption of BIM for cost management purpose in a real-life project is recommended.

## REFERENCES

- Abdul Rahman, I., Memon, A. H. and Abd Karim, A. T. (2013). Significant Factors Causing Cost Overruns in Large Construction Projects in Malaysia. *Journal of Applied Sciences*. 13 (2), 286 – 293
- Aouad, G., Wu, S. and Lee, A. (2007). Advanced Technology for Quantity Surveying. *Proceedings of the Quantity Surveyors International Convention*, Malaysia
- Ashworth, A., Hogg, K. and Higgs, C. (2013). *Willis's Practice and Procedure for the Quantity Surveyor*. John Wiley & Sons, Ltd, UK.
- Azhar, S., Khalfan, M. and Maqsood, T. (2012). Building Information Modelling (BIM): Now and Beyond. *Australian Journal of Construction*. 12 (4). 15 – 28

Boon, J. and Prigg, C. (2012). Evolution of Quantity Surveying Practice in the Use of BIM – The New Zealand Experience. *Joint CIB International Symposium of W055, W065, W089, W118, TG76, TG78 and G84*

Bryde, D., Broquetas, M. and Volm, J. M. (2013). The Project Benefits of Building Information Modelling (BIM). *International Journal of Project Management*. 31, 971 – 980

Building (2005). *The Top 10 Most Disastrous Building Projects In the World Ever*. Issue 06. Retrieved from <http://www.building.co.uk/the-top-10-most-disastrous-building-projects-in-the-world-ever/3046585.article>

Cheung, F. K. T, Rihan, J., Tah, J., Duce, D. and Kurul, E. (2012). Early Stage Multi-level Cost Estimation for Schematic BIM Models. *Automation in Construction*. 27, 67 – 77

Daley, S. (2013). *A Star Architect Leaves Some Clients Fuming*. The New York Times.

Eastman, C.M., Teicholz, P., Sacks, R. and Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*. Wiley, New York, NY.

Flyvbjerg, B., Holm, M. K. S. and Buhl, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects? *Transport Rev*. 23, 71 – 88

Graphisoft. (2015). Open BIM. Accessed on 27th January 2017. Available at: [http://www.graphisoft.com/archicad/open\\_bim/about\\_bim/](http://www.graphisoft.com/archicad/open_bim/about_bim/).

Harris, J. (2011). *Integration of BIM and Business Strategy*. Evanston: BIM Libraries

Ijeh, I. (2015). *Not on the Money: Over Budget Projects*. Building.co.uk

Jiang, X. (2011). Developments in Cost Estimating and Scheduling in BIM Technology. Northeastern University

Lee, A., Marshall-Pointing, A. J., Aouad, G., Wu, S., Koh, W. W. I, Fu, C., Cooper, R., Betts, M., Kagioglu, M. and Fisher, M. (2003). Developing a Vision of nD-enabled Construction. Construct IT, University of Salford.

Mitchell, D. (2012). 5D BIM: Creating Cost Certainty and Better Buildings. *2012 RICS COBRA*, Las Vegas, USA.

Mitsutaka, H. (1989). Evaluation of technology in Construction. *Technical Report No. 16*. Centre for Integrated Facility Engineering. University of Salford, UK.

Nagalingam, G., Jayasena, H. S. and Ranadewa, K. A. T. O. (2013). Building Information Modelling and Future Quantity Surveyor's Practice in Sri Lankan Construction Industry. *The Second World Construction Symposium 2013: Socio-Economic Sustainability in Construction*. Sri Lanka

Nani, G. and Adjei-Kumi, T. (2007). The Challenges of Quantifying Construction Works for Project Control in Ghana. *CIB World Building Congress*. 3134 – 3145

Olanuji, O. A., Sher, W. and Ogunsemi, D. R. (2010). The Impact of Building Information Modelling on Construction Cost Estimation. *W055 – Special Track 18<sup>th</sup> CIB World Building Congress*. Salford, UK.

Sacks, R., Eastman, C. M. and Lee, G. (2004). Parametric 3D Modelling in Building Construction with Examples of Precast Concrete. *Automation in Construction*. 13 (3), 291 – 312

Samphaongoen, P. (2010). A Visual Approach to Construction Cost Estimating. [http://epublications.marquette.edu/theses\\_open/28](http://epublications.marquette.edu/theses_open/28)

Schwegler, B. R., Martin, F. A., O'Connell, J. M., Reijo, H. and Jarmo, L (2001). Near-Medium-and Long-term Benefits of Information Technology in Construction. *Working Paper*. Center for Integrated Facility Engineering (CIFE), University of Salford.

Shen, Z. and Issa, R. R. A. (2010). Quantitative Evaluation of the BIM-assisted construction detailed cost estimates. *Journal of Information Technology in Construction*. 15, 234 – 257

Stanley, R. and Thurnell, D. (2013). Current and Anticipated Future Impacts of BIM on Cost Modelling in Auckland. *Proceedings of 38<sup>th</sup> AUBEA International Conference*. Auckland, New Zealand.

Stanley, R. and Thurnell, D. (2014). The Benefits of, and Barriers to, Implementation of 5D BIM for Quantity Surveying in New Zealand. *Australasian Journal of Construction Economics and Building*. 14 (1), 105 – 117

Succar, B. (2009). Building Information Modelling Framework: A Research and Delivery Foundation for Industry Stakeholders. *Automation in Construction*. 18 (3), 357 – 375

Thomas, K. (2010). Innovation and growth Team Report. UK: Northumbria University

Thuraijah, N. and Goucher, D. (2013). Advantages and Challenges of Using BIM: A Cost Consultant's perspective. *49<sup>th</sup> ASC Annual International Conference*

Tower, D. (2013). *Cost management of construction projects*. UK : Wiley Blackwell.

Vitucci, A. (2007). *Calatrava Bridge, The Yellow Letter*. L'Espresso Local, Italy.

Wilks, S. (2015). *The Century's Most Troublesome Construction Projects*. Golden Construction Review, CIOB. Retrieved from <http://www.globalconstructionreview.com/perspectives/centurys-most-troublesome-construction-pr8oje8ct8s/>

Won, J., Lee, G., and Lee, C. (2011) Comparative Analysis of BIM Adoption in Korean Construction Industry and Other Countries. University, Seoul

Wong, P. F., Salleh, H. and Rahim, F. A. (2014). The Relationship of BIM Capability in Quantity Surveying Practice and Project Performance. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*. 8 (10), 1039 – 1044

Wu, S., Ginige, K., Wood, G. D. and Jong, S. W. (2014). How can Building Information Modelling (BIM) support the New Rules of Measurement (NRM1)? *Research Paper*. Royal Institution of Chartered Surveyors.



# **DELIVERING COST EFFECTIVE SUSTAINABLE PUBLIC RENTAL HOUSING DEVELOPMENTS – THE HONG KONG EXPERIENCE**

**Sr T T CHEUNG, J.P.**

B.Sc.(Hons)(Q.S.), JD, M.Sc., FHKIS, FRICS, FCInstCES, FCECA, RPS(QS),  
RCE(China), Accredited Mediator, Adjunct Professor (HKU & HKPU)

*Director, Aria & Associates Limited  
Member, Hong Kong Housing Authority  
ttcheung@aria.hk*

**Sr CHOI Shing Lam, Sunny**

FHKIS, MRICS, RPS(QS), MCIOB, MHKIE, MHKICM,  
MBA, MbSHK, MHKIBIM, RICS Certified BIM Manager

*Senior Quantity Surveyor, Hong Kong Housing Authority  
sl.choi@housingauthority.gov.hk*

## **ABSTRACT**

Hong Kong Housing Authority (HA) develops and implements a public housing programme to provide homes for Hong Kong people who cannot afford private rental housing. Due to scarcity of land supply in Hong Kong, public housing blocks are usually high-rise building of average 41-storey and accommodating hundreds to a thousand residential units in a single block. In order to improve the living place quality of tenants and to reduce energy consumption in operation, the HA has researched and developed effective green designs and energy efficient installations for the development of public housing. For example, making the best use of natural light and wind, installation of LED lightings and lifts with power regenerative feature, water saving vegetation irrigation systems and acoustic balcony to abate noise from main roads. The HA, as a public organization, is accountable for the proper use of public monies. The decision on the implementation of green and sustainable measures would not only based on economic viability but also the environmental and social costs, such as carbon emission, conservation of non-renewal resources and tenants' satisfaction and aspiration.

## **KEYWORDS**

cost effectiveness, green design, Hong Kong Housing Authority, public rental housing, sustainability.

## **INTRODUCTION**

The Hong Kong Housing Authority (HA) was established in 1973 under the Housing Ordinance with the Housing Department (HD) as her executive arm. The HA develops and implements a public housing programme to meet the housing needs of people who cannot afford private rental housing. As of 31 March 2017, the HA has an existing stock of some 775,000 public rental flats and 384,000 subsidized sales flats [1], providing affordable accommodation for low income families in the Hong Kong Special Administrative Region of China (Hong Kong). The occupants represent about 44% of the seven million populations in Hong Kong. From 2017/18 to 2026/27, the HA targets to construct 200,000 public rental flats and 80,000 subsidised sale flats which will occupy about 60% of flat production of the period.

## **COMMITMENT TO SUSTAINABILITY**

Hong Kong is scarce in land for development; the total land area is about 1,106 km<sup>2</sup> of hilly terrain with only 25% developed and 40% for country parks and nature reserve. Public housing blocks constructed by the HA are usually high-rise building and of average 41-storey accommodating hundreds to a thousand residential units in a single block. The average density of occupant per hectare is high.

The HA is committed to “caring of people” and advocate healthy, safe and green housing design. The Director of Housing, head of the HD, chaired the Housing Department Environmental, Health and Safety Committee (HDEHSC) which was set up to develop and review the sustainability strategy, framework and action plans of the department, and to set up sub-committees to implement and monitor action plans. A series of research and trial have been carried out both by own resources or partnering with tertiary academic institutes to explore the use of effective green designs and energy efficient installations to improve living place quality and to reduce energy consumption in operation. There is a noticeable continual enhancement in the environment, social and economic performance of Hong

Kong's public housing developments in the past two decades. Public housing has moved a long way from basic shelters to comfortable homes to be proud of.

## **SUSTAINABLE STRATEGIES IN PLANNING AND CONSTRUCTION**

### **Green Design and Construction**

#### ***Conducting Micro-climate Studies***

The HA has been applying micro-climate studies and air ventilation assessments at site planning and design stages to optimise passive design of all new housing projects in order to provide comfortable living environment for tenants in sub-tropical climate. Taking advantages of the unique characteristics of individual site, the HA has enhanced the design, orientation and disposition of building blocks through the optimal use of natural resources such as local wind breezes, natural ventilation, daylight and solar heat gain, by applying proven scientific technologies including computational fluid dynamics analysis, wind tunnel tests, daylight simulation tools etc.

#### ***Adopting Low Carbon Building Design***

In support of the Hong Kong Government's target of reducing 50%-60% greenhouse gas emission by 2020 relative to the emission level in 2005, the HA has put substantial efforts to apply various green building strategies during the design and construction stages to cut down carbon emissions of public housing projects. Since 2011, the HA has applied Carbon Emission Estimation (CEE) for all new housing projects. The CEE model embraces the carbon emission from major construction materials and building operations as well as the carbon reduction from renewable energy systems and absorption from trees planting.

Up to March 2016, there were 165 public housing blocks with CEE and the estimated reduction in carbon emission for the whole life cycle of these blocks is around 980,000 tonnes. The current public housing blocks with site specific design have achieved an average of about 13% reduction in carbon emission in terms of construction floor areas than the old housing blocks of standard design [2].

#### ***Green Building Recognition***

HA has stipulated requirements in the contract specifications to ensure that all new housing projects should be ready to achieve "Gold" rating under the Building Environmental Assessment Method Plus (BEAM Plus) scheme run by the Hong Kong Green Building

Council. Individual project even has achieved Platinum rating under the BEAM Plus scheme.

## **HOW TO PROVIDE A SUSTAINABLE FOCUS FOR DEVELOPMENT?**

As the expenditures for the development of public housing are funded by public monies, the HA has great concern on the value of money spent and there is a robust system to scrutinize and control the development expenditures. The HD, the HA's executive arm, has established a Research & Development Steering Committee in the Development and Construction Division (DCD) to approve, monitor and evaluate research topics on new initiatives in materials, design, installation and construction methods. There is also a Design and Standard Section in DCD to prepare standard design details and specifications for public housing development to maximize the benefits of standardization and economies of scale. Improvements or new initiatives in housing design and installation have to be submitted to the Building Committee<sup>1</sup> of the HA for review and approval of the applications and cost implications.

It is not an easy job to make various endeavours to achieve sustainability of public housing development cost effectively and without compromising tenants' aspiration for ever higher living standard. The passive design and greening as mentioned above, the use of higher efficient materials and installations to reduce energy consumption, the use of alternative energy sources such as renewable energy to reduce carbon emission and the adoption of other green initiatives unavoidably will involve additional expenditures in the first place.

The evaluation of green initiatives and practices associated with public housing development has both monetary as well as non-monetary considerations, including the payback for the initial, operation and maintenance cost, the reduction of carbon emission, and the increase in human comfort. The essence of decision-making is to meet present social, economic and environmental needs but not at the expense of future generations.

## **SUSTAINABLE INSTALLATIONS**

Energy consumption in the high-rise public housing blocks is enormous and represents 45% of total energy consumption for residential in Hong Kong [3]. Therefore, adoption of energy

---

<sup>1</sup> Building Committee is comprised of external members appointed by the HA Chairman

efficient building services installation is one of the main focuses of green initiatives in public housing development to reduce energy consumption and greenhouse gas emission.

### **Energy Management**

To improve energy efficiency of a housing project, the HA has implemented energy management system (EnMS) since December 2011 in accordance with the ISO 50001 best practice framework. The HA was awarded the first ISO 50001 certificate on residential building design in Hong Kong in June 2012. The HA has put focus not only on the design and operation of the new domestic blocks, but also mandated her contractors to be certified to ISO 50001. All parties of a HA project should commit to green design and construction to make it successful.

### **Renewal Energy**

The HA has installed grid-connected mono-crystalline photovoltaic (PV) panel systems on the upper roof of domestic blocks to provide at least 1.5% of the communal electricity consumption. As indicated in a pilot public housing project, monetary payback for the initial installation cost of PV system is not achievable within the estimated service life of the system. However, the saving in energy cost is able to cover the maintenance cost; there is also an environmental benefit that the Energy Payback Time is about 2.5 years which is well within the anticipated 25 years' service life of the PV system.

### **Energy Efficient Installations**

To achieve energy efficiency in public housing developments, the HA has implemented several energy efficient building services design and devices to reduce energy consumption.

#### ***LED Lighting***

LED bulkhead is now set as the standard light fittings for communal areas of public housing blocks in lieu of the conventional bulkhead using compact fluorescent tubes. This initiative can reduce the communal energy consumption by 10%. The saving in energy cost is fairly great as the number of bulkhead lighting installed in a typical public housing block of 41-storey will be more than 2,500.

Monetary payback of LED bulkhead installation is achievable, and the estimated carbon reduction for a typical public housing block is about 666 tonnes within the service life of 50,000 hours for LED bulkheads.

### ***Lift Regenerative Power***

Lift can generate electrical energy when it operates under heavy load down or light load up condition. The regenerative power technology enables capturing regenerative power from lift system for feeding into the grid for immediate consumption by the communal installations. The estimated average payback period for the lift system with additional regenerative power feature is about 3.6 years.

### ***Two-Level Lighting Control System***

To strike a balance between energy conservation and adequate illumination meeting the need of users at large, the HA has installed a two-level lighting control system in communal areas of domestic blocks. The illumination levels are adjusted by environmental lighting controls using motion sensors and on-demand switches with timer-controls. The illumination level is maintained normally at 50 lux at lift lobbies and 30 lux at corridors and staircases around the clock, while the illumination level can be elevated to 85 lux, zone by zone, once triggered by users on a need basis. Through this arrangement, the energy consumption of the lighting installation can be saved by about 30% [4]. This installation is practicable, cost effective and environmental friendly.

### ***Hybrid Ventilation System***

The HA had implemented pilot hybrid ventilation system in three shopping centres suited in public housing estates. The design suitably utilizes natural ventilation during cool weather by automatically operating windows and openings of the shopping centres to save electrical energy for air-conditioning and ventilation system. As the cost for hybrid ventilation depends heavily on the layout and complexity of the system design, a set of application criteria and guidelines has been prepared to facilitate implementation of hybrid ventilation systems in shopping centres located in suitable sites.

### ***Effectiveness of Sustainable Installations***

The electricity consumption in public areas of public housing estates has continuously dropped from 69.4 kWh in 2007/08 to 52.7 kWh in 2015/16 per flat per month [5].

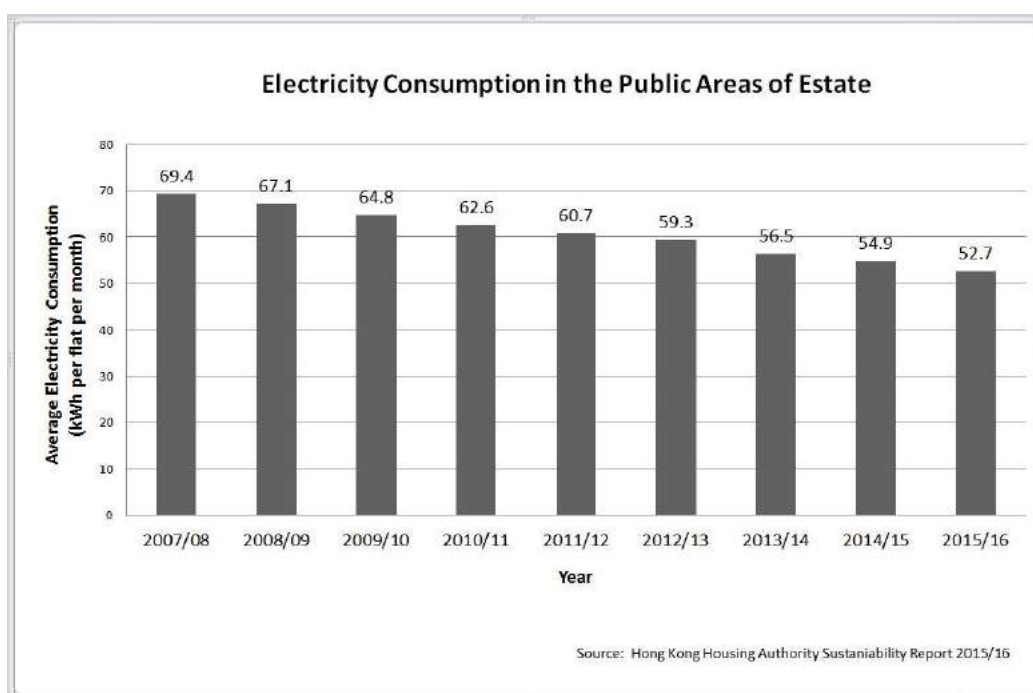


Figure 1

## OTHER SUSTAINABLE DESIGNS IN PUBLIC HOUSING

Social and human factor is one of the key elements of the definition of sustainability, while saving natural resources is part of the environmental subject of sustainability. Apart from endeavour to achieve economic benefits when implementing sustainable practices and initiatives, the HA has also implemented measures to improve or sustain the living condition of tenants, and to save water which is a scarce resource in Hong Kong.

### Greening and Landscaping

The HA has made great effort in the design of external areas in each public housing estate to provide tenants not only with a good landscape areas but also to reduce heat in summer. The target is to achieve an overall 30% or at least 20% minimum green coverage for all new public housing developments to mitigate urban heat island effect.

To achieve the above target, architects can implement in projects through on-grade planting, grass paving system, vertical greening, green roof or green decking, and slope greening. The green roofs, for example, can absorb rainwater, provide insulation, create habitats for wildlife, lower urban air temperatures, mitigate urban heat island effect, and improve air quality. The results obtained in 2013 from a two-years green roof study of high-rise blocks

of a public housing estate indicate that the green roof can give rise to about 12°C temperature reduction in a hot summer afternoon.

## **Noise Control**

Due to scarcity of land in Hong Kong, many public housing developments are situated close to main roads with noise generated by heavy traffic. To sustain a quieter living environment, the HA has implemented several mitigation measures such as optimizing orientation and location of housing blocks in designing the layout of the blocks, construction of acoustic windows, acoustic fins and noise barriers etc.

The latest design initiative by the HA is the second generation acoustic balconies in which a sliding screen is installed in front of the balcony door which provides good noise insulation. Other auxiliary feature such as inclined panel along the parapet and noise adsorptive material at the wall and ceiling of the balcony will be provided for further noise mitigation enhancement. It achieves a better noise attenuation from about 6 to 10 dB(A) while maintaining better ventilation at 1.5 air change per hour the minimum.

## **Saving Water**

### ***Rainwater Harvesting System***

To save precious water resource in Hong Kong, the HA has implemented a number of conservation initiatives in the public housing developments. The Rainwater Harvesting System was installed in the projects where either the BEAM PLUS requirements on potable water saving could be complied with or the system carbon neutrality could be met. The system employs gravity feed without the need for water pumping facilities to minimize the operational energy.

### ***Zero Irrigation System***

Another example is the Zero Irrigation System (ZIS) which contains a self-sustained sub-irrigation system. It is a passive design to deliver storm water stored in sub-soil retention box to the vegetation through capillary action and thus minimizes topsoil evaporation. The ZIS is well recognized as a very efficient water conservation system and saving in manual watering operations.

### ***Twin Tanks System***

Since 2008, the innovative “twin tanks system” has been provided to all new public housing projects. The system not only avoids water supply interruption to residents during tank



cleansing once every three to six months, but also facilitates maintainability and helps conserve the environment by saving water. Residents are no longer need to store fresh water for temporary use or use fresh water to flush toilets. It also eliminates the cases where considerable water remained in the tank has to be drained away for tank cleansing. It is estimated that some 2.8 million litre of water can be saved per 75,000 households every year.

## **WAY FORWARD**

### **Green Education and Awareness**

Green education is an indispensable element of the HA's quest for sustainability, as a public organization. Since 2005, the HA has been partnering with green groups to launch a long-term estate wide community environmental education programme, the "Green Delight in Estates (GDE)" with the aim to foster environmental awareness of tenants. In 2015/16, the HA had started the GDE phase 9 with the theme of "Rehome and Reuse Resources" to encourage tenants to share their excessive but useful resources to other people. Other environmental promotion programmes will continuously be organized to disseminate environmental protection messages to tenants in public housing.

### **Adoption of Information Technology in Design and Construction**

To improve the design and construction process of new housing development, the HA has not only deployed own intelligence and resources but also worked in partnership with the industry to foster sustained quality improvements through innovation and collaboration. For example, design teams have used Building Information Modelling (BIM) to generate 3-dimensional housing block data for analysis of natural ventilation, pollutant dispersion, natural daylight and solar heat gain etc. The use of Geographic Information System (GIS) to facilitate search and enquiry for a range of spatial and textual data required for the identification of suitable building sites for residential blocks. The technologies help to provide more valuable information for designers and thus further improve cost effectiveness of delivering sustainable public housing developments. Continuous improvement with innovation for sustainable development is part of HA's business culture.

## CONCLUSION

The HA works with her core values – the 4Cs (Caring, Customer-focused, Committed and Creative) to implement the various sustainable initiatives in the planning and design of public housing for green and healthy living which brings about:

- a. In terms of environmental sustainability, the impact and pollution to the environment will be reduced both during construction and during occupation phase.
- b. In terms of economic sustainability, lesser electrical energy consumption and operation cost throughout the whole life cycle of the housing stock.
- c. In terms of social sustainability, the tenants and the public can enjoy a greener and healthier living habitat.

The HA estimated that the additional cost to achieve “Gold” rating under the BEAM Plus scheme was about 1.2% of the overall construction cost of a typical project which is cost effective. The Customer Satisfaction Index based on surveys of residents in newly completed estates has increased from 74.15% in 2007/08 to 93.27% in 2015/16, which reveals the effective performance of the HA in the planning, design and construction of sustainable public housing to provide homes for people.

---

## References

- [1] Hong Kong Housing Authority, March 2017, Quarterly Statistical Report.
- [2] Hong Kong Housing Authority, Sustainability Report 2015/16, Executive Summary p. 1.
- [3] Electrical and Mechanical Services Department of Hong Kong, (2012). Hong Kong Energy End-use Data, p. 19.
- [4] Legislative Council Panel on Housing of Hong Kong, (2015). Energy Saving Initiatives in New Public Housing Developments. Paper No. CB(1)702/14-15(04).
- [5] Hong Kong Housing Authority, Sustainability Report 2015/16, Executive Summary p. 4.

# EXPANED POLYSTYRENE BUILDING SYSTEM VERSUS BRICK AND MORTAR BUILDING SYSTEM

Mr J.J.A. Jansen <sup>1</sup>, Mr G. Du Plessis<sup>2</sup>, Mr A. Oosthuizen<sup>3</sup> and Mr S. Jansen van Rensburg<sup>4</sup>

<sup>1</sup> Lecturer, riaan.jansen@up.ac.za

<sup>2</sup> Post Graduate Student, gerhard03@gmail.com

<sup>3</sup> Post Graduate Student, armando990@gmail.com

<sup>4</sup> Post Graduate Student, st.jansenvanrensburg@gmail.com

*Department of Construction Economics, Engineering, Built Environment and Information  
Technology Faculty, University of Pretoria, Corner Lynnwood and University Road,  
Hatfield, Gauteng, South Africa, 0002*

## ABSTRACT

Conventional Brick & Mortar walling systems (BMS) are more commonly used than Expanded Polystyrene Systems (EPS) in South Africa. Although EPS has been certified by Agrément SA, there is little evidence in the use of EPS. Role-players in the construction industry are reluctant to make use of EPS's.

The purpose of this paper is to compare the use of EPS to BMS with emphasises to job creation, embodied energy and initial cost.

A mixed research method was followed was obtain all the relevant information. In terms of job creation, a qualitative approach was followed where the Imison system (IMS), an EPS, was compared to the BMS. With the embodied energy a desktop research was followed and the construction cost was compared through the use of Bills of Quantities for a simple building.

Although the IMS is prefabricated, it does not require specialized equipment, resulting in creating jobs. The total embodied energy of the IMS is much more than that of the BMS, due to the amount of steel used. The construction cost of the IMS is much less than the BMS, due to lower preliminaries & generals, the use of a raft foundation amongst others. The IMS is more cost effective and creates more jobs than the BMS; however it has a larger embodied energy.

Keywords: expanded polystyrene systems, alternative building technologies, brick and mortar systems, embodied energy, job creation.

## INTRODUCTION

The most common building method used for housing in South-Africa today is brick and mortar or timber as building materials, with bricks being preferred choice. BMS is typically classified as a Conventional Building Method (CBM). Although Alternative Building Methods (ABM) such as EPS walling systems is not commonly used in South Africa, these building systems have worthy efficiencies, effectiveness and qualities that need to be considered in the construction industry. These building systems are not well understood in South Africa by the contractors and developers.

EPS is a lightweight thermoplastic foam material produced from solid beads of polystyrene. EPS mainly use to thermally insulate walls, roof and floors and can be fore houses, offices and factories. EPS systems known for its thermal insulation properties and light weight (Guide to building with EPS, 2013, pg15-16).

The purpose of this paper was to compare job creation, embodied energy and financial impact of EPS walling systems against conventional brickwork. In this light, the study contributed to the growing body of knowledge in understanding the difference between conventional and alternative building methods and the benefits of utilizing alternative building methods. Thus the following sub-questions were identified:

- How does ABM's measure up with CBM in terms of job creation?
- What are the difference in embodied energy of conventional and alternative building materials and technologies?
- What is the financial impact on a project when using ABM's vs. CBM?

Being that the research field is vast with the existence of various types of ABM's, this may cause difficulty in getting accurate research results. Mainly because the alternative methods can differ from each other in many aspects including materials used from EPS (Expanded Polystyrene) to prefabricated panels.

## **LITERATURE REVIEW**

There is a growing interest in the building environment for the development of new building systems that will allow more efficiency, accuracy, environmental friendly, efficient use of efficient workforce and produce shorter construction periods. The prefabrication building method is well known in Australia, New Zealand, USA and Europe, and has been in use for more than 110 years. It used mostly for residential housing units. In 2014 a study shown that ABM's in New Zealand consist of less than 600 homes per year or 2% of the residential market. It is expected in the next 10 to 20 years the market will grow to 20% which will increase the home to 6000 per year (Construction Training Fund, 2015, p3).

The buyers of homes will become more familiar to the ABM thus the affordability of modular homes will reduce to 18% in cost and a 50% reduction in erection time can be expected (Construction Training Fund, 2015, p3). The prefabrication building method is one of the most common building methods known in the world. This building method consists of building parts that has been constructed off site and then assemble later on site (Burgess, et al. 2013, p14). Conventional building method is done all on site, where material is ordered and delivered to site and assembled on site for example, cement, aggregate and sand is mixed to form concrete for footings.

Through alternative building methods there are numerous advantages such as erection time, reduction of waste, energy and greenhouse gas emissions during the construction. When using prefabrication, method transportation has to be considered. Prefabrication is where the components of the homes are constructed in a factory and thus the need to transport it to site (Burgess, et al. 2013, p13-14).

Modular homes and panel building homes are also regarded as prefabrication homes.

The construction industry is a large contributor towards job creation and employment internationally and especially in South-Africa (Pakade and Odhiambo 2016, p11). South-Africa is not utilising its job creation potential by not training employees, more specific the labourers, to give them the required skills to improve the production and quality of buildings (CIDB 2014, p2). According to data collected by the CIDB in their annual Construction Monitor report the information obtained has indicated that construction contributed to around 9% of the total formal and informal employment in South-Africa. Looking at the statistics regarding the year-on-year growth in employment, there has been a substantial increase in growth in employment in the construction industry (CIDB 2015, p4). CBM's are still preferred as primary construction methods in South-Africa. Contractors can employ unskilled workers at a minimum wage to do the labour intensive work. The result of this is that these workers become disposable and easy to replace (CIDB 2015, p11). There is also the increased possibility of labour unrest, wage unrest is a result from minimum wages and that the unskilled workforce tends to demand increased wages. This is mostly an issue in the mining sector, but there have been cases in South-Africa where workers from the construction sector refrained to striking

(CIDB 2015, p11). In an article written by Denoon-Stevens (2015: p1), possible alternatives to create job opportunities by developing the skills of the workforce is suggested. The Ocean View Mountain View housing project was used as an example. The building was partially sand-stone and a quote received by the project manager was around R6 million. Looking at alternatives, the project manager decided to use the R6 million in orders to train members of the community in the art of stone masonry. Thirty members received training, and to date seventeen of those finished the training and are working as stonemasons. The project not only had the same result for the same cost, but permanent job opportunities were created. Although it is not a usual ABM certified by Agrément, the same principles could be applied to existing ABM's where job opportunities will increase and more skilled labourers be trained. One example of such an ABM in South-Africa is the Moladi Construction System. Moladi is the manufacturer of a lightweight modular re-usable machine-made formwork system. Although the possibilities are there, the issue is not that ABM's are incapable of creating jobs, but more from the reluctance of using ABM's.

Alternative building techniques is known all over the world. In today's circumstances, there is a need to build structures with alternative building techniques and systems by using alternative building materials. Embodied energy can be defined as the energy required for the collecting, processing, manufacturing and transportation of building materials to the relevant construction site (Ciravoglu, 2005, p910). In other words, the embodied energy of building materials is the energy that is used in the process of mining the raw material, transporting that raw material to the processing plant where the manufacturing process starts. The material is then transformed into the relevant building material or in this case alternative building systems compared to the conventional building materials used. One of the negative side effects of consuming energy is that CO<sub>2</sub> gas is produced, which is known to be one of the major contributors to greenhouse gas emissions (Hammond, 2008, p87). It can therefore be considered that embodied energy is an indicator of the impact on the environment that building materials will have.

There is a global increase in environmental awareness and there are various environmental impacts entailed in the embodied energy of building materials, especially in developing countries. The construction industries in developing countries are still heavily dependent on the use of natural resources in their building materials (Hashemi, et al. 2015, p7867). An example of this is burnt clay bricks/tiles that use clay or cement made from lime stone, the processes in the mining, transportation and burning will consume big amounts of energy (Jayasinghe, 2011, p1). The negative effects go further than just the emission of CO<sub>2</sub> gasses into the atmosphere, for the examples mentioned above there will be a loss of land for the mining of the clay required for the bricks, open pit mines for the limestone and use of wood for the fires for baking the bricks which will lead to deforestation (Jayasinghe, 2011, p1).

There have been many research studies that state that the embodied energy can account for as much as 67% of the operational energy over a lifespan of 25 years (Acquaye, et al: 2009, p3). It is clear to see that the embodied energy plays a large role in the overall energy consumed by a building over its lifespan. The increased awareness on environmental impacts should therefore force the construction industry to take a look at all the possible avenues to decrease the amount of embodied energy in building materials. ABM's can be used to decrease the amount of the embodied energy that will be consumed by the building. The first aspect to contemplate when considering embodied energy is the embodied energy that is involved in the production of the raw material into the various building materials. Next is the energy that is involved with transporting the building material to the relevant construction site. These two processes are some of the first steps where the embodied energy starts to build up for the end value of a specific building material. Transportation is a major contributor to the cost and energy of a building as most of the building materials in developing countries are transported using trucks. There are various distances that these materials have to travel from the plants to the construction sites. These distances can vary from 10 to 100km for basic building materials; whereas the distances for steel can reach up to 500km. Specialised high-end building materials can even be imported internationally, adding greatly to the energy consumption and cost (Reddy, et al. 2001, p132). This study will compare the embodied energies of CBM's and those involved with specific ABM's, such as Expanded Polystyrene Walling Systems.

## RESEARCH METHOD

A mix between qualitative and quantitative approaches was used to collect the data needed. Individual interviews will be held with professionals in the quantity surveying field as well as personnel from EPS walling systems. This information was used to gather qualitative research. In order to collect quantitative research data telephonic and face-to-face interviews were conducted.

At the moment, there is not much data with regards to EPS systems and job creation, so in order to get a clear indication of how the EPS systems impacts job creation a meeting was conducted with a consultant from a known EPS walling system manufacturer, who has extensive knowledge on aspects with regards to EPS walling systems. Furthermore, information has been acquired from the CIDB who has done extensive research on job creation and the data was relevant to the research.

The EPS walling system used in this study is a composite wall system that consists of a range of interlocking wall panels, which could be made from graphite impregnated EPS. Panels are pre-cut in accordance with a panel plan that is based on architectural design of the structure. Steel studs/columns are inserted into grooves that have been cut into the wall panels by a CNC cutting machine. The panels are then stood and secured to the slab using brackets or pre-positioned track. The top of the panel is secured by fixing the stud to at track or bracket on the roof slab, or by inserting a ring beam into the top of the panel. Panels may also include pre-manufactured sub-frames for doors and windows, and in some cases, complete window and doorframe assemblies. Once the panels have been erected, grooves are cut into the panels for the installation of the plumbing and electrical conduit. Once pinned into position with wire ties, a 1.6mm galvanized steel mesh is installed over the panels for the application of a fibrecote, which is high-density fibre cement that is sprayed on both sides of the panel.

## RESULTS

### Results concerning job creation

*The following are advantages and disadvantages for EPS walling systems:*

*Advantages:*

- New in the Market:

Various projects in and around Pretoria are already using EPS walling systems as a choice over brick walls. Being new also makes it an attractive career opportunity for thousands of unskilled labourers.

- Easy to construct:

As EPS walling systems are relatively easy to install in comparison to brick walls, it obviously is quicker to be trained in constructing EPS panels on site with walls in some instances being built up to 70% quicker than conventional brick walls.

- Introducing woman into construction:

Generally, women are not used as labourers in the construction industry; the reason behind this is that constructing brick walls, mixing cement, carrying materials etc. is hard work. However, the lighter panels and the ease of installation have made a considerable impact in creating jobs for woman in the construction industry.

- Job creation for both skilled and unskilled labourers:

As previously, discussed EPS walling systems has a significant contribution in job creation of jobs for unskilled labourers, but job creation is created for skilled labourers as the panels are manufactured in factories. The skilled labourers in the factories are a pivotal factor towards providing high quality products.

*Disadvantages:*

- Not used on a large enough scale:

It isn't used enough in construction industry to make a substantial impact on overall job creation as much as conventional walling has. There is definitely room for growth, and major potential for creating even more jobs in the future.

- Unknown to unskilled labourers:

Most unskilled labourers in communities will not have the resources to learn about the opportunities that EPS products can offer. As conventional construction methods will be the most accepted method for them to learn.

***The following are advantages and disadvantages of conventional brickwork methods:***

*Advantages:*

- Known throughout South-Africa:

Conventional brick walling has been proven and tested for hundreds of years, and will be used in the future as well. In South-Africa it is a major contributor for job creation for unskilled and skilled labourers.

- Training courses:

As discussed before, many companies can give the opportunity of training towards skilled labourers for individuals. Large brick suppliers have highly regarded training courses that are recognized by the Construction Education and Training Authority.

- Large scale production:

As an established method of construction, manufacturing of bricks also has a significant factor on job creation South-Africa.

*Disadvantages:*

- Experience:

The quality of the wall that is built is determined by the quality of workmanship. Large companies who pride themselves in quality will not necessarily employ labourers, who do not have the necessary experience. The more experience a labourer has a vital role in how strong the end product will be.

- Labour intensive:

Masonry construction being labour intensive, does not offer the same as EPS walling systems in terms of creating jobs for women.

## Results concerning embodied energy

The values used for the different elements of the walling systems are general accepted values in the construction industry. These values do tend to differ from different resources, as there are various methods for calculating the embodied energy of building materials. The main processes are:

- Process analysis,
- Input-Output analysis
- Hybrid analysis

The hybrid method is most accepted and seen as the most accurate method available (Crawford and Treloar, 2004, p416).

To compare the embodied energy of the different walling systems a basic table was generated to calculate an estimation of the total embodied energy. The EPS walling system installed complete includes columns, either light gauge steel or cast in-situ concrete columns. Concrete columns have been included in the comparison of the walling systems, assuming it is a large structure being built that will require concrete columns for load bearing purposes. The steel ring beams and tracks will be regarded as only being required for the EPS walling system as this is for the purpose of fastening and securing the system and is not required in a conventional clay brick walling system. Both walling systems will require a plaster coat to achieve a similar finished product and will therefore be included in the comparison for both systems. A steel mesh is part of the EPS walling system, which is utilized as reinforcing. Steel brick reinforcing will be seen a similar type of material and serves a parallel purpose and will thus be included in the comparison. Polystyrene blocks are used for the EPS walling system to achieve the desired insulation. A double skin clay brick will be used for the CBM as this is a more fair comparison than a single skin clay brick wall. Cement mortar is the final element that needs to be included for the CBM to have complete walling systems for the comparison.

**Table 1:** Comparison of the total embodied energy of the walling systems

Building Materials	EPS Walling System Total Embodied Energy (MJ/kg)	Clay Brick Wall Total Embodied Energy (MJ/kg)
Clay Bricks	N/A	6.00
Polystyrene Panels	88.60	N/A
Concrete Columns	1.11	1.11
Steel Ring Beams and Tracks	20.10	N/A
Steel Brick reinforcement	N/A	20.10
Steel Mesh reinforcement	20.10	N/A
Fibrecoat Plaster	1.80	1.80
Mortar	N/A	1.33
Total Embodied Energy	131.71	30.34

On average the total embodied energy of the EPS walling systems is much more than that of a clay brick walling system. The main reason for the vast difference is the amount of steel used in the production and installation of the EPS walling system. Steel uses a large amount of energy to be produced, much more than any other common building material. EPS walling systems has quite a large steel component, adding to the total embodied energy. Even though the transport of steel uses half the amount of energy to transport compared to clay bricks, the large amount of energy used in production makes the steel a large contributor to the total embodied energy of EPS walling systems.



Another major factor in some systems having a larger total embodied energy is the use of the polystyrene blocks as insulation.

EPS walling systems comes into effect where the amount of energy used over the life cycle of the building is concerned. The R-value, as discussed above, is the most accepted way of assigning a measure to the buildings energy efficiency. The study conducted at the CSIR noticeably indicates the advantages of using a well-insulated walling system and the benefits of a higher R-value. EPS walling systems clearly out performs the conventional clay brick walling system with regards to embodied energy.

## Results concerning financial impact

In order to get a cost for the conventional building methods a Bill of Quantities (BoQ) is drawn up, for the EPS walling system a quote (sales order) has been given by a EPS walling manufacturer for this particular building that was used to compare the costs. The total cost of the EPS walling system is in the BoQ as a budgetary allowance, the rest of the building works are under the trades as usual. The preliminaries and general allowed for the project are calculated on 7% of the total building cost with the fixed category consisting of 70% of the total preliminaries, the value category 20% thereof and the time category 10% thereof.

A raft foundation is measured in the BoQ where the EPS walling system is used, the reason is that it is lighter than the conventional strip footing foundation and the EPS system is best suited for a raft foundation. The one advantage of using a raft foundation over a strip foundation is that the raft foundation costs less than the strip foundation.

The rates in these BoQ are market related rates and are inclusive of materials, labour, plant, direct overheads and profit.

**Table 2:** Summary of Bill of Quantities

	Conventional Brickwork	EPS Wall System	Saving in Rand	Saving in %
Preliminaries	20,777.74	16,846.39	3,931.35	18.92%
Earthworks	7,226.00	4,674.11	2,551.89	35.32%
Concrete, Formwork and Reinforcement	38,133.21	28,024.12	10,109.09	26.51%
Masonry	51,243.09	N/A	51,243.09	100%
Waterproofing	1,421.28	3,017.70	-1,596.42	-112.32%
Roof Coverings	27,546.72	27,546.72	-	-
Carpentry and Joinery	8,900.00	8,900.00	-	-
Ceilings	10,710.55	10,710.55	-	-
Ironmongery	1,938.10	1,938.10	-	-
Metalwork	7,305.75	N/A	7,305.70	100%
Plastering	18,235.00	N/A	18,235.00	100%
Tiling	17,963.20	17,963.20	-	-
Glazing	1,382.00	1,382.00	-	-
Paintwork	12,819.90	12,095.10	724.8	5.65%
Budgetary Allowance	N/A	32,411.48	-32,411.48	-
Provisional Amounts, etc.	92,000.00	92,000.00	-	-
Sub-total	317,602.54	257,509.47	60,093.07	18.92%
Contingencies	20,000.00	20,000.00	-	-
Sub-total	337,602.54	277,509.47	60,093.07	17.80%
ADD: Value Added Tax (14%)	47,264.36	38,851.33	8,413.03	17.80%
TOTAL	384,866.90	316,360.80	68,506.10	17.80%

A Bills of Quantities was compiled to compare the costs of CBM's vs. ABM's and it was clear that the construction cost of the EPS walling system is much less than the conventional brickwork method, due to the following reasons:

1. The Preliminaries & General of the EPS system is much lower than the conventional building system. The reason for this is that it takes less time to construct the building and therefore the contractor prices less on the time category. There was a 19% percent saving in this instance
2. The EPS is lighter than conventional brickwork and therefore, it allows a raft foundation to be used instead of a strip foundation. It was clear that the raft foundation is cheaper than a strip foundation.
3. The EPS wall system is constructed from EPS panels and therefore it eliminates the cost of masonry, as in the case of conventional brickwork.
4. The EPS wall system make use of plaster as a plaster to the wall system, which is included in the rate, this eliminates the cost of plaster to walls.
5. The EPS wall system makes use of door and window frames, which is included in the rates and eliminates the cost of metal frames and paint to the frames.
6. Earthworks was found to be cheaper as there was no backfilling required
7. Waterproofing, however, was more expensive due to the use of a raft foundation and raft slab.

## CONCLUSION

On a small scale EPS can go head to head in comparison with brick wall construction for job creation, but ultimately the jobs created by conventional walling systems such as brick wall construction far outweigh that of EPS walling. The reason for the CBM still outweighing ABM is that they are far more established in the construction industry and still trusted more by contractors, companies and the general construction community.

It can be deduced from the study that the embodied energy of the EPS walling systems is higher than that of the clay bricks walling system. With sustainability becoming a point of concern in the construction industry the embodied energy of building materials becomes an important role player in maintaining a sustainability industry. The positive of using the ABM is over the life span of the building, where energy efficiency is significantly improved. A balanced approach is necessary to weigh up the initial embodied energy of the walling system versus the energy usage over the life span of the building.

The financial impact on a project when using EPS walling systems, as opposed to conventional methods, was looked at. The cost of the construction itself is less than that of conventional building methods. This is confirmed where the two BoQ's were drawn up and compared to each other. The use of an EPS wall panel system is indeed cheaper than the clay brick and mortar walling system.

Based on the evidence that has been shown in this research, it is clear that the EPS walling systems are more cost effective and can be constructed in less time than the CBM's such as the clay brick and mortar walling system. Even though a small-scale building was used to illustrate the difference between costs, it is believed that there would be a greater cost saving on a big scale projects. In terms of total embodied energy, the EPS walling system has a greater embodied energy than the CBM, but the energy efficiency over the life span of the building is much more efficient. The EPS walling systems in terms of job creation is more suited for smaller scale projects at this point of time, but this may change as more studies are done on larger projects and as far as EPS walling systems become more accepted in the industry in South Africa.

## REFERENCES

Acquaye, A., Duffy, A. and Basu, B. (2009). Assessment of embodied CO<sub>2</sub>eq in buildings towards a sustainable building design and construction. Dublin Institute of Technology. [online], p1-16  
Available at

<http://arrow.dit.ie/cgi/viewcontent.cgi?article=1009&context=dubencon2>

[Accessed on 8 May 2016].

Burgess, J.B., Bucket, N.R. and Page, I.C., 2013. Study Report, *Prefabrication Impacts in the New Zealand Construction Industry*, s.l.: BRANZ, pg13-14.

Available at:

[http://www.branz.co.nz/cms\\_show\\_download.php?id=2935644f1d998595f3a2d8f5e8167dd08a42a179](http://www.branz.co.nz/cms_show_download.php?id=2935644f1d998595f3a2d8f5e8167dd08a42a179)

[Accessed on 17 May 2016]

CIDB (2014). *Construction Monitor*. Construction Industry Development Board (to be published).

Available at: [www.cidb.org.za](http://www.cidb.org.za)

CIDB (2015). *Labour and Work Conditions in the South African Construction Industry; Status and Recommendations*. Construction Industry Development Board (to be published).

Available at: [www.cidb.org.za](http://www.cidb.org.za)

Ciravoglu, A. (2005). A Research on embodied energy on building materials: Reflections on Turkey. *The 2005 World Sustainable Building Conference*, Tokyo, Japan, September, p.910-917.

Available at: <https://www.irb.fraunhofer.de/CIBlibrary/search-quick-result-list.jsp?A&idSuche=CIB+DC3525>

[Accessed on 25 May 2016]

Construction Training Fund. (2015). *The Impact of New Techniques and Technologies on the Residential Housing Sector of the Construction Industry by Government of Western Australia*, January 2015, pg3.

Available at:

[https://bcitf.org/upload/documents/research\\_reports/WebversionImpactofNewtechniquesonResidentialSectorv20150110c.pdf](https://bcitf.org/upload/documents/research_reports/WebversionImpactofNewtechniquesonResidentialSectorv20150110c.pdf)

[Accessed on 17 May 2016]

Crawford, R.H. and Treloar, G.J. (2004). *Assessment of embodied energy analysis methods for the Australian construction industry*. [online] p.415-421

Available at: [http://anzasca.net/wp-content/uploads/2014/08/ANZAScA2004\\_Crawford.pdf](http://anzasca.net/wp-content/uploads/2014/08/ANZAScA2004_Crawford.pdf)

[Accessed on 3 June 2016]

Denoon-Stevens, S. (2015). *Alternative construction techniques create jobs in South Africa*. [online]. *Urban Africa.net*.

Available at: <http://www.urbanafrica.net/urban-voices/alternative-construction-techniques-create-jobs-in-south-africa>

[Accessed on 13 August 2016]

Energy Efficiency & Environmental Impact, 2013. Guide To Building With EPS In Compliance With SANS 204 by EPSASA, July 2013, pg15-16.

Available at: <http://expandedpolystyrene.co.za/eps-user-guides/building-with-eps-sans-204>

[Accessed on 24 June 2016]

Hammond, G.P. and Jones, C.I., (2008). *Embodied energy and carbon in construction materials*. [online]. p87  
Available at:  
[http://opus.bath.ac.uk/12382/1/Hammond\\_%26\\_Jones\\_Embodied\\_energy\\_%26\\_carbon\\_Proc\\_ICE-Energy\\_2008\\_161\(2\)\\_87-98.pdf](http://opus.bath.ac.uk/12382/1/Hammond_%26_Jones_Embodied_energy_%26_carbon_Proc_ICE-Energy_2008_161(2)_87-98.pdf)  
[Accessed on 23 June 2016]

Hashemi, A., Cruickshank, H. and Cheshmehzangi, A. (2015). *Environmental impacts and embodied energy of construction methods and materials in low-income tropical housing*. [online] p.7869-7883  
Available at: [www.mdpi.com/2071-1050/7/6/7866/pdf](http://www.mdpi.com/2071-1050/7/6/7866/pdf)  
[Accessed 8 May 2016].

Jayasinghe, C. (2011). *Embodied energy of alternative building materials and their impact on life cycle cost parameters*. [online], p.1-20  
Available at: [http://www.civil.mrt.ac.lk/conference/ICSECM\\_2011/SEC-11-166.pdf](http://www.civil.mrt.ac.lk/conference/ICSECM_2011/SEC-11-166.pdf)  
[Accessed 7 May 2016].

Pakade, B.J. and Odhiambo, J., (2016). *The contribution of Alternative Building Technologies in the Transformation of the Construction Industry in South Africa*. Independent Development Trust.  
[online], p1-13.  
Available at:  
[http://www.cidb.org.za/publications/Document%20Store/cidb%20National%20Stakeholder%20Form%20Meeting%20Presentation%20on%20-%20The%20Role%20of%20ABTs%20in%20The%20Transformation%20\(29-03-2016\).pdf](http://www.cidb.org.za/publications/Document%20Store/cidb%20National%20Stakeholder%20Form%20Meeting%20Presentation%20on%20-%20The%20Role%20of%20ABTs%20in%20The%20Transformation%20(29-03-2016).pdf)  
[Accessed on 4 November 2016].

Venkatarama Reddy, B.V. and Jagadish, K.S. (2001). *Embodied energy of common and alternative building materials and technologies*. [online] p.129-137.  
Available at:  
[http://www.academia.edu/17203474/Embodied\\_energy\\_of\\_common\\_and\\_alternative\\_building\\_materials\\_and\\_technologies](http://www.academia.edu/17203474/Embodied_energy_of_common_and_alternative_building_materials_and_technologies)  
[Accessed 8 May 2016]

**GREEN COSTS MORE?  
AN EMPIRICAL STUDY ON THE COSTING OF GREEN BUILDING PROJECTS WORLDWIDE**

Mei-yung LEUNG<sup>1</sup>, Isabelle Y.S. CHAN<sup>2</sup>

<sup>1</sup>Department of Architecture and Civil Engineering, City University of Hong Kong, Tat Chee Avenue, Hong Kong, email: [bcmei@cityu.edu.hk](mailto:bcmei@cityu.edu.hk)

<sup>2</sup>Department of Real Estate and Construction, University of Hong Kong, Pokfulam Road, Hong Kong; email: [iyschan@hku.hk](mailto:iyschan@hku.hk)

Sustainability is an inevitable trend. However, the number of green building developments is still limited. Previous studies have attributed this to the perception of “Green costs more” as presented by quantity surveyors to construction clients. It is argued that the commonly adopted figure of 5-15% as the extra cost for green has ‘seriously’ overestimated capital cost. In view of the above, the current study aims to investigate green buildings from the ‘cost’ perspectives. To achieve this aim, a questionnaire survey has been designed to investigate the cost and features of green building projects across the globe. The survey was sent via various professional institutes, green building consultants, architectural, engineering and construction firms, and so on, in countries across the globe, including Brunei, China, Hong Kong, Japan, New Zealand, Singapore, Sri Lanka, Philippines, United Arab Emirates, Nigeria, and so on. The statistical data collected was then analyzed using SPSS. The study results indicate that, when comparing with conventional building projects, i) there are more than 35% increases in capital cost in green building projects, ii) amongst the various green building design and features, green planning & design and green construction are the most frequently adopted ones, which incurred 8.63% increase and 30.33% decrease in the spending of the items respectively, and iii) the values of green building projects are higher in terms of price, rental cost and premium in market valuation. The study results are essential in fostering the development of green buildings around the world.

Keywords: Construction time, Costing, Green buildings

### **Research Background**

Sustainability is an inevitable trend. However, the number of green building developments is still limited. Previous studies have attributed this to the perception of “Green costs more” as presented by quantity surveyors to construction clients. It is argued that the commonly adopted figure of 5-15% as the extra cost for green has ‘seriously’ overestimated capital cost. In view of the above, the current study aims to investigate green buildings from the ‘cost’ perspectives. To achieve this aim, a questionnaire survey has been designed to investigate the cost, construction time and features of green building projects across the globe.

## Method

### Survey Design

To achieve the aim of investigating the costs and cost effectiveness of green buildings from a global perspective, a survey study was conducted. The survey was designed to include four main parts, including, I) background information of respondents and their green building projects, II) costing of green buildings projects, and III) benefits of green building projects. Purposive sampling was adopted, in which only professionals who have participated in green building projects within the past 2 years were involved in the study. Respondents were invited to fill in the survey based on one single recent green project.

Respondents were recruited through the HKIS and PAQS networks. There are 169 responses received in total. However, since some of the information can be sensitive, question items were not set mandatory in the survey. There are thus different number of responses under different items and sections, with the largest ones being 97 in Part II and 53 in Part I respectively.

### Respondents' Background

As shown in Table 1, more than 80% of the respondents were quantity surveyors, and more than 70% of the respondents worked in QS consultant firms. Nearly 70% of the respondents were working at professional levels, while nearly 30% of them worked at management or top management levels.

Table 1 Respondents Background

Respondents' Background		Frequency	Percentage
Organization	Developer	3	6.12
	Contractor	4	8.16
	<b>QS consultant</b>	<b>36</b>	<b>73.47</b>
	Green building consultant	1	2.04
	Others	5	10.20
	Total	49	100
Profession	Building surveyor	1	2.08
	<b>Quantity surveyor</b>	<b>41</b>	<b>85.42</b>
	Architect	1	2.08
	Building services engineer	1	2.08
	Project manager	3	6.25
	Others	1	2.08
	Total	48	100
Position	Senior management	7	15.91
	Management	5	11.36
	<b>Professional</b>	<b>30</b>	<b>68.18</b>
	Others	2	4.55
	Total	44	100

Regarding the green projects that the respondents were participated in, more than 30% of these projects were located in Hong Kong, followed by Philippines (23%), Brunei (9%), and so on. The majority of these projects were public (43%) or private (43%) owned. Most of the green projects were academic buildings (39%) and new commercial buildings (37%). LEED was the most commonly adopted green building assessment standard (29%), followed by BEAMPLUS (20%). Nearly 80% of the projects would be completed by 2017, and the project duration is 2.6 years on average. Please refer to Table 2 for more details.

Table 2 Project Background

Project Background		Frequency	Percentage
Project location	<b>Hong Kong</b>	<b>16</b>	<b>30.19</b>
	Philippines	12	22.64
	Brunei	5	9.43
	Sri Lanka	4	7.55
	UAE	4	7.55
	South Africa	2	3.77
	Japan	2	3.77
	New Zealand	2	3.77
	Singapore	1	1.89
	Indonesia	1	1.89
	Canada	1	1.89
	China	1	1.89
	Others	2	3.77
	Total	53	100
Project ownership	<b>Public</b>	<b>22</b>	<b>43.14</b>
	<b>Private</b>	<b>22</b>	<b>43.14</b>
	Semi-public	7	13.73
	Total	51	100
Project type	<b>Academic building</b>	<b>20</b>	<b>39.22</b>
	<b>New Commercial</b>	<b>19</b>	<b>37.25</b>
	New residential	4	7.84
	Existing residential	1	1.96
	Others	7	13.73
	Total	51	100.00
Green building scheme	<b>LEED</b>	<b>13</b>	<b>28.89</b>
	BEAMPLUS	9	20.00
	BCA Green Mark	2	4.44
	CASBEE	1	2.22
	Living Building Challenge	1	2.22
	GSAS-Global Sustainability Assessment System	1	2.22
	Others	18	40.00
	Total	45	100

### Capital Cost and Benefits of Green Buildings

As shown in Table 3, the majority of respondents indicated that, when comparing with conventional buildings, green buildings were found to have higher capital cost (an increase of 37% on average, as indicated by 97% of respondents). However, it is interesting to note that

there was a small amount of respondents who indicated a decrease in capital cost (3%) in green projects. For the market values, nearly all of the respondents indicate that there would be an increase in the selling price (an increase of 8% on average, as indicated by 90% of the respondents), rental cost (an increase in 6% on average, as indicated by all of the respondents) and market valuation premium (an increase in 6% on average, as indicated by all of the respondents) in a green building project. Lastly, the payback period is 10.3 year on average (N=9).

Table 3 Percentage of change in capital cost and values of green buildings as a whole (when comparing with conventional buildings)

% of change in Cost		When comparing with conventional buildings...	
Capital cost	n=34	<b>Increase (97%)</b>	<b>Decrease (3%)</b>
		37.22%	10%
% of change in Values		When comparing with conventional buildings...	
Price per m2	n=10	<b>Increase (90%)</b>	<b>Decrease (10%)</b>
		7.56%	12.00%
Rental cost	n=9	<b>Increase (100%)</b>	<b>Decrease (0%)</b>
		5.67%	-
Premium in market valuation	n=9	<b>Increase (100%)</b>	<b>Decrease (0%)</b>
		5.75%	-

In order to investigate the impact of project type and ownership on the capital cost of green building projects, one way between-groups analyses of variance (ANOVA) were conducted. As shown in Table 4, the capital cost of green academic buildings was significantly higher than that of green commercial and green residential buildings ( $F=46.777$ ;  $p<0.01$ ), and the capital cost of public green projects is also significantly higher than that of private and semi-public green projects ( $F=23.013$ ;  $p<0.01$ ).

Table 4 One-way between-groups ANOVA for the percentage of change in **capital cost** of green buildings with different project types and ownerships

% of Change in Capital Cost						Post-hoc test			
Project Types (A)	Mean	SD	F (ANOVA)	Sig. (ANOVA)	Sig. (Levene)	Project Types (B)	Mean Diff. (A-B)	S.D.	Sig.
New commercial buildings (19)	+7.82	10.29	46.777	0.000	0.891	Academic building	-62.19	5.74	0.000
New residential buildings (4)	+4.50	4.77				Academic building	-65.50	9.58	0.000
Academic buildings (20)	<b>+70.00</b>	19.35				New commercial building	+62.19	5.74	0.000
						New residential buildings	+65.50	9.58	0.000
Project Ownerships (A)	Mean	SD	F (ANOVA)	Sig. (ANOVA)	Sig. (Levene)	Project Ownerships (B)	Mean Diff. (A-B)	S.D.	Sig.
Public (22)	<b>+60.06</b>	28.89	23.013	0.001	0.003	Private	+55.29	8.43	0.000
						Semi-public	+45.72	14.10	0.008
Private (22)	+4.76	9.29				Public	-55.29	8.43	0.000
Semi-public (7)	+14.33	10.21				public	-45.72	14.10	0.008



### Costing of Green Building Elements in Details

As shown in Table 5, most of the respondents had conducted green analyses and adopted green elements in relation to construction (n=26), followed by planning and design (n=10), efficient use of material (n=9), energy use (n=9), water use (n=9), and so on. Adoption of **greening in construction** was found by most of the respondents to reduce the spending on these two items by 43% (n=17). While most of the respondents indicated an increase in spending in the items of planning and design (9%, n=8), efficient use of material (4%, n=7), energy use (10%, n=6), water use (10%, n=6), and maintenance and operation (13%, n=6) in their green building projects.

Table 5 Costing of Different Green Building Elements

(Due to the multiple responses, number/frequency of responses, instead of percentage, were used in the first five columns.)

Green building assessment element(s) (n=97 in total, including multiple responses)	Green analyses conducted	Freq	Green element(s) adopted	Freq	Spending of the item (when comparing with conventional buildings) (%)		Average change in spending
a) Site acquisition (n=1)	- Geophysical consideration	0	- Geophysical consideration	0	Increased (n=1) 30%	Decreased (n=0)	+30.00%
	- Ecological impact	0	- Ecological impact	0			
	- Transportation	1	- Transportation	1			
	- Soil pollution		- Soil pollution	0			
	- Heat island effect	1	- Heat island effect	0			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
b) Planning & design (n=10)	- Building orientation with better energy performance	5	- Building orientation with better energy performance	5	Increased (n=8) 8.63%	Decreased (n=0)	+8.63%
	- Building configuration for better energy performance	5	- Building configuration for better energy performance	6			
	- Underground space development for saving land resources	2	- Underground space development for saving land resources	1			
	- Building envelope optimization for thermal performance	5	- Building envelope optimization for thermal performance	5			
	- Landscape design	3	- Landscape design	3			

*Green Costs More? An Empirical Study on  
The Costing of Green Building Projects Worldwide*

	- Green roof	6	- Green roof	6			
	- Flexibility and adaptability to future needs of occupants and systems	4	- Flexibility and adaptability to future needs of occupants and systems	4			
	- Maintenance of heritage value	2	- Maintenance of heritage value	0			
	- Social values	0	- Social values	0			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
<b>c) Construction</b> (n=26)	- Prefabricated concrete	5	- Prefabricated concrete	4	Increased (n=7) 5.72%	Decreased (n=17) 43.06%	<b>-30.33%</b>
	- Construction safety	20	- Construction safety	19			
	- Others (Please specify: Reflective index of roof tile)	1	- Others (Please specify: _____)	0			
<b>d) Efficient use of material</b> (n=9)	- Building fabric insulation (e.g., roof, wall, etc.)	7	- Building fabric insulation (e.g., roof, wall, etc.)	7	Increased (n=7) 3.83%	Decreased (n=1) 15.00%	<b>+1.48%</b>
	- Environmental friendly material for HVAC systems	8	- Environmental friendly material for HVAC systems	6			
	- Minimization of virgin materials use	4	- Minimization of virgin materials use	3			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
<b>e) Waste management</b> (n=8)	- Reuse of architecture features	2	- Reuse of architecture features	0	Increased (n=2) 1.50%	Decreased (n=3) 1.33%	<b>-0.20%</b>
	- Reuse of warehouse on future projects	2	- Reuse of warehouse on future projects	1			
	- Architectural salvage sales	3	- Architectural salvage sales	1			
	- Recycling shuttering or hoarding	2	- Recycling shuttering or hoarding	2			
	- Reuse of aggregates	2	- Reuse of aggregates	2			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			

*Green Costs More? An Empirical Study on  
The Costing of Green Building Projects Worldwide*

f) Pollution (n=4)	- Atmospheric emissions (e.g., greenhouse gas)	1	- Atmospheric emissions (e.g., greenhouse gas)	2	Increased (n=3) 3.17%	Decreased (n=0)	+3.17%
	- Pollution of aquifers or water ways	3	- Pollution of aquifers or water ways	3			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
g) Energy use (n=9)	- Renewable energy (e.g., solar system)	6	- Renewable energy (e.g., solar system)	6	Increased (n=6) 10.17%	Decreased (n=1) 15.00%	+6.57%
	- Peak electricity demand control	3	- Peak electricity demand control	1			
	- Ground source heat pump	0	- Ground source heat pump	0			
	- Others (Please specify: grey water)	1	- Others (Please specify: sensor controlled fittings)	1			
h) Water use (n=9)	- Minimization of potable water use	6	- Minimization of potable water use	5	Increased (n=6) 9.73%	Decreased (n=1) 15.00%	+6.20%
	- Decentralized rainwater system	4	- Decentralized rainwater system	3			
	- Wastewater system	4	- Wastewater system	4			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
i) Maintenance and operation (n=8)	- Ample ventilation (natural, hybrid, mechanical) for pollutant, thermal, and humidity controls	3	- Ample ventilation (natural, hybrid, mechanical) for pollutant, thermal, and humidity controls	1	Increased (n=6) 13.00%	Decreased (n=0)	+13.00%
	- Integration of natural lighting and electric lighting systems	4	- Integration of natural lighting and electric lighting systems	4			
	- Acoustics control (e.g., low E insulation window)	5	- Acoustics control (e.g., low E insulation window)	4			
	- Green technology monitor and maintenance system	3	- Green technology monitor and maintenance system	3			

*Green Costs More? An Empirical Study on  
The Costing of Green Building Projects Worldwide*

	- Green facility management	3	- Green facility management	3			
	- Others (Please specify: _____)	0	- Others (Please specify: _____)	0			
j) Health and well-being (n=3)	Please specify: - user requirements, preferences	1	Please specify: - good view, comfortable environment	1	Increased (n=3) 2.37%	Decreased (n=0)	+2.37%
k) Innovation and addition (n=7)	Please specify: _____	0	Please specify: _____	0	Increased (n=1) 15.00%	Decreased (n=0)	+15.00%
l) Demolition (n=3)	Please specify: _____	0	Please specify: _____	0	-	-	-
m) Others (n=0)	Please specify: _____	0	Please specify: _____	0	-	-	-

## **Conclusion**

The study results indicate that, when comparing with conventional building projects, i) there are more than 35% increases in capital cost in green building projects, ii) amongst the various green building design and features, green planning & design and green construction are the most frequently adopted ones, which incurred 8.63% increase and 30.33% decrease in the spending of the items respectively, and iii) the values of green building projects are higher in terms of price, rental cost and premium in market valuation. The above analyses and results were done based on the data collected as in mid-May 2017. Data collection is still in progress. Conclusion will be drawn after the data collection is fully completed.

## **Acknowledge**

This project is supported by the Hong Kong Institute of Surveyors (HKIS).

# HONG KONG'S BUILDING ENERGY SAVING PLANS IN RESPONSE TO CLIMATE CHANGE

Paul H K Ho

*Principal Lecturer, City University of Hong Kong  
Chairman (2017-18), the Professional Green Building Council  
Past Chairman (2005-06), QS Division, the Hong Kong Institute of Surveyors  
88 Tat Chee Avenue, Hong Kong  
bshkho@cityu.edu.hk*

## Abstract

Buildings in Hong Kong consume 90% of the total electricity consumption and generate 60% of the total carbon emissions. In fulfilling its obligation under the Paris Agreement, the government has set a carbon intensity reduction target of 65-70% by 2030. This study aims to explore and evaluate the applicability of building energy saving initiatives in response to climate change. A comprehensive list of initiatives is proposed under legislative, environmental, economic/financial and social categories. For assessing its applicability, four evaluation criteria are adopted: effectiveness, efficiency, fairness and institutional feasibility. Questionnaire survey was utilised to collect building professionals' views on the proposed initiatives. Based on 355 completed questionnaires, it was found that four initiatives were rated above 'very high' in terms of effectiveness: 'tightening the current GFA concessions scheme', 'allocating sufficient funding to the housing authority for retrofitting existing public housings', 'providing sufficient funding to government organisations for retrofitting existing government buildings' and 'increasing the stringencies of current regulations', while other three criteria were equally found to be high. Other ten initiatives were also rated between 'moderately high' and 'very high', indicating their high levels of applicability. These initiatives form a practicable roadmap and action plan which are currently lacking in Hong Kong. While this is a country-specific study, it also provides a good references for those countries with a similar situation.

Keywords: climate change, energy saving plans, green buildings, Hong Kong.

## INTRODUCTION

The Paris Agreement, which was adopted by 195 nations in December 2015, sets out an action plan to reduce the impacts of climate change. Countries signed the said agreement agreed to (1) keep the increase in the global average temperature below 2°C, (2) aim to control the temperature increase to 1.5°C to lessen impacts of climate change, (3) keep global carbon emissions to peak the soonest possible and then undertake rapid reductions. They also agreed to meet together every 5 years to report how well to implement their short-term targets, and track progress towards the long-term goal (European Commission). China signed the agreement which came into effect on 4<sup>th</sup> November 2016.

Since the agreement also applies to Hong Kong, the government has set a carbon intensity reduction target of 65-70% by 2030 (with 2005 as the base year). In absolute terms, it is equivalent to 26-36% reduction (Environment Bureau, 2017). At present, 70% of carbon emissions are arising from the electricity generation. As such, one of the logical strategies for large-scale carbon emission reduction is to gradually replace the existing coal-fired electricity generation by natural gas. It is estimated that by 2020, natural gas will be used to generate 50%

of electricity. This helps achieve the target of 50-60% carbon intensity reduction. To achieve further reduction of 65-70% by 2030, the remaining coal plant must be phased down after reaching their normal service life and replaced with natural gas and renewable energy.

The government has not actively promoted the development of large-scale commercial renewable energy generation. Thus, so far, the amount of electricity generated from renewable sources are minimal. Even though the current policy is to be changed, it is estimated that based on the current available technologies, renewable energy arising from solar, wind and waste-to-energy would only generate 3-4% of the total energy.

Although carbon emissions could be controlled at the electricity generation or 'supply' side, it could not reduce the actual electricity consumption and would not therefore be sustainable. In the long-term, saving energy from the 'demand' side is the real and cost-effective solution for reducing carbon emissions. In particular, 90% of the total electricity is consumed by buildings. The commercial and residential building sectors account for 65% and 27% of the electricity respectively. Therefore, the most proper direction for achieving the 2030 target reduction is to save energy used in buildings instead of changing the fuel mix from coal to natural gas.

A complete climate action plan normally include three main aspects: adaptation, resilience and mitigation. Hong Kong, as a well-developed city, has done substantial works over past years on climate adaptation and resilience, particularly in public infrastructure, urban fabric, slope safety, flood management, coastal protection and social response to climate-related emergencies. However, as pointed out above, it would require a great effort to reduce the total electricity consumption in buildings in order to achieve the targeted carbon emission reduction by 2030 and beyond. Therefore, the aim of this study is to explore and evaluate potential building energy saving initiatives in response to the climate change challenge.

## **CURRENT BUILDING ENERGY SAVING INITIATIVES**

While the government has set out its targeted carbon intensity reduction of 65-70% by 2030, there are neither action plan nor roadmap and timetable for achieving the target. Therefore, the current building energy saving initiatives must be identified and reviewed to see whether and to what extent it would be feasible and effective to achieve the set target eventually. According to the World Green Building Trends 2016, energy saving initiatives can be classified into four main categories: legislative, environmental, economic/financial and social driven (Dodg Data & Analytics, 2016), details of which are described in the following sub-sections.

### **Legislative Initiatives**

Legislative initiatives are those regulatory measures to set minimum standards for building envelopes, building service installations and electrical appliances with a view to reducing electricity consumption. Around 65% of the total electricity is consumed by commercial buildings. Enhancing the thermal transfer standard of commercial buildings is one of the most important measures for reduction of carbon emissions. The *Building (Energy Efficiency) Regulation* aims at reducing solar heat gain through building envelopes, thus saving electricity used in air-conditioning. Roofs and external walls of hotel and commercial buildings must attain the specified overall thermal transfer value (OTTV) according to the *code of practice for OTTV*. The OTTV standard was tightened in 2011 and was also extended to residents' club houses in 2015. However, the current OTTV standards are still considered to be low for cutting down the

solar heat gain significantly. In particular, the OTTV code is only applicable to new buildings and existing buildings are not required to upgrade to the latest OTTV standard.

Residential buildings account for around 27% of the total electricity. Enhancing the thermal transfer standard of residential buildings is also one of the important measures for reduction of carbon emissions. In this regard, *Guidelines for Energy Efficiency of Residential Buildings* was promulgated in 2015 to control the residential thermal transfer value (RTTV) of external walls and roof and also promotes natural ventilation design for reducing electricity used in air-conditioning. Same as the OTTV, this guideline is only applicable to new buildings and there is no requirement for existing buildings to upgrade to the latest RTTV standard. While introduced recently, the RTTV values must also be periodically reviewed to keep pace with advancement in building design and technological development.

Enhancing the energy efficiency of building service installations is one of the important measures for effective reduction of carbon emissions. The *building energy code* sets out energy efficiency standards of air conditioning, lighting, lift and escalator and electrical installations in both new buildings and existing buildings when carrying out major retrofitting works. In addition, the *energy audit code* requires all existing commercial buildings to conduct energy audits in respect of four specified types of building services installation every 10 years. While the energy audit normally provides recommendations for building owners to improve energy efficiency, the current code does not have a mandatory requirement for them to carry out the improvement work according to the latest standards.

Besides building envelopes and major building service installations, it is also important to help the public choose the most energy efficient electrical appliances. Under the *energy efficiency labelling scheme*, five types of prescribed appliances are mandatorily required to provide an energy label to show the energy efficiency of the appliance. This scheme currently covers refrigerators, dehumidifiers, room air-conditioners, washing machines and fluorescent lamps which account for 60% of electricity consumption in residential buildings. It should cover more different types of appliances and its grading standards must also be tightened to keep pace with the technological development.

## **Environmental Initiatives**

Environmental initiatives are those measures voluntarily undertaken to combat the negative impacts of climate change. Green buildings which use less energy than conventional buildings enables individual organisations to demonstrate their commitment to sustainable development. A number of green building assessment methods are available such as the LEED, BREEAM and Three Stars. The predominant method in Hong Kong is *BEAM Plus*, covering new buildings, existing buildings, interiors and neighbourhood. The green building rating provides an objective assessment of a building's overall performance including energy use. However, there is lack of verification between the designed and actual performances; this shortcoming must be rectified.

Building energy benchmarking is an important tool for developers/building owners to reconcile the actual energy performance and the assumption made during the design stage. The *Benchmarking and Energy Saving Tool* developed by the local green building council (HKGBC) provides an online tool for owners of existing commercial, office and retail buildings to measure and compare their energy consumption to market peers and to identify potential energy improvement measures to enhance performance. Upon completion of benchmarking, energy



performance certificate, label rating and specific energy efficiency improvement recommendations will be provided.

Using environmental friendly or green building products is not only a way to improve indoor environmental quality, but also a means to improve the overall environmental performance of a building. The *Green Product Accreditation and Standards* is a local labelling scheme to certify greener building products, materials and components, currently covering 20 product categories. In addition, the *Carbon Labelling Scheme* provides carbon footprint information of construction products for users to make informed decision. At present, the scheme is still at its beginning stage, covering cement, reinforcing bar and structural steel only. To be useful to serve its intended purposes, the coverages of both schemes must be significantly enlarged to include most construction materials and products.

### **Economic/Financial Initiatives**

Economic/financial initiatives are those measures for attaining a higher economic value such as gaining bonus gross floor areas, achieving higher property values, saving building operational costs and increasing the users' productivities. To enhance the built environment, the government provides *gross floor area (GFA) concession scheme* for private developers to invest in innovative and green new buildings. Green features, which adopt a holistic life cycle approach, maximise renewable resources and green materials, reduce construction waste and minimise the energy consumption, are exempted from gross floor area calculations. The concession is currently capped at 10% of the total gross floor area of the development. Since the local property price is very high, 10% bonus floor area represents a huge incentive for private developers to pursue green buildings. At this moment, the amount of GFA concession is same for all projects even though they achieve different green building assessment ratings. With such a large incentive at stake, the government could grant a higher amount of concession for a building with a higher performance.

The city's total building stock consists of about 42,000 existing buildings. A large number of these buildings was designed and constructed before introducing various environmental related measures. Thus, most existing buildings cannot achieve a similar high energy performance as new buildings. The *Environment and Conservation Fund* supports two types of green projects. The first type aims to assist building owners in conducting *energy-cum-carbon audits* to review energy consumption and quantify carbon emissions. It also identifies opportunities for improvements of energy efficiency and reductions in carbon emissions. The second type is to assist building owners in upgrading the energy efficiency of central building services installations in existing buildings. However, public fund as a whole is limited and only a small number of building owners can benefit.

Proportionally speaking, the largest amount of energy reduction would rely on upgrading the energy efficiency of existing buildings as new buildings were normally designed and built with relatively high standards. Thus, the real challenge is how to motivate existing building owners to spend money in the energy upgrading work. In some western countries, there is a substantial market for retrofitting existing buildings through an energy performance contract. However, Hong Kong is differed from these countries where its construction cost is high and its electricity cost is low. Under such environments, it is doubtful whether the same business model would be financially feasible. Therefore, the government must assist existing building owners in carrying retrofitting works by granting certain incentives, which could be in form of government rate, stamp duty and tax concessions.

In Hong Kong, the tenant typically pays a flat management fee, irrespective of the electricity being actually used. The *Green Tenancy Driver* developed by the HKGBC promotes collaboration between the landlord and tenant to create a sustainable working environment. Under the green lease arrangement, energy usage data are shared between the landlord and tenant to increase the scope for enhancement and behavioural change. Cost savings through more environmental operation are fairly split between the landlord and tenant so that both parties would benefit from adopting green measures.

### **Social Initiatives**

Social initiatives are those measures used to promote environmental protection through social events and public education. The *Green Building Week* is an annual territory-wide campaign co-organised by the local Construction Industry Council and HKGBC to boost the public awareness on green lifestyle, promote green building development and drive behavioural change in saving the earth. A series of events are arranged, including speaking contest, drawing competition and green building open house and tours.

The *Green Building Award* organised by the HKGBC provides recognition to building projects with an outstanding performance in sustainability. These exemplary projects demonstrate the innovative green building designs and practices to building professionals.

The United Nations has marked 5 June as the World Environment Day. Echoing with this international initiative, the local Green Council organises the *Green Day* on every 5 June to raise citizens' environmental awareness and to build a greener community. Citizens can support the green day through a series of social events, including dress green, green photo competition, green cooking competition and green shop campaign.

### **PROPOSED ENERGY SAVING INITIATIVES TOWARDS ACHIEVING 2030 TARGET**

The current building energy saving initiatives outlined in the preceding section have built up a good foundation for dealing with the climate change challenge. However, as briefly commented above, some standards set by regulatory initiatives are low, financial initiatives granted are not larger enough for existing building owners to carry out energy upgrading works, and environmental and social initiatives are not yet widely adopted in the community. If the current pattern of energy consumption continues, there would definitely be more carbon emissions due to the population and economic growth. To fill the gap between the projected energy consumption and the targeted reduction by 2030, the government must strengthen existing initiatives and pursue additional initiatives to attain greater energy saving. A list of new and modified initiatives is suggested as follows (HKGBC, 2012).

#### **Legislative Initiatives**

- A1 Progressively increasing the stringencies of current OTTV and RTTV codes in line with the public aspirations, international standards and the latest technological development.
- A2 Further developing the current *building energy code* to provide a specific energy performance requirement for each type of buildings and also a minimum metering requirement for logging the actual operational performance of a building.
- A3 Further extending the scope of the current *energy audit code* to cover not only commercial buildings, but also other types of buildings (i.e. educational, residential, cultural and

- industrial buildings) to conduct energy audits every 7 years (instead of 10 years) and also requiring a reporting standard to allow consistent benchmarking purposes.
- A4 Enhancing the grading standards of the current *energy efficiency labelling scheme* and also expanding its scope to cover more different types of electrical appliances.
  - A5 Introducing a statutory requirement for building owners to ensure that all existing private and public buildings aged over 40, 30 and 20 years ago must be retrofitted in compliance with relevant energy efficiency regulations by 2020, 2025 and 2030, respectively (as most building services installations should have exceeded its normal working life according to this timetable).
  - A6 Introducing a carbon tax for users with large energy consumption to stimulate behavioural change in energy saving.
  - A7 Adjusting the current electricity tariff structure to promote energy saving.
  - A8 Allowing relaxation or modification of current building regulations to allow more green building features incorporated in the building design and construction.

### **Environmental Initiatives**

- B1 Enhancing the robustness of the current green building assessment system to keep up with the latest technological development, international green building rating standards and changes in energy efficiency regulations and also further tightening the energy reduction requirements for different grades of green building assessment rating.
- B2 Utilising the energy data collected to help develop an objective energy performance benchmarking system.
- B3 Extending the coverage of the current *green product accreditation* and *carbon labelling scheme* to help reduce the embodied energy of building materials and products.
- B4 Encouraging the public and private sector to adopt a green procurement policy for procuring and using energy efficient installations and appliances only.
- B5 Developing a green home certification scheme for residential buildings so that developers or building owners can display their environmental performance on their marketing materials.
- B6 Encouraging the landlord and tenant to enter into a green lease by making known the energy use information, conducting energy audit, changing the behaviours in using energy and sharing the energy reduction.

### **Economic/Financial Initiatives**

- C1 Tightening the current *GFA concessions* scheme to ensure that bonus GFAs would only be granted for new buildings with a high green building assessment rating, which can achieve an average annual energy reduction of 30%. Actual performances should be verified to ensure that the designed energy consumption matches with the actual energy demand during the occupancy stage.
- C2 Providing subsidies and financial incentives in form of government rate, stamp duty and income tax concessions for private building owners to retrofit their existing buildings in line with the green building assessment ratings (existing buildings).
- C3 Encouraging the private sector to provide a green financing for retrofitting existing buildings.
- C4 Providing sufficient funding to various government organisations for retrofitting their existing buildings in compliance with relevant energy efficiency regulations according to the timetable specified in A5 above.
- C5 Allocating sufficient funding to the Housing Authority for retrofitting their existing public housings in compliance with relevant energy efficiency regulations according to the timetable specified in A5 above.

- C6 Providing income tax concessions to organisations (including existing power supply companies) for the development of large-scale renewable energy for commercial use.
- C7 Enlarging the amount of public fund to support the transformation of existing buildings into green buildings.

### **Social Initiatives**

- D1 Supporting universities and manufacturers to undertake pure and applied research in green building related technologies.
- D2 Providing sufficient training courses for building professionals on the green building design, rating and audit for the capacity building.
- D3 Developing practical guidelines for building owners and property managers to provide sufficient technical supports.
- D4 Continuing to organise the green day, green building week, green building award and other social events to demonstrate green building designs and technologies to the building professional and the public.
- D5 Organising general education programmes (such as environmental awareness campaign and guided tours to exemplary green buildings) to boost the public awareness of energy saving.
- D6 Requiring publicly listed companies to disclose their corporate social responsibility report annually.

### **MULTI-CRITERIA EVALUATION**

A list of proposed energy saving initiatives has been identified in the preceding section; many are current initiatives with a stringent standard and wider scope, while others are new initiatives. In order to evaluate their overall applicability, it is essential to carry out an *ex-ante* assessment before its implementation. Different types of policies, measures or instruments would require different evaluation criteria. For instances, for monitoring, evaluating and reporting carbon emission reductions, O'Brien (2000) proposed seven evaluation criteria: estimated emission impact, likely public support, likely political support, easiness of execution, staffing resources required, cost and benefit, and other benefits (e.g. creating job and other economic opportunities and improving air quality). In choosing the Canada's carbon emission reduction policies, Demerise and Bramley (2008) adopted eight evaluation criteria: environmental effectiveness, economic efficiency, cost-effectiveness, fiscal impact, fairness, simplicity of administration, political feasibility and avoidance of international competitiveness impacts.

The Intergovernmental Panel on Climate Change (IPCC) used four main criteria to evaluate policy instruments: institutional feasibility, distributional effects including equity, environmental effectiveness and cost-effectiveness (IPCC, 2007). For evaluating the UK's renewable energy policies, the International Renewable Energy Agency (IREA) also adopted four similar criteria: equity, institutional feasibility, effectiveness and efficiency (Nicholls, et al. 2014). For evaluating the OECD member countries' regulatory policies, the Organisation for Economic Co-Operation and Development (OECD) also used four criteria: effectiveness/impact, cost-effectiveness, net benefit/efficiency and equity/distributional fairness (Coglianese, 2012).

For evaluating the proposed energy saving initiatives, this study adopts the same four evaluation criteria as the IPCC, IREA and OECD, details of which are described as follows:

- *Effectiveness* is concerned with the extent to which an energy saving initiative will contribute to the reduction of carbon emissions. Its effectiveness can be directly measured

through the reduction in energy consumption or indirectly measured through a shift in behaviour to use more renewable energy. This is one of the most crucial criteria to evaluate to what extent the main goal in energy saving would be attainable.

- *Efficiency* is concerned with the cost-and-benefit of an energy saving initiative, i.e. the ratio of environmental gains (i.e. outcomes) to economic resources required (inputs). This is a useful criterion for comparing various initiatives with similar effectiveness but different efficiencies.
- *Fairness* is concerned with the distributional consequences of an energy saving initiative, including such dimensions as affordability, equity, justice, proper use of public fund and impact on low income groups. As a matter of principle, polluters should pay the costs associated with the pollution and those investing in energy saving upgrades should receive the benefits associated with the improvements. An unfair initiative is not likely to be accepted by the public.
- *Institutional/political feasibility* is concerned with the extent to which an energy saving initiative is considered to be legitimate, able to gain public support and able to be implemented. In addition to the above three criteria, this also depends on the economic, social and political environments when introducing the initiative. An infeasible initiative would not be implementable even through its effectiveness and efficiency are very high.

## RESEARCH METHODOLOGY

Different evaluation criteria will require the collection of different data such as the level of energy consumption, amount of subsidies for energy efficiency upgrades, behavioural change to energy consumption and potential to implement the initiative. At this stage, factual data could not be available since the proposed energy saving initiatives are yet to be implemented. As an *ex-ante* assessment, questionnaire survey was utilised to collect building professionals' opinions on the proposed energy saving initiatives.

The questionnaire comprised two main parts. Part 1 collected the respondents' demographic data, aiming to explore the suitability and diversity of respondents. These include their job positions, professional backgrounds, levels of academic education and years of working experience. Part 2 collected the respondents' ratings on the proposed energy saving initiatives. Respondents were requested to rate each initiative under four criteria: effectiveness, efficiency, fairness and institutional/ political feasibility. The ratings of each criterion were based on the five-point interval scale. The rating descriptions for these criteria are as follows: 1=no impact, 2=mildly high, 3=moderately high, 4=very high and 5=extremely high. A high level of performance leads to a higher score value, and vice versa. Respondents were also requested to express their opinions on each of the proposed initiative.

The targeted respondents are professional architects, engineers and surveyors. Thus, the survey sample was based on the relevant professional institute's registers, including the Hong Kong Institute of Engineers, Hong Kong Institute of Surveyors and Hong Kong Institute of Architects. A web-based questionnaire was utilised and opened between early January and end March 2017. E-mails were sent to the 1,700 respondents to invite them to participate in the survey. 335 surveys were eventually completed, representing a response rate of 19.7 per cent. The software, SPSS, was used to carry out the statistical analysis.

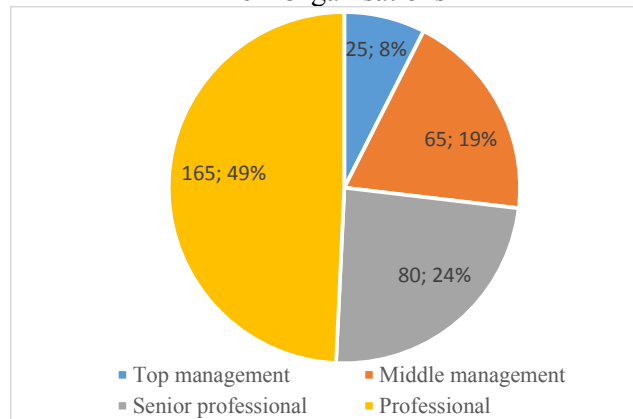
## FINDINGS AND DISCUSSIONS OF RESULTS

### Demographic Data

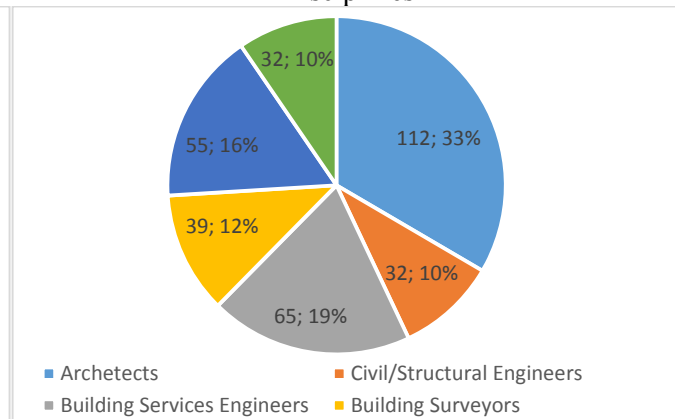
A questionnaire survey was conducted to evaluate the applicability of the proposed energy saving initiatives. In total, 355 respondents completed the on-line questionnaire survey. Figures 1-4 present the demographic characteristics of respondents. As shown in Figure 1, most respondents were either professionals (49%) or senior professionals (24%), and the rest were in middle or top management positions (27% in total). In light of their job positions, they should have an enough professional knowledge about energy saving measures in buildings.

As shown in Figure 2, major respondents came from the architectural discipline (33 per cent), while the remaining came from the building services engineering (19%), quantity surveying (16%), building surveying (12%), civil/structural engineering (10%) and other (10%) disciplines. In view of their professional disciplines, they should be able to provide wide diversified views from different professional perspectives.

**Figure 1: Respondents' Job Positions in Their Organisations**

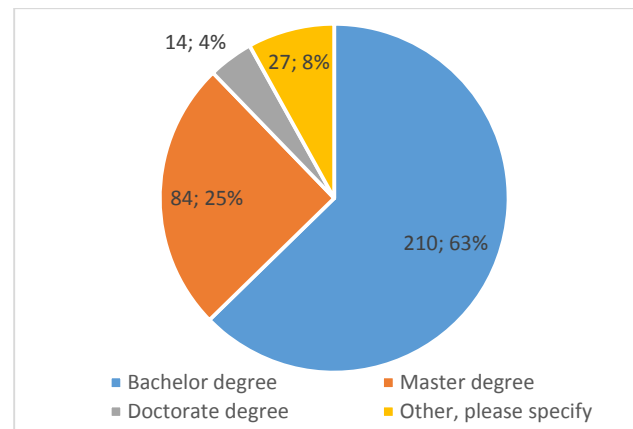


**Figure 2: Respondents' Professional Disciplines**

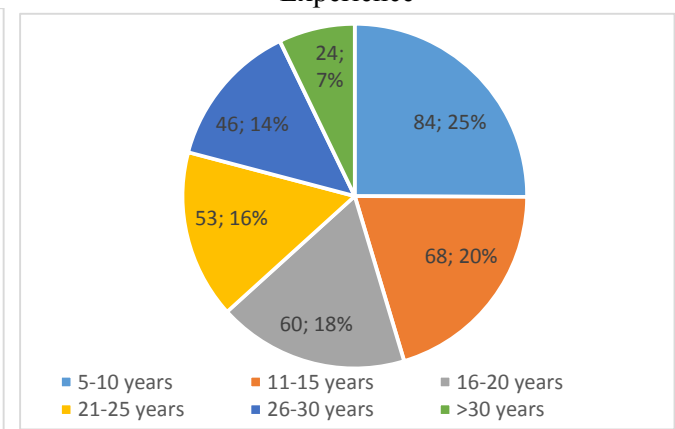


As shown in Figure 3, most respondents possessed a bachelor's degree or above qualifications (92%). In terms of working experience, 75% of the respondents had over 5 years of working experience as shown in Figure 4. Therefore, as a whole, they should have sufficient academic qualifications and working experience to evaluate the proposed energy saving initiatives.

**Figure 3: Respondents' Educational Levels**



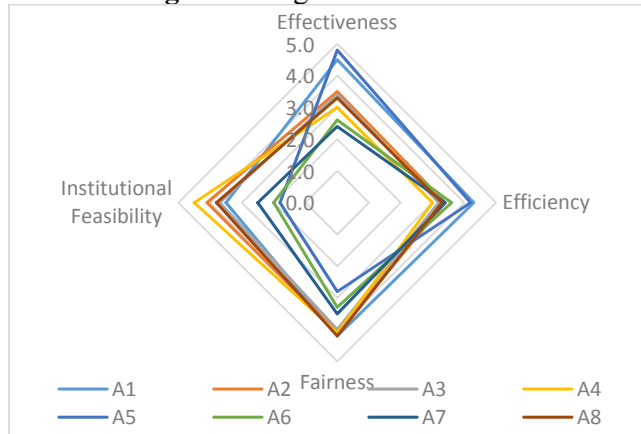
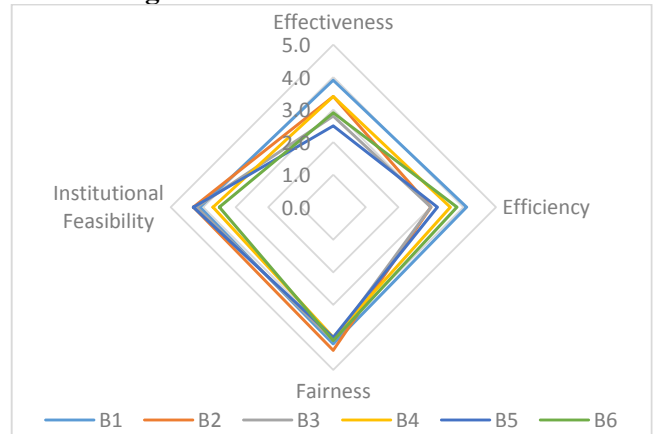
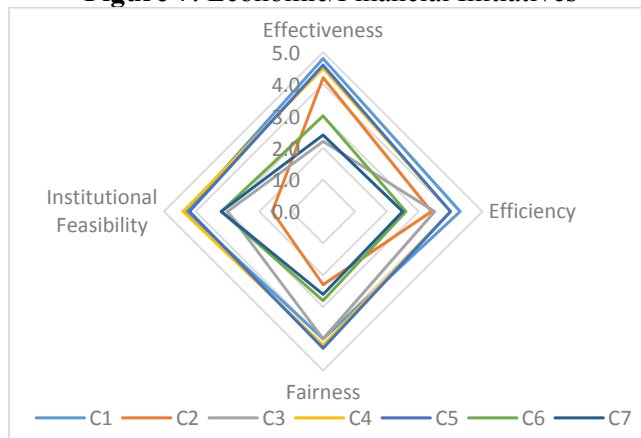
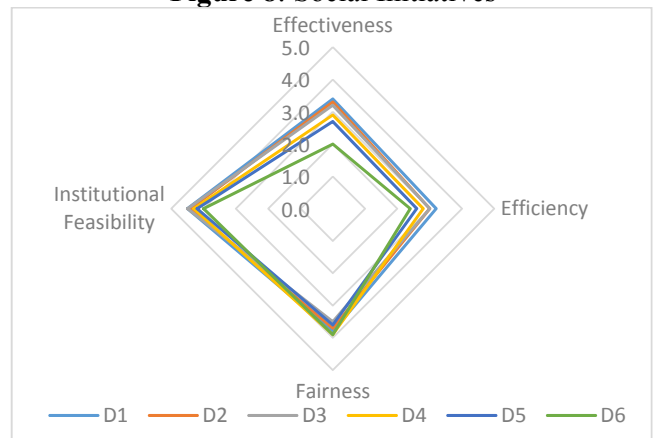
**Figure 4: Respondents' Years of Working Experience**



## Questionnaire Survey

Based on part 2 of completed questionnaires, data were analysed by descriptive statistics. Based on its mean values, the results are summarised in Table 1 and diagrammatically shown in Figures 5, 6, 7 and 8. For easy interpretation, each criterion in Table 1 is marked with light red, yellow and green colours for indicating their low, median and high priorities respectively. Evaluation of each initiative with multi-criteria require a holistic judgement. Probably, the first and simple step is to eliminate those energy saving initiatives with relative low score values (say, lower than 3) on any one or more of the criteria to ensure that only robust and viable initiatives will be considered. The next step is to prioritize the remaining initiatives according to the relative importance of criteria. Among the four specified criteria, it is considered that the most and second most important criteria are 'effectiveness' and 'efficiency' respectively, while the remaining two criteria 'fairness' and 'institutional/political feasibility' should attain a definite threshold value to ensure the public's acceptance.

<b>Table 1: Respondents' Ratings of Each Energy Saving Initiative</b>					
Proposed Energy Saving Initiatives		Evaluation Criteria			
		Effectiveness	Efficiency	Fairness	Institutional Feasibility
Legislative:	A1	4.5	4.3	4.2	3.5
	A2	3.5	3.4	4.1	4.1
	A3	3.4	3.2	4.0	3.7
	A4	3.0	3.0	4.1	4.5
	A5	4.8	4.2	2.8	1.8
	A6	2.6	3.6	3.3	2.0
	A7	2.4	3.4	3.5	2.5
	A8	3.3	3.3	4.2	3.8
Environmental:	B1	3.9	4.1	4.2	4.1
	B2	3.4	3.0	4.4	4.3
	B3	2.8	3.0	4.1	4.2
	B4	3.4	3.6	4.0	3.7
	B5	2.5	3.2	4.0	4.3
	B6	2.9	3.8	4.1	3.5
Economic/ Financial:	C1	4.8	4.3	4.0	4.3
	C2	4.2	3.4	2.3	1.6
	C3	2.2	3.5	4.0	3.0
	C4	4.5	4.0	4.2	4.4
	C5	4.6	4.0	4.3	4.2
	C6	3.0	2.6	2.8	3.2
	C7	2.4	2.5	2.6	3.2
Social:	D1	3.4	3.2	3.8	4.5
	D2	3.3	3.0	3.7	4.4
	D3	3.2	3.0	3.5	4.5
	D4	2.9	2.8	3.9	4.3
	D5	2.7	2.6	3.6	4.2
	D6	2.0	2.4	3.9	4.0

**Figure 5: Legislative Initiatives****Figure 6: Environmental Initiatives****Figure 7: Economic/Financial Initiatives****Figure 8: Social Initiatives**

### ***Legislative Initiatives***

In total, there are seven energy saving initiatives within this category. The initiative ‘introducing a statutory requirement for building owners to retrofit their existing buildings (4.8)’ was rated with the highest score value in terms of effectiveness, but its ratings were low in terms of fairness (2.8) and institutional feasibility (1.8). This indicated that while this initiative would be very effective in saving overall energy, most private building owners would not accept being imposed a new legislation to force them to retrofit their existing buildings in compliance with relevant energy efficiency regulations. This is because this would create a significant burden for most building owners, some of them might have financial difficulties to do so. Therefore, under the current political environment, it is unlikely that the local legislative council would pass a controversial regulation.

Two legislative driven initiatives ‘introducing a carbon tax’ and ‘adjusting the current electricity tariff structure’ were rated between ‘mildly high’ and ‘moderately high’ in terms of effectiveness (2.6 and 2.4 respectively) and political feasibility (2.0 and 2.5 respectively). This indicated that unlike some overseas countries, carbon tax and pricing mechanism are not considered as an effective and acceptable means that can change the public’s behaviour in energy consumption. Since the public is habitual to pay a high petrol tax and electricity charge, it would not be effective unless relevant rate or charge is exceptionally high.



In terms of effectiveness, one initiative rated between 'very high' and 'extremely high' was 'progressively increasing the stringencies of current regulations (4.5)'. The remaining four initiatives were rated between 'moderately high' and 'very high': 'further developing the current building energy code (3.5)', 'further extending the scope of the current energy audit code (3.4)', 'allowing relaxation or modification of current building regulations (3.3)' and 'enhancing the grading standards of the current energy efficiency labelling scheme (3.0)'. In terms of other three criteria, these five initiatives were all rated above 'moderately high'. As a whole, all of these five legislative initiatives are considered be a very effective, cost-efficient, fair and politically feasible means for saving energy. However, it must be noted that a new regulation does not usually applied to existing buildings unless and until they carry out a major retrofitting work. Therefore, the legislative initiative still could not resolve the problem of low energy efficiency of existing buildings, until the initiative 'introducing a statutory requirement for building owners to retrofit their existing buildings' is accepted.

### ***Environmental Initiatives***

There are totally six energy saving initiatives within this category. Three initiatives under this category were only rated between 'mildly high' and 'moderately high' in terms of effectiveness: 'encouraging the landlord and tenant to enter into a green lease (2.9)', 'extending the coverage of the current green product accreditation and carbon labelling schemes (2.8)' and 'developing a green home certification scheme (2.5)', while they were all rated above 'moderately high' in other three criteria. Since green lease is yet to become popular in Hong Kong, its effectiveness in energy saving is not apparent. Nevertheless, its potential benefit was well recognised and therefore, its effectiveness was rated relatively high (2.9). On the other hand, green product and carbon labelling schemes were also rated similar high as the green lease, reflecting its potential value in energy saving. Green home certification scheme is a completely new initiative. When buying a new or existing residential flats or houses, the local citizen is more concerned with the property price, location, maintenance and transportation instead of its energy efficient performance. In the long-run, the public would gradually change their attitude. Then, this might be one of the considerations when purchasing a property.

The remaining three environmental driven initiatives were all rated above 'moderately high' in terms of effectiveness: 'enhancing the robustness of the green building assessment system (3.9)', 'developing an energy performance benchmarking system (3.4)' and 'encouraging the government and private sector to adopt a green procurement policy (3.4)'. In terms of other three criteria, they were all rated above 'moderately high'. Given its high rating, the importance of the green building assessment system was well recognised as a greatly effective means in saving energy. While the green building assessment is popular in new buildings, it is not yet common in existing buildings. Energy performance benchmarking system was considered as an important and practicable tool for building owners to identify their energy consumption so that the relevant upgrading works would be undertaken. Green procurement policy was rated similarly high as the energy performance benchmarking system. By adopting green procurement policy, all products and services purchased should have minimal adverse environmental impacts.

### ***Economic/Financial Initiative***

There are totally seven energy saving initiatives within this category. The initiative 'providing subsidies and financial incentives for private building owners to retrofit their existing buildings (4.2)' was rated between 'very high' and 'extremely high' in terms of effectiveness, but its

ratings were below 'moderately high' in terms of its fairness (2.3) and institutional feasibility (1.6). If no sufficient financial incentive would be provided, many building owners would not retrofit their existing buildings in line with the latest energy efficient standards. However, this would contradict to the principle that polluters should pay the costs of pollution, while creating a huge burden on the government's fiscal budget. At this stage, this initiative would not likely be accepted by the public and therefore, the problem of existing buildings with low energy efficiency would still be unresolved.

Similarly, in terms of effectiveness, the initiative 'providing income tax concessions and other financial subsidies to organisations for the development of renewable energy (3.0)' was also rated with 'moderately high', but its ratings were below 'moderately high' in terms of efficiency (2.6) and fairness (2.8). Many overseas countries provide financial incentives for the development of renewable energy due to its comparatively high capital cost and low rate of return. However, providing public funding or subsidy to a private organisation is controversial. Therefore, so far, there is no large-scale renewable energy generation for commercial use. It is however hoped that both the government and public would gradually change their attitude toward the development of renewable energy after realizing its environmental gains.

Likewise, the initiative 'enlarging the amount of the current public fund to support the green building transformation' was rated between 'mildly high' and 'moderately high' in terms of effectiveness (2.4), efficiency (2.5) and fairness (2.6). While public funding support is somehow important for those building owners with financial difficulties, it is also realized that the funding amount would not be substantial and generous. As such, the extent of improvement works that can be undertaken would be limited.

The remaining three economic/financial-driven initiatives were all rated above 'very high' in all four criteria: 'tightening the requirements of the current GFA concessions scheme', 'providing sufficient funding to various government organisations for retrofitting their existing buildings' and 'allocating sufficient funding to the housing authority for retrofitting their existing public housings'. For the private building sector, the GFA concession scheme provides a large incentive for private developers to pursue green buildings. Therefore, it is rated to be the most effective initiative for driving high energy performance buildings. For the public building sector, the government owns and manages a large number of existing buildings and, in particular, the public housings which accommodate more than 40% of the local population. It is considered that the government should take a leading and exemplary role to gradually transform all existing government buildings into high energy performance green buildings. Currently, the government proceeds a huge amount of reserve budget and should have no financial problem to undertake these initiatives.

### ***Social Initiatives***

There are totally six energy saving initiatives within this category. In terms of effectiveness and efficiency, three social-driven initiatives were rated below 'moderately high': 'continuing to organise the green day, green building week, green building award and other social events (2.9 and 2.8 respectively)', 'organising general education programmes (2.7 and 2.6 respectively)' and 'requiring listed companies to disclose their corporate social responsibility report annually (2.0 and 2.4 respectively)', while they were rated above 'moderately high' in terms of fairness and institutional feasibility. While the effectiveness and efficiency of these initiatives were not significantly high, it was considered to be fair and feasible.

The remaining three social-driven initiatives were rated above ‘moderately high’ in all four criteria: ‘supporting universities and manufacturers to undertake pure and applied research’, ‘providing sufficient training courses for building professionals’ and ‘developing practical guidelines for building owners and property managers’. This reflected that these initiatives would generally be an effective, efficient, fair and feasible means for saving energy.

## CONCLUSIONS

In combating the climate change, the Hong Kong government has set an ambitious carbon reduction target of 65-70% by 2030. However, there are neither action plan nor roadmap for achieving this target. This is probably because the reduction target could be largely achieved by gradually shifting the fuel mix in electricity generation from coal to natural gas. However, if the current energy consumption behaviour remains unchanged, there would definitely be an increasing demand for energy due to the general economic and population growth in the future. As such, saving energy from the demand side would be the sustainable solution for the long-term reduction of carbon emissions. As 60% of carbon emissions are generated by the electricity consumption in buildings, therefore this study aims to identify and evaluate the identified energy saving initiatives in the building sector.

Based on a large-scale questionnaire survey, four proposed energy saving initiatives were identified to be very strong: ‘tightening the requirements of the current GFA concessions scheme (4.8)’, ‘allocating sufficient funding to the housing authority for retrofitting their existing public housings (4.6)’, ‘providing sufficient funding to various government organisations for retrofitting their existing buildings (4.5)’ and ‘increasing the stringencies of current regulations (4.5)’. Another ten proposed initiatives were also identified to be strong: ‘enhancing the robustness of the green building assessment system (3.9)’, ‘further developing the current building energy code (3.5)’, ‘further extending the scope of the current energy audit code (3.4)’, ‘utilising the energy data to help develop an energy performance benchmarking system (3.4)’, ‘encouraging the government and private sector to adopt a green procurement policy (3.4)’, ‘supporting universities and manufacturers to undertake pure and applied research (3.4)’, ‘allowing relaxation or modification of current building regulations (3.3)’, ‘providing sufficient training courses for building professionals (3.3)’, ‘developing practical guidelines for building owners and property managers (3.2)’ and ‘enhancing the grading standards of the current energy efficiency labelling scheme (3.0)’. Other initiatives were also identified to be applicable to different extents. These initiatives would form a practicable roadmap and action plan, leading Hong Kong to achieve the targeted reduction of carbon emissions.

As an *ex-ante* assessment, this study was based on the questionnaire surveyor. In the future when some of these initiatives are implemented, an *ex-post* study could be undertaken on the basis of factual data to verify and compare the results between these two types of study. Since the government needs to report how well they implement their targets, longitudinal studies based on the same research framework could be carried out every 5 years to track the progress and change. Some of the proposed energy saving initiatives which were considered to be ineffective or unfeasible for the time being might become effective or feasible in the future when the public changes their mind-set and attitude.

While this study is mainly to identify energy saving initiatives for reducing carbon emissions in Hong Kong, many of the proposed initiatives and, in particular, its evaluation criteria are also applicable to other international cities where the city’s development and energy consumption

behaviours are similar. This study can demonstrate to other cities on how Hong Kong could resolve the climate change problem, thus contributing significantly to the international society.

## REFERENCES

- Coglianesi, C. (2012), *Measuring Regulatory Performance: Evaluating the Impact of Regulation and Regulatory Policy*, Expert Paper No. 1, Organisation for Economic Co-Operation and Development (OECD).
- Demerse, C. and Bramley, M. (2008), *Choosing Greenhouse Gas Emission Reduction Policies in Canada*, Report Prepared by the Pembina Institute for Don Drummond, TD Bank Financial Group, Canada.
- Dodge Data and Analytics (2016), *World Green Building Trends 2016: Developing Markets Accelerate Global Green Growth*, SmartMarket Report, Bedford, MA, US.
- European Commission, *Paris Agreement*, retrieved 19 May 2017, [https://ec.europa.eu/clima/policies/international/negotiations/paris\\_en](https://ec.europa.eu/clima/policies/international/negotiations/paris_en).
- Environment Bureau (2015), *Energy Saving Plan for Hong Kong's Built Environment 2015~2025+*, HKSAR Government, Hong Kong.
- Environment Bureau (2017), *Hong Kong's Climate Action Plan 2030+*, HKSAR Government, Hong Kong.
- Green Council, *Hong Kong Green Day*, retrieved 26 May 2017, [http://www.greencouncil.org/en/page.php?sub\\_id=14](http://www.greencouncil.org/en/page.php?sub_id=14)
- Hong Kong Green Building Council (HKGBC) (2012), *HK3030 – A Vision for a Low Carbon Sustainable Built Environment in Hong Kong by 2030*, HKGBC, Hong Kong.
- Hong Kong Green Building Council (HKGBC) (2014), *Market Drivers for Transformation of Green Buildings in Hong Kong: A Roadmap to Deep Energy Reductions*, HKGBC, Hong Kong.
- Intergovernmental Panel on Climate Change (2007), *Climate Change 2007 Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)*, Cambridge, UK.
- Nicholls, J., Mawhood, R., Gross, R. and Castiloo-Castillo (2014), *Evaluating Renewable Energy Policy: A Review of Criteria and Indicators for Assessment*, International Renewable Energy Agency, UK.
- O'Brien, V.S. (2000), *Strategic Framework for Quantifying, Monitoring, Evaluating, and Reporting Local Greenhouse Gas Emissions Reductions*, Workshop on Best Practices in Policies and Measures, Copenhagen.

# **Internal Project Cost Audit for Mitigation of Risks and Reduction of Construction Costs of High Performance Buildings in Hong Kong Property Developers**

Joseph H.C. Chong

*FHKIS RPS(QS) MHKICM RCM BEAM Pro(incl. BI), The Hong Kong Institute of Surveyors, josephhku@gmail.com*

## *Abstract*

Most property developers in Hong Kong are listed companies. They are required to establish sound internal control and risk management system and procedures to avoid significant losses.

As construction projects involve substantial capital expenditures, internal project cost audit functions are often established within Hong Kong property developers to mitigate risk and reduce construction costs, even though independent cost consultants have been used. Quantity surveyors (Qs) are best qualified professionals to carry out internal project cost audit functions as they are familiar with tender procedures, construction contracts and costs.

This paper will discuss the scope of work of internal project cost audit function in different property developers of Hong Kong. The paper will also set forth examples of high risk areas and common issues identified.

Keywords: cost audit, property developers, internal audit, project audit, technical audit.

## **WHAT IS INTERNAL CONSTRUCTION/ PROJECT COST AUDIT?**

The Hong Kong SAR Government's Manual for Technical Audits on Works Contracts defined audit as "*a systematic and independent examination of specific activities...to determine whether such activities/ related results comply with planned arrangements, and whether these arrangements are implemented effectively and are suitable to achieve objectives*". Also it further defined an internal audit as "*an audit carried out by one organisation on itself*" (HKSAR Government, 2002A).

Park et al. (2015) defined internal audit as supervising and monitoring the management and works in the organization from an independent and objective position. It takes the role of executive manager's eyes and ears to identify how the executive manager's plans and orders are performed, and when the performance results are deviated from the firm's goals, the internal audit points out the problem and suggests a solution for it.

There are different terms used to describe audits on construction projects, e.g. project audit, project management audit, contract audit, construction audit and technical audit. These terms are used interchangeably in this paper. Project cost audit is a kind of project audit focusing on project costs.

Hauber et al. (2013) considered audit is not just looking for cost recoveries but also recommend process improvement for the project team, from solicitation of bids to final payment.

Sichombo et al. (2009) defines technical auditing as an independent, objective assurance and consulting activity designed to assess both the effectiveness and efficiency of an organisation's operations.

Nalewaik (2006) suggested that audit function is an essential project controls tool: project audit by an independent party does not only test the accuracy of invoices but may include a review of processes used in project management and project cost/schedule control, and a comparison with best practices. It is common in US to have a right to audit clause in construction contracts, which provides owner with right to audit the contractors continuously, at intervals or at closeout.

## **WHY CONSTRUCTION/ PROJECT COST AUDIT IS REQUIRED?**

Ollmann and Schuchart (2012) pointed out that **major construction risks** faced by developers include design failure, structural failure, scope creep – “adding additional features, requirements, or work that is not authorized” (Larson & Larson, 2009), financial risks, contract compliance, billing fraud, completion delays, loss of stakeholders' confidence, cost inflation, policy compliance and bid-rigging.

Some key risks faced by developers are discussed below:

### *Aggressive/ Abusive Billing and Overcharges*

Overbilling, which is not in the developers' best interest, is quite common in the construction industry. Contractors are focused to maximize their profits and using the terms of contract to their benefit. Also they may rely on their sub-contractors' and suppliers' inflated quotations and then transfer the high cost to the developers.

When developers procure any works by obtaining a single quotation and confirmed it without comparison with other companies' prices and market prices, they would probably suffer from overcharges.

Even for projects with proper tendering process and negotiation for best offers conducted, star rates would often be submitted during the construction stage by contractors in variation claims. In some cases, contract rates are not applied by reasons of small quantities and change of working conditions.

Construction projects are probably the largest and most complex financial expenditures companies undertake, with most projects containing overcharges of 1 to 2 percent (Brown Smith Wallace LLP, 2009).

Wall Street Journal (2012) reported that in the US, an Australian contractor was found to **over-bill** its clients by adding 2 hours of overtime pay on top of regular hours for as many as 60 foremen. The contractor has defrauded their clients for US\$19 million in total.

In another news, Houston City Controller's Audit Division has recovered over \$800,000 in overcharges and unsupported costs at the Hobby Airport New East Concourse construction project (Hearst Newspapers LLC, 2013).

There is a recent case in **Hong Kong** that the Main Contractor's quantity surveyor allegedly submitted fake quotations from sub-contractor to the officers of the Architectural Services Department for approval in the amount of HK\$3M (ICAC, 2017; Ng, 2017).

A survey by Cashell et al. (1999) revealed that 90% of the internal auditors responded found significant overcharges after performing construction cost audits. Developers can avoid overcharges completely by performing a construction audit. Also audit can help develop a control system to save costs on future projects (Brown Smith Wallace LLP, 2009).

### *Bid-rigging*

Bid-rigging is another common phenomenon in construction all over the world. With bid-rigging, developers may not be able to obtain the best competitive prices even though many competent tenderers are, superficially, invited to tender.

In **US**, FBI was investigating in 2013 a former project manager of the University of Texas at San Antonio over allegations that he routinely used the same three bidding contractors, which are in fact controlled by the same person. He also inflated the bids upto 5 times the actual cost before he sent them to the purchasing department in order to get some cash rebates. He was finally sentenced to prison for 38 months (Contreras, 2013; US Dept. of Justice, 2016).

In Montreal of **Canada**, a former construction company owner told the corruption commission in 2012 that collusion has existed in the construction industry since the 1980's. Collusion included market segmentation, complementary bidding and payoffs to city officials (CBC News, 2012; Clark et. al, 2017).

In Toronto, Auditor General's Office found inflated prices by paving contractors cost the city an additional \$2.5M over five years. Small group of contractors dominated in a district and submitted virtually identical bids (CBC News, 2017).

In **UK**, Office of Fair Trading (OFT) has imposed fines totalling £129.2 million on 103 construction firms in England in 2014 for engaging in illegal bid-rigging in the form of "cover-pricing". Cover pricing is where bidders get artificially high prices from competitors and mislead employers as to the real extent of competition.

Employers unknowingly paid a higher price. The infringements involved building projects of over £200 million including schools, universities, hospitals and numerous private projects (Office of Fair Trading, UK, 2014).

In **South Africa**, 21 construction companies admitted to the Competition Commission for rigging bids of contracts in 131 projects. Another 22 companies will face penalties for not heading to the Commission to give evidence of bid-rigging (Competition Policy International, 2013).

In **Singapore**, the Competition Commission issued proposed infringement decision against 4 electrical companies for their involvement in bid-rigging for Formula 1 Singapore Grand Prix from 2015-2017. The lowest bidder prepared all pricing schedule and final bid prices for the other tenderers (CCS Singapore, 2017; The Straits Times, 2017).

In **Hong Kong**, there was a court case in 2010 *Sit Kam Tai v Gammon Iron Gate Co Ltd* regarding bid-rigging. Some stainless steel gates suppliers signed a cartel agreement and they fixed the minimum tender price for tendering the supply contracts of the Housing Authority. The cartel designated a winning bidder and the other companies who submit tenders with higher prices. Profits will then be allocated evenly in the cartel (Wilkinson, 2015).

Bid-rigging in **Hong Kong** is more serious in the housing estate renovation sector. Reporter was told by an anonymous contractor that 3 separate groups of contractors and surveyors allocate renovation projects through manipulated tender processes. Their winning bids are often three times the market norms (Robertson and Yau, 2014). In a recent case, a sub-contractor is sentenced for 35 months imprisonment for a rigged HK\$260M project. He bribed the chairman of incorporated owners, executive director and property manager of the property management company to set up some dummy bidders (Lau, 2016).

With the Competition Ordinance came into effect in Hong Kong in December 2015, the Competition Commission has not yet taken action against contractors yet for bid rigging. However it has carried out a market study of residential renovation/maintenance market and issued some brochures on preventing and detecting bid-rigging (Hill, 2016).

### *Cost Inflation*

A survey by Construction Industry Institute in the US found about one out of three projects is over budget (Applegate and Matthews, 2002). In theory, a construction project would be tendered based on a fully completed design. In reality, due to complexity and time, all projects could hardly have complete designs. Instead, there could be provisional sums, provisional quantities, variations to allow late decision making by client and to deal with ambiguities in the contract documentations (Yates, 2003).

With the recent increase in land cost, unforeseen increase in construction costs would further squeeze developers' profit margin. The President of the Hong Kong Institute of Surveyors (HKIS) explains that construction worker costs have risen by 8-10 per



cent annually in the past few years and those of specialist trades have gone up 15 per cent in a year (Chen, 2016; Chow, 2017). Cost inflation risk should be properly controlled and projects should be tendered out at right time.

#### *Audits as a means to minimize risks and reduce costs*

Many problems in construction projects can be avoided if owner has good understanding of project risks and appropriate project controls. Internal cost audit process can minimize the risk mentioned above.

Hauber et al. (2013) pointed out that internal audits provide independent and objective assurance that corporate fund is handled properly. Construction audits are not an expense as they reduce total project costs and are an indispensable internal control process.

Cashell et. al. (1999) surveyed 61 internal auditors across the U.S. and interviewed seven companies who carried out contract auditing. The study concluded that cost recoveries from construction contract audits can cover or even exceed the entire annual budget for the internal audit department. Most common findings in construction audits by the internal auditors are:

- Charges for costs that were never incurred (48%).
- Inclusion of non-allowable costs in the target cost (45%).
- Failure to give credit for original contract costs revised by change orders (38%).
- Inflated burden rates (17%).
- Duplicate charges (14 %).

Sichombo et al. (2009) echoed the benefits resulting from technical audits of construction projects include: lowering the cost of finance by reducing corruption; identifying fraud situations; recovery of any fraudulent financial loss; minimising weaknesses in project procedures, processes and administration; providing an independent and objective perspective; availability of information in case of a dispute etc.

ASD (2006) concluded that technical audits have a direct positive effect on the performance of the contractors, consultants and in-house staff - increasing their awareness of all laid down procedures; feedback from the audit reports help prevent recurrence of non-compliance and ultimately improve the performance standard of all parties. Also, ambiguous clauses and grey areas in contract documents are identified and then these documents are improved. These audits also facilitated implementation of new policies, such as site safety, which auditors will include in their audit agenda.

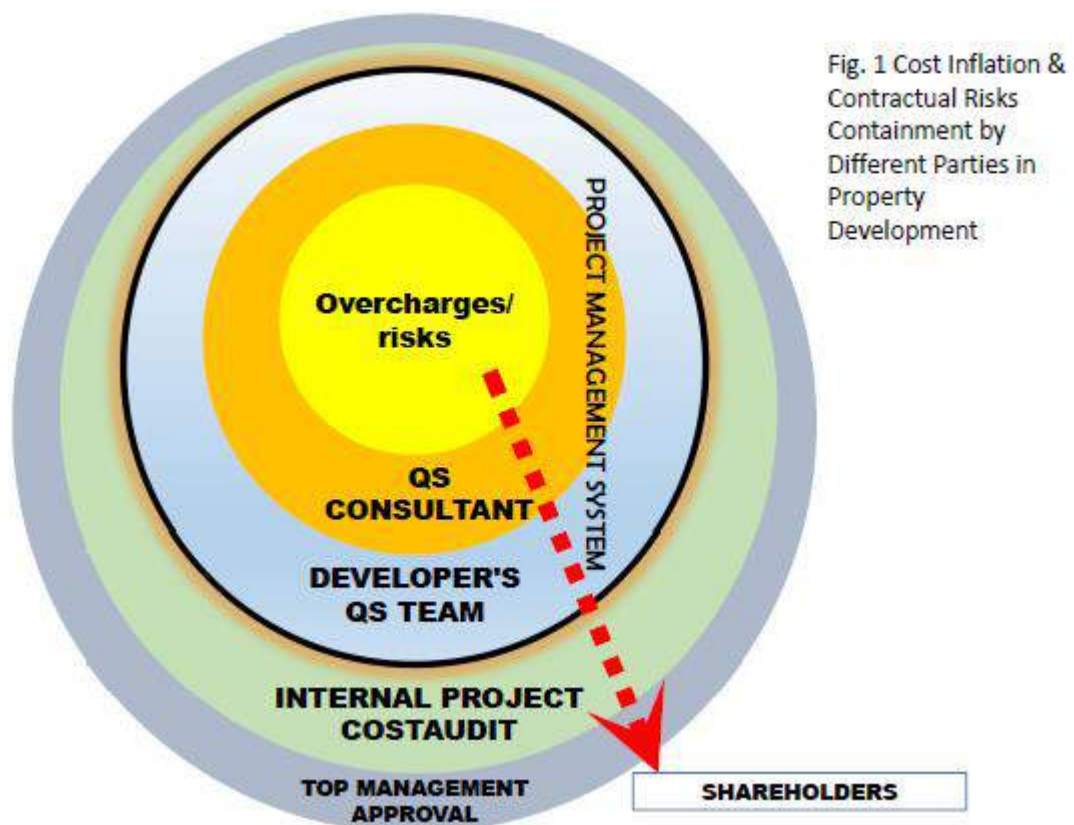
#### *Corporate Governance Requirements*

In the US, the Public Company Accounting Reform and Investor Protection Act of 2002 stipulated that all regulated companies have to establish an audit committee to document internal controls and evaluate their effectiveness. With growing corporate awareness of accountability and expenditure controls, “right to audit” clause is commonly found in construction contracts (Nalewaik, 2006 and 2007).

In Hong Kong, the listing rules require listed companies to have an internal audit function and disclose whether they have it in the annual report. The Audit Committee under the Board also has to ensure the internal audit function is adequately resourced, including qualified staff to analyze and appraise the effectiveness of the internal control and risk management (HKEx, 2016). Most property developers in Hong Kong are listed companies and they usually set up internal project cost/ construction audit departments with a team of quantity surveyors to complement the internal audit department/ team (usually with accounting background) to monitor construction cost/ internal cost control system.

### *Independent Appraisal*

With so much at stake on billions dollars construction projects, management would need independent project appraisals/ controls to ensure the owner's interest are protected (Applegate and Matthews, 2002).



It is common that property developers would appoint QS consultants at the beginning of the projects to prepare cost estimates, tender documents, contract documents and control construction costs until settlement of all final accounts. In turn, QS team in the property developers would monitor QS consultant's performance, review their deliverable and assessments.

QS consultants sometimes have to follow instructions from the project team and may not be able to control/ assess the costs objectively all the time. For example, a consultant maybe asked by developer's QS to assess a variation on the high side of a reasonable range for easier agreement with contractor and to facilitate progress.

Similarly, QS teams in some developers are under management and instruction of project directors/ project managers. In view of project manager's higher priority of project progress, Qs have no choice but to relax on cost control.

If internal project cost audit team is allowed and authorized to monitor project issues and cost outside the existing project management system, "extra line of defense" can be secured against overcharges and risks. Independent views and comments can still be given to management for consideration. Normally audit team would not directly involve in the day-to-day project operation or in direct contacts with or manage the consultants and contractors. This is to avoid interfering smooth implementation of the project or cause confusion to consultants and contractors due to contradicting instructions from audit team and project team. Also audit team is not having the same reporting line as project managers and QS team to maintain its independence.

Some external auditors would also audit project cost, but outsourced auditors have less stature within the company to do their job effectively and probably miss connecting the dots between the many issues and risks that can pop up at a company. Internal auditors who actually work inside the company day-to-day are more aware of the inner-workings and can see the interrelationships between processes and departments, therefore strengthening an organization's risk-management strategy (Johnson, 2006).

## **INTERNAL PROJECT COST AUDIT IN HONG KONG**

There could be different types of construction audit, either limited scope (e.g. only audit some change orders or payments applications) or full scope (From bidding to project close out). However, it is better to get auditor's involvement before contract signing (Hauber et al., 2013). Earlier involvement of auditors can assure the auditors are familiar with the projects.

A survey conducted by Cashell et. al. (1999) indicated that most companies would employ multi-scope audits as follows:

<b>% of respondents</b>	<b>Scope of Audit</b>
97%	Verifying that that payments to the contractor agree with contract terms
79%	Audit of whether the organisation division is authorized to sign contract and capable to monitor
69%	Audit of contractor's records to verify propriety of costs charged on the contract

**Table 1:** a summary of project cost audit/ technical audit functions in property developers (ASD, 2006; HKSAR Government, 2002A and 2002B)

	Developer A	Developer B	Developer C	Developer D	Developer E	Works Departments under Development Bureau incl. ASD	Housing Department of HKSAR Government
a) Full/ Partial Audit	Full	Partial	Full	Full	Full	Partial	Partial
b) Name of Dept. Handling internal project cost audit	√ Cost Control Section	X (Audit by other team not involved in the project)	√ Project Cost Audit Department	√ Audit Department	√ Audit Department	√ Contract Advisory Unit	√ Technical Audit Unit
c) Post of Audit Head (Back-ground)	Cost Controller (QS)	N/A	Project Cost Audit Manager (QS)	Associate Director - Quantity Surveying (Internal Audit) (QS)	General Manager (Audit) (Account-ant)	Contract Advisers (QS)	Senior QS (Technical Audit) (QS)
d) Audit Unit/ Department Reporting to	CEO	CEO	CFO	Project Director	Executive Director	Head or Deputy Head of Department, or equivalent	Assistant Director (Independent Checking Unit)/ Audit Sub-Committee of Housing Authority
e) Composition of Audit Team/ Dept	QS and cost control officer (non-QS background)	N/A	QS	QS	QS	QS, Principal Survey Officers and Survey Officers	QS and Architect
<b>AUDIT SCOPE</b>							
Budget	√		√ Only audit budget change				
Tenderer List	√		√	√	√	√	√
Tenderer Documents	√		√	√	√	√	√

<b>Tenderer Recommendation</b>	√		√	√	√	√	√
<b>Payments</b>	√		√	√	√	√	√
<b>Variations</b>	√		√	√ >\$500K	√	√	√
<b>Final Account</b>	√	√	√	√	√	√	√

*Remark: Information of Developers A to E was gathered based on the writer's experience and informal interview with friends working in these companies.*

Most private developers have internal audit/ internal control departments with internal auditors with accounting background. On the other hand, there is usually set up of separate project cost audit department/ team other than internal audit department (although different names are used in different developers (see b) above in Table 1).

For Developer B, although there is no internal project cost audit department, Qs not involved in the project under audit would form a task force to audit the final accounts before management approval as a compensatory measure to minimize risk before release of final payment.

For Developer A, the external auditor found many issues, such as no consistent policies and procedures established and documented for business units to follow purchase and payments, so many payments were issued without proper contract, contracts awarded without tenders or cost assessments. The external auditor therefore suggested enhancement of the corporate governance and internal controls of the company including setting up an cost control department to minimize the risks.

In the government, there are also technical audit teams to audit project cost and other technical issues of construction projects in different departments. History of technical audit in government can be traced back to 1974 (ASD, 2006).

#### *QS in Audit Teams/ Departments*

As shown in c) and e) of Table 1, most of the internal project cost audit heads and team members in property developers and government are Qs. Qs are experts in construction costs, construction contract and also tendering arrangement. Even in some developers' internal cost audit team is set up under the internal audit department led by accountants, members of internal cost audit team are with QS background.

Sichombo et al. (2009) pointed out that audit can be commenced at any stage of a project life cycle. Due to complex nature of construction, it is difficult for anyone who does not understand construction processes and procedures to uncover illegal activities.

#### *Reporting Line*

For the reporting line, as shown in d) of Table 1, internal project cost audit teams/ departments in most developers report to the CEO/ CFO/ top management or heads of the government departments.

Internal audit often reports to both the audit committee and management. Reporting lines that promote objectivity and effectiveness are critical to a high-performing internal audit function. In the survey by the Institute of Internal Auditors in 2016, it is found that internal audit administratively reports most often to the CEO (35%) or CFO (35%) (IIA, 2016; PWC, 2016). These reporting lines can avoid the internal project cost audit teams auditing their own boss and empower them with enough management support. Only project cost audit team in 1 of the private developers shown in Table 1 reports to the Project Director, which is not a very desirable arrangement.

### *Audit Scope*

Audit scope in Hong Kong private property developers varies from company to company, but most of them adopt full scope audits, except for budget. Construction budget is usually prepared by QS team at the land acquisition stage and submitted to top management for direct approval without audit team's checking to ensure high confidentiality.

Most people when they hear the word "audit", they would think auditors would take a detective approach to identify problems. However, there is a recent trend for internal audit's role changed from "a police" - posterior compliance audit to a consultant - prior effectiveness audit (Park, et al., 2015).

In fact, internal project cost audit departments in most Hong Kong private developers is involved in the approval flow, i.e. to approve/ concur project team's recommendation to management from project outset to final account settlement of the projects. This preventive approach is better in controlling risk than a posterior and forensic check of only some samples at the close of the projects, although more resources would be required.

Early involvement of the audit team/ department yields more saving than a close-out audit. This can also shorten the close-out period after project completion (Brown Smith Wallace LLP, 2009). Also, audit team could be more familiar with the project details. They could feedback their identified issues earlier to the project team and avoid unnecessary cost/ inflated cost. In addition, they can remind the project team to process the variations until leaving them unsettled at the final account.

To take a consultant role, the audit team would give independent advice to the management. At the same time, they would submit regular reports to the Audit Committee of the Board/ management for non-compliance issues.

For works-related departments in the Hong Kong SAR government, a traditional posterior audit approach is adopted.

For Housing Department (responsible for subsidized public housing) projects, there are two different kinds of audits. One is carried out by the Audit Commission - value for money audit. Another audit is carried out by their Technical Audit Unit (HK Housing Authority, 2012). Their function includes performing system audits and reviews on operations and practices relating to Housing Authority's (HA) construction, maintenance and improvement works; carrying out ad hoc studies and investigations. They would consider the magnitude and frequency of risk and select system, projects and issues to audit. They will go to site for visit, check files and also interview with

project staff. However, their technical audit team would **not involve in the routine approval process**. Also they would audit issues other than cost. After audit, they will collect their findings and submit their reports with recommendations to the Audit Subcommittee of Strategic Planning Committee of the Housing Authority in half years.

For other works department in the Government like Architectural Services Department (responsible for building works of government buildings), they would carry out similar technical audits according to the checklist in the Technical Audit Manual. Their Contract Adviser would submit quarterly report to the head or deputy head of the department with copies to the Development Bureau (ASD, 2006).

## **COMMON FINDINGS/ CASES IN INTERNAL PROJECT COST AUDITS AT DIFFERENT STAGES**

There are some typical risks and audit findings in recommendations from project teams at different stages and they are discussed below.

### *Tenderer List*

Pre-qualification of sufficient number of contractors is very important before invitation of tender to ensure sufficient competition. Regular review of tenderers in the “pool” or list of pre-qualified tenderers to check if there is any change in financial and technical status is also very important.

There are many mergers and acquisitions of construction companies and consultants in recent years. Since 2015, there are more than 46 construction or renovation companies become listed in IPO in Hong Kong and change of shareholding has become more frequent (AA Stock, 2017). Some companies in the tenderer list may be companies under the same Group without notice. At the same time, some companies after listed, may use their capital for other investments or may change their focus on new business other than construction.

In some cases, some price-competitive but less technically competent tenderers are removed by Project Team from the tenderer list. However, it is not in a developer’s best interest without price-competitive tenderers in the tenderer list to induce those more technical competent ones to submit lower tenders. For example, company A is not technically competent but always submit lower tender prices, but company B and C who are more technically competent would offer more discounts if they know company A is also in the tenderer list.

A matrix showing tenderers’ recent ranking and decline to tender status can be used to analyse tenderers’ performance and detect trace of bid-rigging before approval of a tenderer list. For example in Table 2 below, Company D always decline to tender but they were invited to tender in every Project. For Project D, second lowest tenderer was awarded the contract as project team considered Company C is not technical competent for the project. Also, it can be seen in Table 2 that most contracts are awarded to Company B and C. Contracts always awarded to the same contractor for 5 or 6 years could be risky as they know very well how to get around the internal controls (Brown Smith Wallace LLP, 2009).

**Table 2: Sample Matrix to Analyse Tenderers' Ranking and Decline to Tender Status**

	Project F	Project E	Project D	Project C	Project B	Project A
Company A	3	3	3	5	3	5
Company B	2	<b>1</b>	<b>2</b>	2	<b>1</b>	2
Company C	<b>1</b>	2	<b>1</b>	<b>1</b>	2	<b>1</b>
Company D	X	X	X	X	X	X
Company E	4	4	5	3	4	4
Company F	5	5	4	4	5	3

Remark: X denotes decline to tender; 1, 2, 3...denotes tender ranking; bolded one denotes awarded

tenderer,  denotes lowest tenderer but not awarded

#### *Tenderer Documents*

- 1) Requirements stated in the Conditions of Tender/ Preliminaries Specification would affect the tender prices, including the amount of liquidated damages (LD), type of surety bond required, payment terms etc. These requirements have to suit the nature of the works and in line with the market, otherwise the contractors would add significant amount of risk premium in their tender.
- 2) In Hong Kong, for mass transit railway corporation (MTRC) residential projects, MTRC would impose LD against the Developer if there is a delay in completing the development after the Key Date(s). If developers could not recover similar LD from contractors due to contractors' delay, then the developers would suffer loss.
- 3) Different procurement arrangements can end up with different construction costs. For example, cost of landscape and signage works under a nominated sub-contract (NSC) arrangement is normally lower than a provisional sum arrangement with named domestic sub-contractors. Main Contractor would normally charge 10-15% on top of named sub-contractor's cost, but only 3-5% under a NSC arrangement for profits and overhead.
- 4) For very specialized trades, such as facade lighting system, some consultants may rely on the expertise of some contractors by directly including their specification in the tender documents. If the developer cannot notice, the consultant may just recommend these contractors in their tender assessment, as other companies could not fulfill the same specification or provide the specified brands/ system. Similarly, for AV system, water feature and sauna systems, in which contractors are also competent in designing, developers should check the tender specification to ensure real tender competition.



### *Tender/ Quotation Recommendations*

When tenders/ quotations are not submitted via tender box and not submitted at the same time, prices in these tenders/ quotations may not be at competitive market prices. If a single tender/ quotation is obtained and then accepted, the tender/ quotation price may be higher than market price if no further assessment and negotiations are conducted. Special justification should be given by the project team on this situation. Insufficient number of returned tenders to meet a minimum of 3 (which most developer's tender procedure would require) is usually due to:

- very specialized nature of the tender scope of works and very few contractors are available in the market to carry out the works;
- the project team has already chosen a preferred contractor and intentionally include some tenderers who would probably decline or submit high "cover" tenders in the tenderer list;
- the market is good and tenderers have lots of other works/ opportunities to choose from;
- many tenderers are included in the tenderer list and tenderers lose their interest due to low chance to win the bid.

For artwork or sculpture which can only be supplied from a single source, it is quite difficult to judge whether its price is reasonable.

Even proper tender process is gone through and lowest tender is awarded, the lowest tender may still include some qualifications or some very high unit rates for future variations. Tender evaluation has to be conducted carefully to minimize risks after tender award.

Sometimes, for convenience, project team may only source an agent to procure sculpture or furniture items from overseas, without checking whether there is a sole agent in Hong Kong. The writer encountered a case that the sole agent is cheaper than another procurement agent for about 20%.

### *Variations*

For some projects, cost of variations may be as high as 50-100% of original contract sum.

The cost of variations could be reduced significantly after internal audit team goes through the necessity and reasons of variations and correctness of application of unit rates and quantities in their valuation before final account settlement.

Sometimes architect's instructions may not be 'real' variations - architects may mistakenly issue AIs which duplicate with the original contract requirements because they have not checked the contract drawings and specifications before issuing instructions. These instructions in fact do not have cost implications.

Star rates are often claimed by contractors when contract rates are applicable for the variations. Even worse sometimes contractors would just submit their sub-contractor's quotations with 15% marked-up, which is not in line with competitive market price level.

For valuation of variations based on daywork, professional judgment or actual site record should be used to screen out excessive mandays.

In some cases, additional cost is valued for the variations but the relevant omission cost is not credited. Audit team has to check this as well.

Project team would be more careful in agreeing in advance with contractors for valuation of variations if they know the audit team would check their variation cost assessment. In order to give incentives for contractors to complete the variation work on site quicker, project team may sacrifice necessity of negotiation for the best deal.

### *Payments*

Payments for materials on site or off-site authorized in contract sometimes may not be checked diligently by consultant QS or in-house QS team. They may include these by relying on delivery notes from the contractors without checking in detail.

The writer has encountered a case that the consultant QS has included rebar materials for variations in the materials on site (MOS) due to late assessment of variations. Amount of materials on site has to be checked against the progress, e.g. for rebar and stone panels, quantities of MOS should be reduced progressively towards structure topping-out.

It is normal that there is a time lag between Architect's Instructions issue, work carried out on site, contractor's variation claim submissions and the variation assessment by consultants. Some variations are usually paid on account due to completion of variation works on site without retrospective cover by Architect's Instructions or Contractor's Confirmation Letter and completion of cost assessment. To avoid over-payment to the contractors, amount of payment on account has to be monitored and variation schedule has to be checked carefully.

It is quite useful to draw up actual cashflow graphs of projects and then benchmark in each interim payment, i.e. to compare cumulative workdone % against time elapsed % of this project with other projects. Of course, project scale and work sequence has to be taken account in this check.

### *Extension of Time (EOT)*

For some projects with substantial delay, project managers and consultants may just grant EOT to cover up contractor's and their responsibility of poor management of their projects. Inclement weather is easier to be substantiated based on records of the Observatory and contractors are not entitled to claim loss and expense.

For loss and expense claim, audit team has to check carefully whether they are related to neutral events or not, e.g. delay of approval of government authorities. The writer has encountered millions dollars recommendation by project team (assessed by consultant QS) for loss and expense to a contractor which is related to delay due to neutral events.

## **SUCCESS FACTOR OF INTERNAL PROJECT COST AUDIT**

### **1. Top Management's Support**

Management support of internal project cost audit is an important signal to the role and value of audit throughout the company. It also gives the audit department empowerment to perform its duties and responsibilities. Research also shows the greater the management support to internal audit (in terms of involvement in audit planning, responses to internal audit reports, and provision of sufficient resources), the more effective the internal audit (Alzeban & Gwilliam, 2012).

Management support can also ensure recommendations from audit department can be implemented. This can also avoid head of project team to interfere with the auditing process.

### **2. Cooperation of Auditees**

It is critical to build right relationship with the auditees, so that audit team can add value. This can be done by avoiding being arrogant, asking non-confrontational and open-ended questions, and showing you are not there to judge their work (Breon, M. and Stellwag, R.).

Auditors are bound to face hostility from auditees as nobody likes to be investigated or audited. After audit, there would be many recommendations for change. In the minds of most auditees, change is not popular due to ego, change of relationships, change of operations etc. Internal auditor has to maintain an open mind or publish audit finding earlier for auditee to object (Dittenhofer et al., 2011).

### **3. Timely Comments**

Time is a most usually used excuse/ reason for objecting the internal cost audit process by the project team. It is important for audit team to monitor the time to provide necessary comments to the project team and set up of relevant KPI can assist to improve the performance.

## **CONCLUSION**

Most property developers in Hong Kong would seek for BEAM Plus certification, a local green building certification, as they can get bonus Gross Floor Area and to improve their CSR image. For office buildings, it is more common to seek both LEED and BEAM Plus certifications. Extra cost would be incurred in meeting the extra requirements to achieve these certifications and become "high performance" buildings.

Most private property developers in Hong Kong have established internal cost audit team to audit project team's recommendations and to complement the work of internal audit departments to minimize unnecessary costs and risks in construction projects. Their audit is usually in a preventive approach during the project period rather than in a posterior forensic audit approach. In order to ensure the audit is successful, audit team has to gain management's support, cooperate with the auditees and provide timely comments.

## References:

- AA Stock (2017) IPO Plus - Listed IPOs  
(<http://www.aastocks.com/en/ipo/ListedIPO.aspx?iid=6021&orderby=DA&value=DESC&index=1>)
- Alzeban, A. & Gwilliam, D. (2012). Perceptions of managers and internal auditors as to factors affecting the effectiveness of internal audit in the public sector context. In *10th European Academic Conference on Internal Audit and Corporate Governance. University of Verona: Italy*. (<http://www.iacmaster.it/iacgconference2012/wp-content/2012/04/aziz-gwilliam.pdf>).
- Applegate, D. and Matthews, C. (2002) Building Controls into Capital Construction, *The Internal Auditor*, Jun 2002, 59(3), pp. 49-55
- Architectural Services Department (ASD) (2006) The Review and Outlook of the Quantity Surveying Branch and the Quantity Surveying Profession  
([http://www.archsd.gov.hk/media/11633/qsb\\_professional.pdf](http://www.archsd.gov.hk/media/11633/qsb_professional.pdf))
- Breon, M. and Stellwag, R. Soft Skills to Improve Internal Audit Results “Auditee Relations”, The Institute of Internal Auditors.  
(<http://www.theiia.org/chapters/pubdocs/88/InternalAuditSoftSkills.pdf>)
- Brown Smith Wallace LLP (2009) Building Wisely: How Construction Audits Can Help Control Project Costs (<http://bswllc.com/building-wisely-how-construction-audits-can-help-control-project-costs/>)
- Cashell, J. D., Aldhizer, G. R., & Eichmann, R. (1999) Construction Contract Auditing. *Internal Auditor*, Feb 1999, 56(1), pp. 30.
- CBC News (2012) Ex-Montreal construction boss describes bid rigging system, 26 Nov 2012 (<http://www.cbc.ca/news/canada/montreal/ex-montreal-construction-boss-describes-bid-rigging-system-1.1197436>)
- CBC News (2017) Audit uncovers possible 'bid-rigging' in city paving contracts, 22 Mar 2017 (<http://www.cbc.ca/news/canada/toronto/audit-bid-rigging-1.4035728>)
- Chen, C. (2016) Soaring land prices continue to shrink developers' margins, South China Morning Post 29 June 2016  
(<http://www.scmp.com/business/companies/article/1982999/soaring-land-prices-continue-shrink-developers-margins>).
- Chow, Jimmy (2017) Surging prices: rising construction costs of homes fuel concerns in Hong Kong, analysts warn, South China Morning Post 06 Jan 2017  
(<http://www.scmp.com/special-reports/property/topics/weekend-property/article/2059929/surging-prices-rising-construction>).
- Clark, R., Coviello, D., Gauthier, J. and Shneyeov, A. (2017) Bid rigging and entry deterrence: Evidence from an anti-collusion investigation in Quebec, unpublished paper. ([http://tintin.hec.ca/pages/decio.coviello/research\\_files/CCGSdec2015.pdf](http://tintin.hec.ca/pages/decio.coviello/research_files/CCGSdec2015.pdf))

Competition Commission of Singapore (CCS Singapore) (2017) CCS Issues Proposed Infringement Decision for Bid-Rigging in Electrical Services and Asset Tagging Tenders, Media Releases on 21 March 2017 (<https://www.ccs.gov.sg/media-and-publications/media-releases/pid-bidrigging-in-electrical-services-and-asset-tagging-tenders>)

Competition Policy International (2013) South Africa: 21 firms admit to construction bid-rigging, 22 more penalized (<https://www.competitionpolicyinternational.com/south-africa-21-firms-admit-to-construction-bid-rigging-22-more-penalized/>)

Contreras, G. (2013) FBI probes \$1 million bid-rigging at UTSA, San Antonio Express News, 21 Feb 2013 ([http://www.mysanantonio.com/news/local\\_news/article/FBI-probes-1-million-bid-rigging-at-UTSA-4297845.php](http://www.mysanantonio.com/news/local_news/article/FBI-probes-1-million-bid-rigging-at-UTSA-4297845.php))

Dittenhofer, M.A., Luke Evans, R., Ramamoorti, S. and Ziegenfuss, D.E. (2011) Behavioral Dimensions of Internal Auditing: An Exploratory Survey of Internal Auditors, The Institute of Internal Auditors Research Foundation (IIARF) ([http://www.interniaudit.cz/download/Publikace-IIA/5015.2.dl-Behaviorial%20Dimensions-Survey%20report-FINAL\\_copy%20for%20web%20zip.pdf](http://www.interniaudit.cz/download/Publikace-IIA/5015.2.dl-Behaviorial%20Dimensions-Survey%20report-FINAL_copy%20for%20web%20zip.pdf))

Hauber, R.J., Gardner M.R. and Reisch, A.R. (2013) Construction Auditing Risks and Cost Segregation Strategies for 2013 and Beyond, The Institute of Internal Auditors (IIA) Atlanta Chapter training on June 14, 2013. (<https://chapters.theiia.org/atlanta/ChapterDocuments/Construction%20Auditing.pptx>)

Hearst Newspapers LLC (2013) Controller's audit recovers \$800,000 in overcharges at Hobby Airport construction, *chron.com*, Published 10:49 am, Monday, June 17, 2013 (<http://www.chron.com/neighborhood/deerpark/news/article/Controller-s-audit-recovers-800-000-in-9358269.php>)

Hill, T. (2016) Hong Kong - Combating Bid-Rigging Cartels: HK Competition Commission's Report On Study In The Residential Building Renovation And Maintenance Market, *Conventus Law* (<http://www.conventuslaw.com/report/hong-kong-combating-bid-rigging-cartels-hk>)

HKSAR Government (2002A) Environment, Transport and Works Bureau. Technical Circular (Works) No.53/2002. Manual for Technical Audits on Works Contracts. (<http://www.devb.gov.hk/filemanager/technicalcirculars/en/upload/115/1/c-2002-53-0-1.pdf>)

HKSAR Government (2002B) Works Bureau. Technical Circular (Works) No. 15/2002. Contract Advisers and Technical Audits on Works Contracts (<http://www.devb.gov.hk/filemanager/technicalcirculars/en/upload/134/1/wb1502.pdf>)

Hong Kong Housing Authority (2012) Business Portfolio - Independent Checking Unit (<https://www.housingauthority.gov.hk/en/about-us/housing-department/organisation-chart/business-portfolio/independent-checking-unit.html>)

Hong Kong Exchanges and Clearing Limited (HKEx) (2016) Amendments to the Main Board Listing Rules relating to the Risk Management and Internal Control section of the Corporate Governance Code and Corporate Governance Report (effective for accounting periods beginning on or after 1 January 2016) - Appendix 14 Corporate Governance Code and Corporate Governance Report ([https://www.hkex.com.hk/eng/rulesreg/listrules/mbrulesup/Documents/mb\\_rmic\\_1601.pdf](https://www.hkex.com.hk/eng/rulesreg/listrules/mbrulesup/Documents/mb_rmic_1601.pdf))

Independent Commission Against Corruption (ICAC) (2017) Ex-staff of ArchSD contractor in court for \$3.9m works orders fraud, Press Releases 2017-6-6 ([http://www.icac.org.hk/en/press/index\\_id\\_419.html](http://www.icac.org.hk/en/press/index_id_419.html))

Johnson, S (2006) Should Internal Audit Report to the CFO? CFO.com, October 13, 2006 (<http://ww2.cfo.com/accounting-tax/2006/10/should-internal-auditor-report-to-the-cfo/>)

Larson, R. & Larson, E. (2009) Top five causes of scope creep ... and what to do about them. Paper presented at PMI® Global Congress 2009—North America, Orlando, FL. Newtown Square, PA: Project Management Institute. (<https://www.pmi.org/learning/library/top-five-causes-scope-creep-6675>)

Lau, C. (2016) Bid-rigging scheme: Hong Kong judge jails renovation subcontractor, calls for more industry regulation, South China Morning Post 30 Sept 2016 (<http://www.scmp.com/news/hong-kong/law-crime/article/2023681/bid-rigging-scheme-hong-kong-judge-jails-renovation>)

Nalewaik, A. A. (2006) Construction audit - an essential project controls function. *AACE International Transactions*, CS41-CS45. Retrieved from <https://search.proquest.com/docview/208171708?accountid=14548>

Nalewaik, A. A. (2007) Construction Audit - An Essential Project Controls Function. *Cost Engineering Vol. 49/No. 10 OCTOBER 2007* (<http://www.icoste.org/ICMJ%20Papers/Nalewaik2.pdf>)

Ng, K.C. (2017) Quantity surveyor denies defrauding Hong Kong government with fake quotes, South China Morning Post 6 June 2017 (<http://www.scmp.com/news/hong-kong/law-crime/article/2097167/quantity-surveyor-denies-defrauding-hong-kong-government>)

Ollmann, T. and Schuchardt, E. (2012) Construction Fraud Prevention and Detection, AHIA 31<sup>st</sup> Annual Conference (<https://www.resourcenter.net/images/AHIA/Files/2012/AnnMtg/Handouts/A2.pdf>)

Office of Fair Trading, UK (2014) Bid rigging in the construction industry in England ([http://webarchive.nationalarchives.gov.uk/20140402142426/http://www.oft.gov.uk/OFTwork/competition-act-and-cartels/ca98/decisions/bid\\_rigging\\_construction](http://webarchive.nationalarchives.gov.uk/20140402142426/http://www.oft.gov.uk/OFTwork/competition-act-and-cartels/ca98/decisions/bid_rigging_construction)).

Park, J. S., Oh, Y. C., Yoo, J. G., Shin, Y., & Kim, J. B. (2015). A Study on Audit Information Systems Improved Model based on Public Internal Audit Paradigm

Shift. *International Journal of Security and Its Applications*, 9(8), 231-242.  
([http://www.sersc.org/journals/IJSIA/vol9\\_no8\\_2015/20.pdf](http://www.sersc.org/journals/IJSIA/vol9_no8_2015/20.pdf))

PWC (2016) Getting the most out of internal audit, Audit Committee Excellence Series, Aug 2016, PWC Governance Insights Center  
(<http://www.pwc.com/us/en/governance-insights-center/publications/assets/pwc-aces-getting-the-most-out-of-internal-audit.pdf>)

Robertson, B. and Yau, E. (2014) Beating the bid-riggers: Angry homeowners use competition law to battle price-fixing, South China Morning Post 15 Sept 2014  
(<http://www.scmp.com/property/hong-kong-china/article/1592797/beating-bid-riggers>)

Sichombo, B., Muya, M., Shakantu, W., & Kaliba, C. (2009). The need for technical auditing in the Zambian construction industry. *International Journal of Project Management*, 27(8), 821-832.

The Institute of Internal Auditors (IIA) (2016) 2016 North American Pulse of Internal Audit, Audit Executive Centre (<http://contentz.mkt5790.com/lp/2842/201608/2016-2113%20CAE-2016%20Pulse%20of%20Internal%20Audit%20Report-FNL-Lo-CX3.pdf>)

The Straits Times (2017) Competition Commission uncovers five firms involved in tender bid-rigging for Singapore F1 Grand Prix contract, published on MAR 21, 2017, 1:23 PM SGT (<http://www.straitstimes.com/singapore/competition-commission-uncovers-five-firms-involved-in-tender-bid-rigging-for-singapore-f1>)

United States (US) Department of Justice (2016) Former UTSA Projects Manager Sentenced to Federal Prison for his Role in Bribery Scheme  
(<https://www.justice.gov/usao-wdtx/pr/former-utsa-projects-manager-sentenced-federal-prison-his-role-bribery-scheme>)

Wall Street Journal (2012) Firm to Pay \$56.5 Million In Fraud Case Construction Scam Hit Major Projects  
([http://www.wyattmarley.com/uploads/Lend\\_Lease\\_to\\_pay\\_\\_56.pdf](http://www.wyattmarley.com/uploads/Lend_Lease_to_pay__56.pdf))

Wilkinson, J. (2015) Hong Kong Competition Ordinance, 27 Nov 2015  
([https://www.cic.hk/cic\\_data/pdf/about\\_cic/news\\_and\\_update/past\\_event/eng/20151127%20-%20Mr\\_%20James%20WILKINSON.pdf](https://www.cic.hk/cic_data/pdf/about_cic/news_and_update/past_event/eng/20151127%20-%20Mr_%20James%20WILKINSON.pdf))

Yates, D. J. (2003) Can claims and disputes (in construction contracts) be prevented or reduced?, *Building Journal Hong Kong China June 2003*  
([http://www.building.com.hk/forum/10\\_03canclaims.pdf](http://www.building.com.hk/forum/10_03canclaims.pdf))

### **Bibliography:**

Forbes, J. D. (1965) Control of Construction Costs. *NAA Bulletin*, National Association of Accountants, June 1965, pp.44.

Nalewaik, A. (2013) Factors affecting capital program performance audit findings. *International Journal of Managing Projects in Business*, 6(3), 615-623.  
Retrieved from <https://search.proquest.com/docview/1417095530?accountid=14548>

Ollmann, T. and Smith, V. (2014) Construction Fraud: Prevention and Detection and Lessons Learned, AHIA 33<sup>rd</sup> Annual Conference  
(<http://s3.amazonaws.com/media.guidebook.com/service/rkFuDgEZv9Q3WVtwsnMXjm54fyoNqGB6/A8.pdf>)

PR Web (2013) The Construction Audit & Cost Control Institute will be Discussing How to Detect and Prevent Bid Rigging at Seminars to be Held in Las Vegas on March 26-27, 2013  
(<https://caacci.memberize.net/clubportal/images/clubimages/1622/The%20Construction%20Audit%20&%20Cost%20Control%20Institute%20will%20be%20Discussing%20How%20to%20Detect%20and%20Prevent%20Bid%20Rigging.pdf>)



# **SOUTH AFRICAN PERSPECTIVES ON THE BUSINESS CASE FOR GREEN BUILDING**

D J Hoffman<sup>1</sup>, C Coetzee<sup>2</sup> and E Farmer<sup>3</sup>

*<sup>1</sup>Lecturer, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [danie.hoffman@up.ac.za](mailto:danie.hoffman@up.ac.za)*

*<sup>2</sup>Post graduate, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [u13023889@tuks.co.za](mailto:u13023889@tuks.co.za)*

*<sup>3</sup>Post graduate, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [u13046307@tuks.co.za](mailto:u13046307@tuks.co.za)*

## **ABSTRACT**

This paper evaluated growth constraints for green building in South Africa, specifically perspectives from architects, quantity surveyors and developers on the green building business case that may hamper green building growth in South Africa.

82% Of respondents support green building and 87% agree on the growth of green building, however quantity surveyors were much less supportive. Of all respondents 36% had no previous green building experience. Future education and communication with green building stakeholders must accommodate these differences.

The majority (86%) of respondents agree that green building carries a substantial cost premium while 84% agree that tenants will not pay green rental premiums. These two opinions create a significant challenge to the growth of green building in South Africa. Proven industry data on the business case of green building must be required to address this challenge. The GBCSA can do even more to communicate green building benefits. Government should also consider green building incentives.

The study only evaluated respondents from Gauteng. Property owners, engineers or ESD consultants were not included. Findings should be confirmed by a larger study. Professional industry councils, the GBCSA, voluntary associations and training institutions should take note of the findings.

**Keywords:** Challenges, Economic benefits, Green building, Growth, South Africa.

## **CLIMATE CHANGE AND CONSTRUCTION**

Sound scientific evidence exists of the unprecedented climate change levels experienced over the last two centuries (Lüthi et al, 2008; Yeang & Woo, 2010; American Institute of Physics, 2016, NASA, 2016a). Most climatic scientists believe that human activities such as burning of irreplaceable fossil fuels for industrial production, deforestation, transportation systems and modern construction methodologies resulted in this climate change (UNEP, 2014; NASA, 2016b, livescience, 2016).

Buildings consume 32% of global resources, 40% of global energy and generate 30% of global greenhouse gas emissions (WGBC, 2016b; GBCSA, 2015a; Magoulès and Zhao, 2010; Toller et al, 2011; Mahajan, 2012). Similar statistics have been confirmed for the South African construction industry (Cidb, 2009; Milne, 2012). The substantial challenge to address global environmental sustainability required international coordination and led to the founding of the World Green Building Council (WGBC) in 1999 (WGBC, 2016a). The WGBC support the growth of the global green

building movement, creates an information sharing network and a platform for rating and certification systems and benchmarking standards (WGBC, 2016a).



**Figure 1:** Variation of Global CO<sub>2</sub> levels (NASA, 2016a)

The growing market demand for environmentally friendly buildings required scientific measuring tools to structure and regulate the green building certification process (Haapio & Viitaniemi, 2008). Some of the most well-known green building rating systems are the Building Research Establishment Environmental Assessment Method (BREEAM) tool launched in the United Kingdom in 1990, Leadership in Energy and Environmental Design (LEED) launched in the United States in 2000 and the Green Star system launched in Australia in 2003 (GBCA, 2015a). The South African Green Star SA rating tool was launched by the GBCSA in 2009 and is based on the Australian Green Star tool, but customised for the South African landscape and context (GBCSA, 2016b).

## GREEN BUILDING

Fischer (2010) describes green building as integrated building practices that significantly reduce the environmental footprint of a building over the entire life cycle of a building. Kats and Capital (2003) adds that sustainable buildings are sensitive to the environment, energy and resource consumption, impact on people and the world as a whole. Green buildings offer many benefits such as lower operating costs, higher returns on assets, increased property values, improved marketability, lower tenant turn-over and increased employee productivity (GBCSA, 2016b). The Green Building Council of South Africa (GBCSA) was established in 2007 and is still the only established member of the WGBC on the African continent with Ghana, Kenya, Mauritius, Namibia and Nigeria as prospective members and Tanzania as an emerging member (WGBC, 2016a).

## GREEN BUILDING TRENDS

The initial uptake of green building in South Africa has been slow. South Africa's traditionally low energy cost due to abundant coal supplies had over many years hidden the effect of energy inefficient buildings which lessened the motivation to switch to green building. Between 2008 and 2012 Eskom, the main electricity utility company in South Africa has however raised tariffs by average 25,1% per year and since 2012 with above inflation % each year (UrbanEarth, 2017). Since 2012 the certification of green buildings in South Africa has accelerated. The GBCSA recently celebrated a milestone of 200 Green Star SA certified buildings in the first 10 years of its existence (GBCSA, 2016c). In 2015 an important international report on progress in prominent green building countries indicated that South Africa leads the indicator with a market share of 41% of projects classified as green

construction (Dodge Data & Analytics, 2016). Several potential challenges for green building growth do however remain.

## **GREEN BUILDING CHALLENGES**

### **Lack of information and skills**

Lack of green building skills can be a hindrance to green building growth (Hankinson & Breytenbach, 2012; Häkkinen & Belloni, 2011). South Africa's young green building industry suffers from insufficient data on reduced lifecycle costs, increased green rentals and insufficient industry knowledge and skills (Milne, 2012). Developers with insufficient data will be hesitant to accept green design alternatives and resort to proven and conventional habits as a result (Montoya, 2011). Consultants need to develop new skills to be able to advise clients on all aspects of green building (Seah, 2009).

### **Green cost premium**

Many international studies on green building challenges confirmed that even after a decade of green building development the perception of substantial green building cost premiums has persisted (Morris, 2007; Delhagen et al, 2009; Kubba, 2010; Garg, 2011; Bond and Perrett, 2012 and Fitch and Laquidara-Carr, 2013). South Africa has a very young green building market and therefore the green premium may be expected to be larger than that of countries with more mature green building industries (GBCSA, 2012). A comprehensive 2016 study on green building costs and trends found an average green building cost premium for Green Star SA certified office buildings of only 5,0% (ASAQS, 2017). A small green building cost premium however requires for the sustainable designs to be incorporated from the conceptual stage of the project (Milne, 2007; Groves, 2016; Hoffman & Cowie, 2014

## **RESEARCH METHODOLOGY**

The purpose of this research is to gain insight in the growth constraints of the young green building industry in South Africa. The local industry is experiencing growth challenges that affected more mature markets 5-10 years ago. Much insight can be gained from the perspectives of industry stakeholders towards enabling the drafting of solutions to address growth challenges.

The study data was obtained through a Likert scale based questionnaire sent to 176 firms of architects, developers and quantity surveyors practising in the Gauteng province of South Africa. Gauteng is the powerhouse of the South African economy with an annual GDP of US\$211 billion generating 33,9% of the national GDP and almost 5% of that of the African continent (Gauteng Online, 2017). A response rate of 38,6% was attained and 18 architects, 21 developers and 29 quantity surveyors returned completed questionnaires.

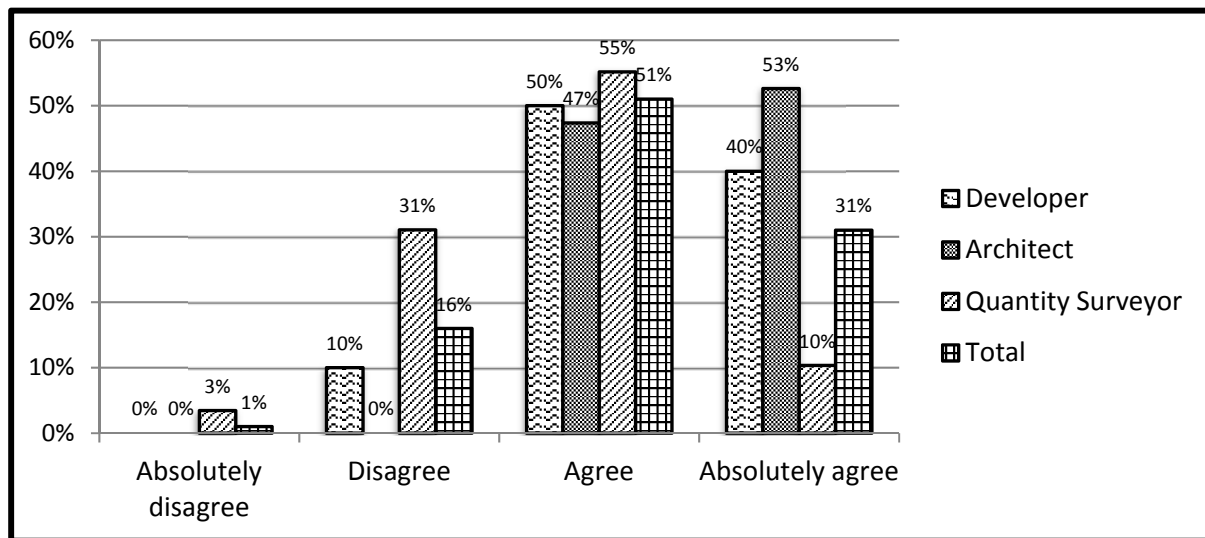
To assist basic statistical analysis, the data was awarded numerical values: Strongly Disagree = 1, Disagree = 2, Agree = 3 and Strongly Agree = 4. Average scores were calculated for the different statements and questions of the questionnaire. An average score of 1 – 1,6 was considered a significantly negative opinion. An average score of 1,61 – 2,20 was considered as negative, an average score of 2,21 – 2,80 was considered as neutral, an average score of 2,81 – 3,40 was considered positive and an average score of more than 3,41 was considered as significantly positive.

## **THE DATA**

The profile of the respondents confirmed the experience of firms with more than 82% of firms being older than 10 years and 63% being older than 16 years. The average firm age varied between 15 and

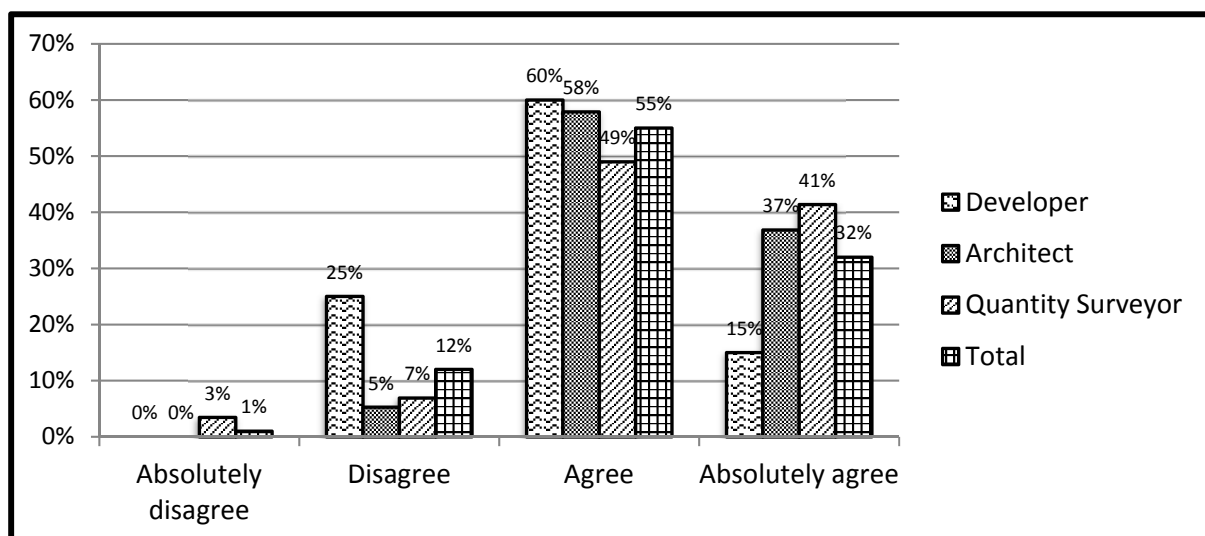
17 years for the three groups of respondents. The firms can therefore be considered to be knowledgeable of their industry.

*The potential and need for green building* - Figure 2 indicates that a total of 82% of respondents were positive about the potential and need for green building (average score of 3.1 out of 4). Both the architects (100% and average score of 3,5 out of 4) and developers (90% and average score of 3,4 out of 4) were extremely positive about green building. Quantity surveyors were however significantly less positive (65% and average score of 2,6 out of 4). More than a third of quantity surveying firms does not yet believe in the need for green developments. This finding is reason for concern as the role of quantity surveyors in future is changing to a much more supporting and advising function to their clients (Seah, 2009; Engineering News, 2015).



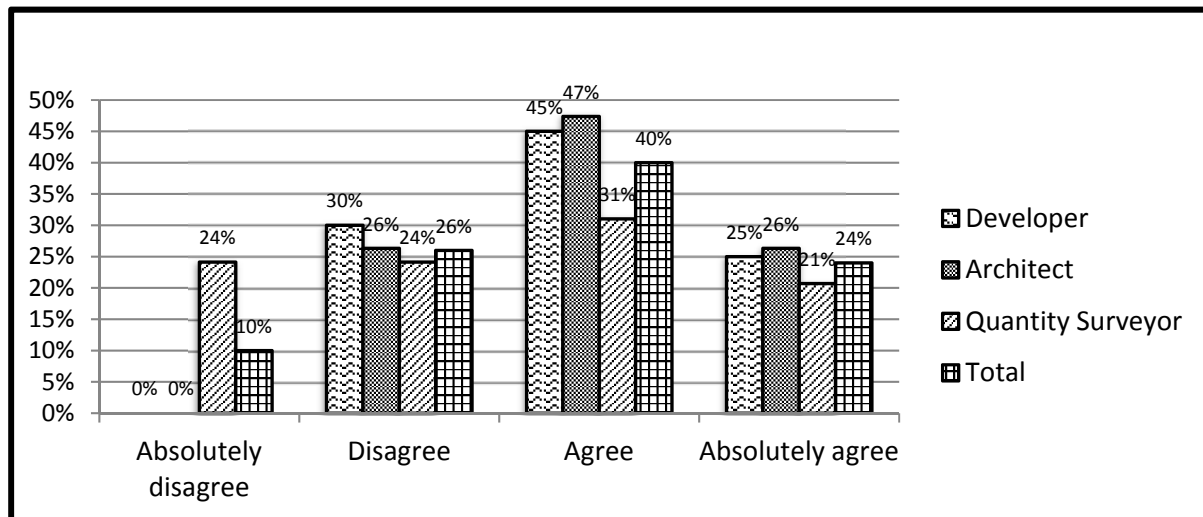
**Figure 2:** My Firms believes in the potential and need for green building

*Growing trend in green buildings* - The study indicates that 87% of respondents agreed that the development of green building in South Africa is growing (average score of 3,2 out of 4). Architects were most aware of this trend (95% and an average score of 3,3 out of 4) with quantity surveyors also providing strong confirmation (90% and an average score of 3,3 out of 4). However only 75% of developers were in agreement (average score of 2,9 out of 4). This finding when read in combination with Figure 2 above reveals that a substantial number of developers disagree that green building is growing, even though they themselves may be positive about green building.



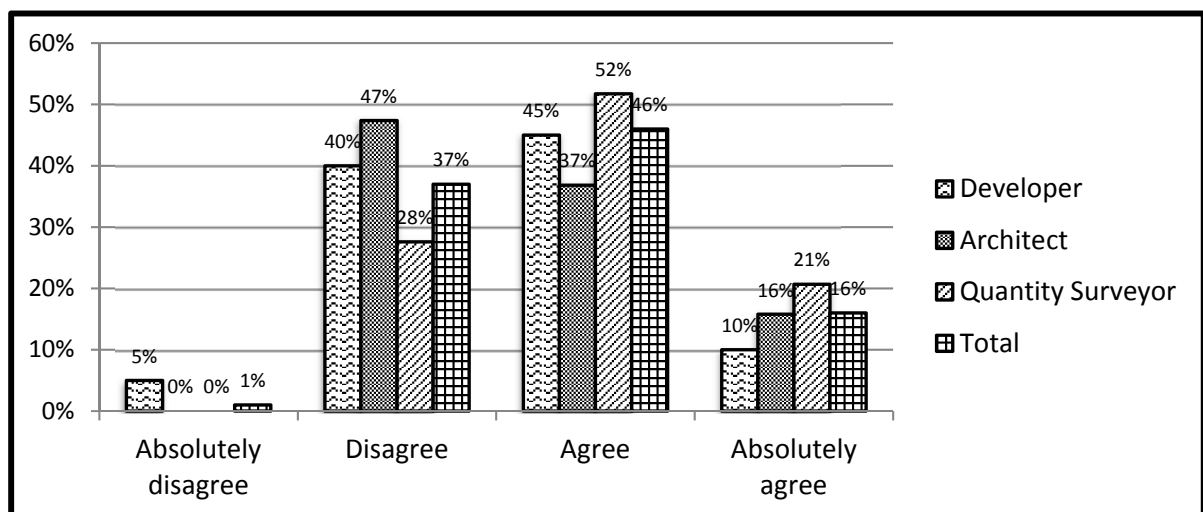
**Figure 3:** There is a growing trend to develop green buildings

*Green building experience* - Figure 4 indicates that 64% of firms had green building experience (average score of 2,8 out of 4). This finding confirms the Dodge Data & Analytics report (2016) of the penetration of green building into the South African real estate industry. Architects (71% and average score of 3,0 out of 4) and developers (70% and average score of 3,0 out of 4) lead this indicator, but again the quantity surveyors were significantly less involved with green building (52% and average score of 2,5 out of 4). The total of 48% of quantity surveyors without green building experience are echoed by the 35% of quantity surveying firms not convinced of the merits of green building. This finding confirms that much education and communication with some industry stakeholders are still needed to ensure optimal growth of green building.



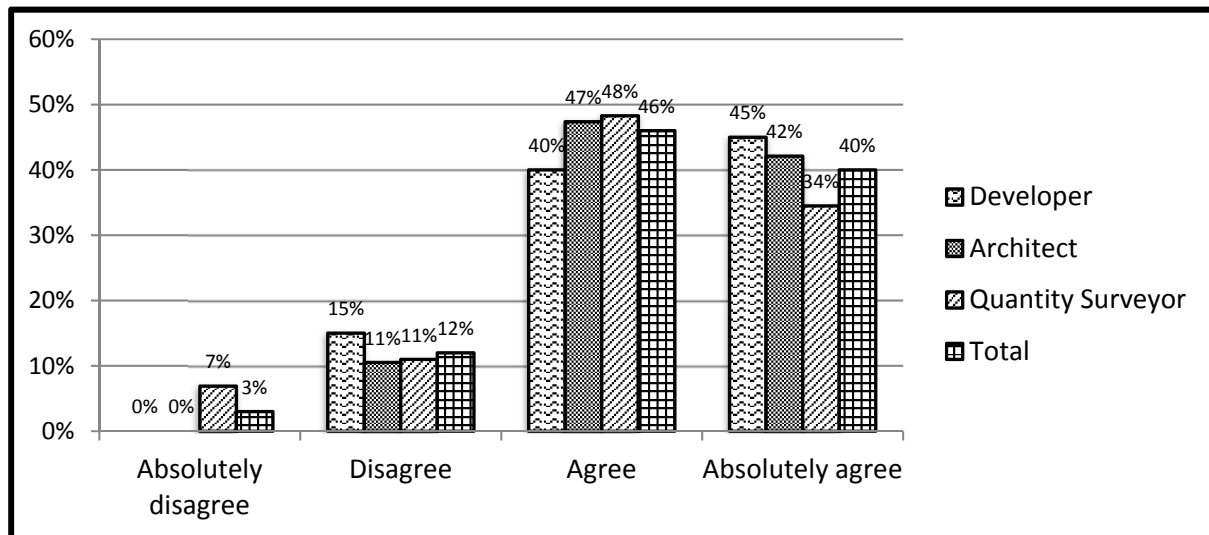
**Figure 4:** My firm has been involved with developing green buildings

*Green building is driven by the owner* - Figure 5 revealed some contradicting facts. A total of 45% of developers, who are very closely associated with the building owner and who often may be the owners themselves, disagrees that owners are the driving force of green building. Quantity surveyors who should be very much involved with advising on the investment decisions of building owners, however agree that owners are driving green building (73% agree with average score of 3,0 out of 4). Architects seem to be more comfortable with owners not taking the lead, as 47% of architects also disagrees that initiating green building rests with the building owner (53% agree with average score of 2,7 out of 4). The combined finding indicates 62% agreement with average score of 2,8 out of 4. Respondents also commented that owners often decide to pursue a green building due to the public image or marketing value alone.



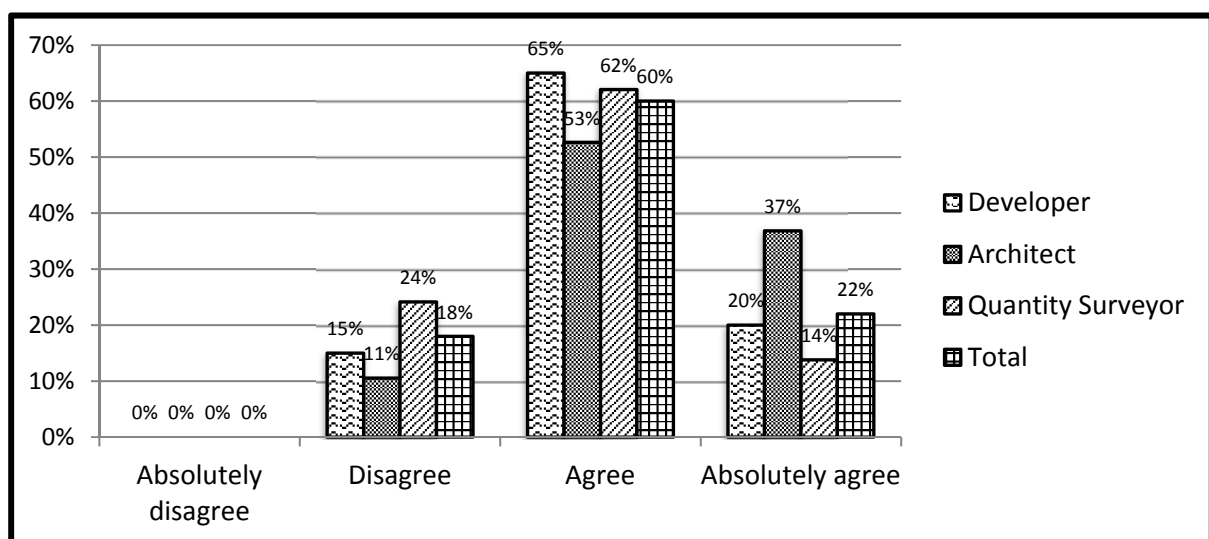
**Figure 5:** Developing green buildings is driven by the owner

*Green building cost premium* - The large majority of 86% of respondents agreed that a green building will incur a substantial cost premium compared to conventional construction (average score 3,3 out of 4). Since 64% of respondents' firms also have green building experience, this expressed opinion must in part be based on personal experience. However general perceptions in the industry regarding green building cost as referred to in the literature may also explain part of this opinion. The levels of agreement between the different disciplines varied between 89% agreement by Architects to 81% agreement by quantity surveyors. To address the issue of green cost some respondents commented that government must be more involved through legislation and tax break incentives to assist the green building industry.



**Figure 6:** Green buildings carry a substantial cost premium over conventional buildings

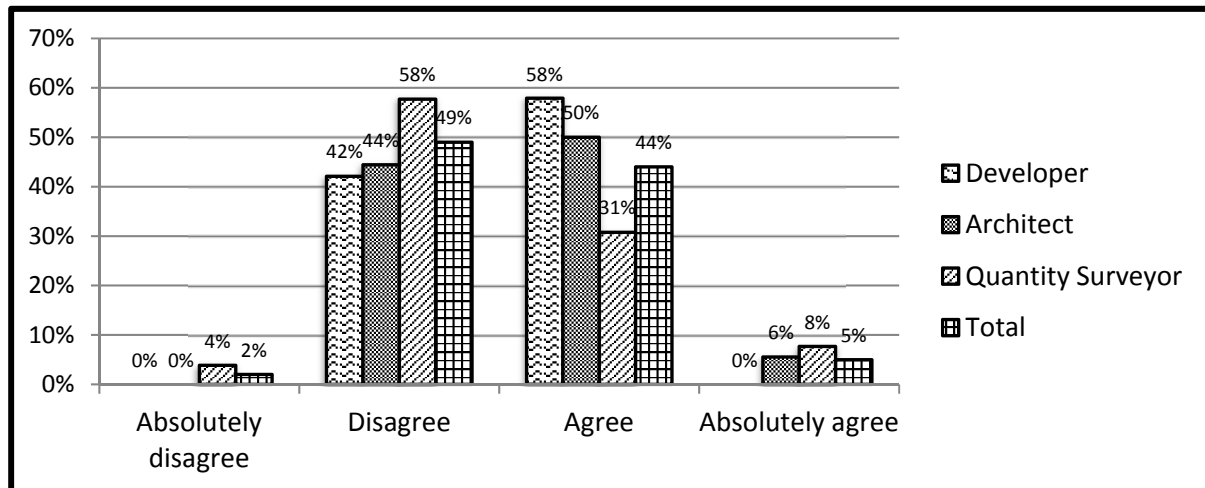
As much as 82% of respondents agreed that investors regard the time it takes to recover the initial capital outlay or payback period for green building investment as too long (average score 3,0 out of 4). A too long payback period may lead to hesitance of investors to invest in green buildings and this finding can therefore be considered as a green building growth constraint. Some respondents commented that only large corporate investors can afford the lower initial returns resulting from higher upfront costs.



**Figure 7:** Investors believe the payback period for green building is too long

*Owners often pursue green building certification after design completion* - As much as 49% of the respondents agreed that owners often decide to pursue green building certification when the design

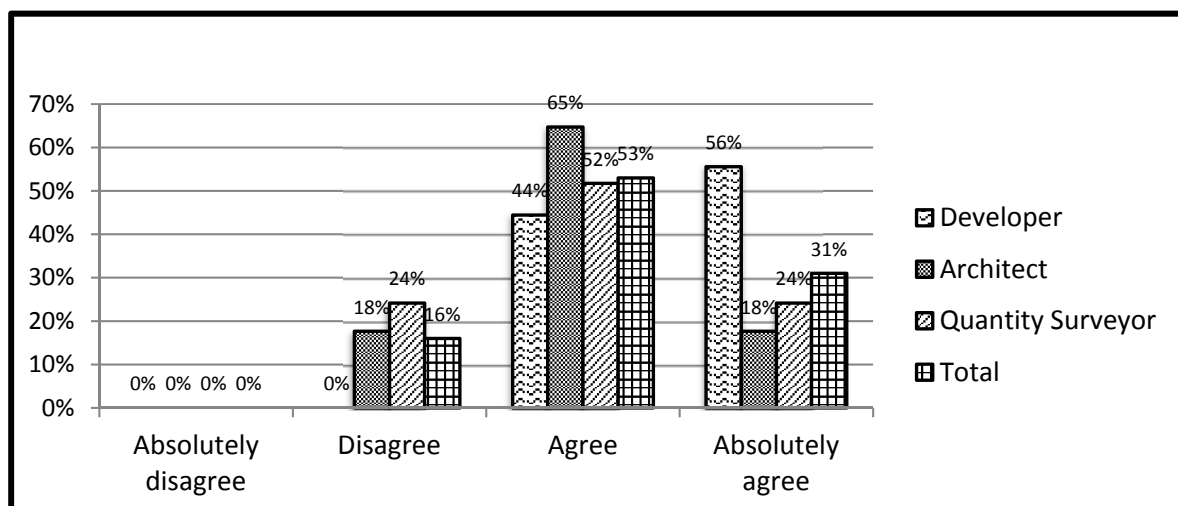
has already been completed (or even later than that). If one further argues that most of the above 49% of agreements were probably from the 65% of respondents with green building experience, it may indicate that as much as 75% (49% as percentage of 65%) of decisions to pursue green building status may be made too late. The literature previously referred to (Milne, 2007; Groves, 2016; Kubba, 2010) all agreed that the green building cost premium will increase substantially if a developer decide to pursue a green building status at such a late stage. The above finding may be one of the causes underpinning the belief that green buildings are very expensive. As such the finding defines another green building hampering factor.



**Figure 8:** Owners often pursue green building certification after design completion

*Green building rental premiums* - All of the developers agreed (average score 3,6 out of 4) that tenants are unwilling to pay rental premiums for green building space. The core function of developers is to satisfy tenant demand. Developers are therefore very much aware of tenant behaviour and what tenants will/will not pay for. This very strong opinion expressed by developers is supported by 83% of architects and 76% of quantity surveyors. The combined response was 84% agreement (average score 3,3 out of 4).

The above finding points towards a weak tenant demand for green building space and will acts as a growth constraint of green building in the South African industry. The finding also confirms that the South African green building industry is experiencing similar constraints to the 2012 New Zealand study of Bond and Perrett that indicating low client demand is a primary barrier to green building growth. Respondents further pointed out that many new projects are developed to be sold and if no green rental premium is achieved, the extra capital required by green building is simply not available.



**Figure 9:** Tenants are unwilling to pay rental premiums for a green building

## CONCLUSION AND RECOMMENDATIONS

This study made some important findings based on the perspectives of developers, architects and quantity surveyors as three primary stakeholders of the South African green building industry. Positive findings were that 82% of respondents supported green building and 87% agreed that green building in South Africa is growing. Much good work has been done to firmly establish green building in South Africa.

The study however also found that only 65% of quantity surveyors were positive about green building (average score of 2,6 out of 4) compared to 100% of architects and 90% of developers. More than a third of quantity surveying firms does not yet believe in the need for green developments. A total of 48% of quantity surveying firms did not have green building experience compared to 30% for developers and 36% for architects.

This finding confirms that room for education and communication with industry stakeholders still exists to ensure optimal growth of green building. The study also indicates that different groups of stakeholders hold differing opinions on green building. Future efforts to educate and communicate stakeholders on green building matters should take that into account. Quantity surveyors may need special focus in this regard.

The large majority of 86% of respondents agreed that a green building will incur a substantial cost premium. (average score 3,3 out of 4). Based on the recent findings of an actual green building cost premium of only 5,0%, a dedicated and specific educational drive to change this (often incorrect) perception amongst stakeholders should be an industry priority. To address the issue of green cost some respondents commented that government must be more involved through legislation and tax break incentives to assist the green building industry.

Another major challenge for green building growth confirmed by the study is the unwillingness of tenants to pay green rental premiums. All the developers agreed on this and the average study response was 84% agreement. This finding, read in combination with the stakeholders' perception of green cost premium provides the most significant challenge to the green building industry identified by the study. The fact that 82% of respondents also agreed that investors regard the payback period of green building investment as too long, confirms the consistency of the responses.

A last important finding that also indicates another hurdle for green building growth is that 49% of respondents agreed that building owners often decide to pursue green building status at a too late stage of the project's design development. This scenario will almost inevitably add to the green building cost and often prevents designers to include optimal green building solutions.

## REFERENCES

American Institute of Physics. 2016. *The Discovery of Global Warming*. [Online] Available from: <https://www.aip.org/history/climate/timeline.htm> [Accessed 23 March 2016]

Association of South African Quantity Surveyors, 2016. *Green building in South Africa: Guide to Cost and Trends*. [Online] Available from [http://www.asaqs.co.za/page/free\\_publications](http://www.asaqs.co.za/page/free_publications). [Accessed 1 May 2017]

Bond, S. & Perrett, G., 2012. The key drivers and barriers to the sustainable development of commercial property in New Zealand. *The Journal of Sustainable Real Estate* 4(1), pp. 48-77.



CIDB. 2009. *Greenhouse gas emission reduction: Potentials from Buildings*. Construction Industry Development Board (CIDB) Discussion document. [Online] Available from: [www.cidb.org.za](http://www.cidb.org.za) [Accessed 22 March 2016]

Delhagen, E., McKeenan, S., Nicholas, S., Hamilton, B. & Neme, C., 2009, '*Scaling Up Building Energy Retrofitting in U.S. Cities: Resource Guide for Local Leaders*', Version 1.0, Living Cities, Institute for Sustainable Communities, Harvard University.

Dodge Data & Analytics. 2016. *Smart Market Report: World Green Building Trends*. [Online] Available from: <http://www.analyticsstore.construction.com/2016WorldGreen-9408.html> [Accessed 28 June 2016]

Engineering News, 2012. '*Eskom seeks yearly increases of 16% to 2018*', [Online] Available from: <http://www.engineeringnews.co.za/article/eskom-seeks-yearly-increases-of-16-to-2018-2012-10-22> [Accessed on 02 October 2016]

Fischer, E.A. 2010. *Issues in Green Building and the Federal Response: An introduction*. Congressional research service, Washington.

Fitch, E. & Laquidara-Carr, D (eds.), 2013, *World green building trends: Business benefits driving new and retrofit market opportunities in over 60 countries*, McGraw-Hill Construction.

Garg, A.K., 2011, 'Financial aspects of green building', *Journal of Engineering, Science and Management Education* 4, p. 12-15.

Gauteng Online [Online] Available at: <http://www.gautengonline.gov.za/Business/Pages/TheEconomyofGauteng.aspx> [accessed 25 April 2017]

GBCSA. 2016a. Evidence of Global Warming. Available from: <https://www.gbcsa.org.za/about/about-green-building/> [Accessed 28 April 2016]

GBCSA. 2016b. *Green Star SA Overview*. Available from: <https://www.gbcsa.org.za/green-star-sa-rating-system/> [Accessed 28 April 2016]

GBCSA. 2016c. *GBCSA news*. Available from: [https://www.gbcsa.org.za/news\\_post/green-building-council-celebrates-milestone-200-green-star-sa-certifications/](https://www.gbcsa.org.za/news_post/green-building-council-celebrates-milestone-200-green-star-sa-certifications/) [Accessed 02 October 2016]

Groves, A. 2016. *The green building industry growth in South Africa and the possible growth constraints from stakeholders' point of view*. [Interview] 18 May 2016.

Haapio, A., & Viitaniemi, P. 2008. A critical review of building environmental assessment tools. *Environmental Impact Assessment Review*, Volume 28, Number 7, pages 469-482

Häkkinen, T. & Belloni, K. 2011. *Barriers and Drivers for Sustainable Building*, *building Research & Information*, 39(3), P 239-255

Hankinson, M & Breytenbach, A. 2012. *Barriers that Impact on the Implementation of Sustainable Design*. In: Proceedings of Cumulus Conference, hosted by Aalto University School of Art and Design, Helsinki, Finland, 24-26 May 2012, 1-11

Hoffman, D.J., & Cowie, D., 2014, '*Factors limiting Green Developments in South Africa – Developers comments*'. ASOCSA 2014. The 8<sup>th</sup> Built Environment Conference – Reflection on Direction in Construction. Durban, South Africa, 27-29 July 2014.

Kats G & Capital E. 2003. *The Cost and Financial Benefits of Green Buildings: a Report to California's Sustainable Building Task Force*, California

Kubba, S, 2010. *LEED practices, certification and accreditation handbook*. Elsevier publishers, Burlington, USA

Live Science, 2016. *What Is The Greenhouse Effect?* [ONLINE] Available from: <http://www.livescience.com/37743-greenhouse-effect.html> [Accessed 10 November 2016]

Lüthi, D, Le Floch, M., Bereiter, B., Blunier, T., Barnola, J., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K. & Stocker, T.F. High-resolution carbon dioxide concentration record 650,000–800,000 years before present. *Nature* 453, 379-382 (15 May 2008).

Mahajan, B. 2012. *Sustainable Development and Climate Change*. CEPT University, Navrangpura, Ahmedabad: Gujrat

Margolès, F. & Zhao, H. European Parliament and Council Directive 2010/31/EU of the European Parliament, and of the Council of 19 May 2010 on the energy performance of buildings. *Official Journal of the European Union* 2010, L153, pp.13–35.

Milne, N. 2012. *The Rands and Sense of Green Building: Re-visited. Building the Business case for Green Commercial Buildings in South Africa*. Green Building Council, Cape Town, South Africa. pp.16

Montoya, M. 2011, *Green building fundamentals*, 2<sup>nd</sup> ed., (Prentice Hall New Jersey)

Morris, P. 2007, 'What does Green Really Cost?' The Green Issue Feature, [Online] Available from: <http://www.davislangdon.com/upload/images/publications/USA/Morris%20Article.pdf> [Accessed: 15 March 2016]

NASA. 2016a. *Evidence of Global Warming*. Available from: <http://climate.nasa.gov/evidence/> [Accessed 28 April 2016]

NASA. 2016b. *Causes of Global Warming*. Available from: <http://climate.nasa.gov/causes/> [Accessed 28 April 2016]

Seah, E. 2009. *Sustainable Construction and the Impact on the Quantity Surveyor: 13<sup>th</sup> Pacific Association of Quantity Surveyors Congress*. [Online] Available from: [http://www.academia.edu/1160074/sustainable\\_construction\\_and\\_the\\_impact\\_on\\_the\\_quantity\\_surveyor](http://www.academia.edu/1160074/sustainable_construction_and_the_impact_on_the_quantity_surveyor) [Accessed 8 May 2016]

Toller, S., Wadeskog, A., Finnveden, G., Malmqvist, T. & Carlsson, A. (2011). Energy use and Environmental Impacts of the Swedish Building and Real Estate Management Sectors. *Journal of Industrial Ecology*.15(3). pp.394 – 404

UNEP. 2014. *Annual report*. [Online] Available from: <http://www.unep.org/annualreport/2014/en/climate-change.html> [Accessed 02 April 2016]

UrbanEarth, 2017. [Online] Available from <http://www.urbaneearth.co.za/articles/nersa-allows-yearly-8-electricity-price-increase-2013-2018>. [Accessed on 1 May 2017].

USGBC. 2016. *About USGBC* [Online]. Available from: <http://www.usgbc.org/about> [Accessed 02 October 2016]

WGBCa. 2016. *World Green Building Council Members* [Online]. Available from: <http://www.worldgbc.org/worldgbc/members/> [Accessed 01 October 2016]

WGBCb. 2016b. *WGBC history* [Online]. Available from: <http://www.worldgbc.org/index.php/worldgbc/history/> [Accessed 01 October 2016]

Yeang, K & Woo, L. 2010. *Dictionary of Eco design*. Routledge: New York

# STAKEHOLDER PARTICIPATION TRENDS IN GREEN BUILDINGS DURING 2009-2016

D J Hoffman<sup>1</sup>, J Cloete<sup>2</sup>, L van der Schijff<sup>3</sup> and L Wagner<sup>4</sup>

<sup>1</sup>*Lecturer, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [danie.hoffman@up.ac.za](mailto:danie.hoffman@up.ac.za)*

<sup>2</sup>*Post graduate, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [u13144317@tuks.co.za](mailto:u13144317@tuks.co.za)*

<sup>3</sup>*Post graduate, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [u13030150@tuks.co.za](mailto:u13030150@tuks.co.za)*

<sup>4</sup>*Post graduate, Department of Construction Economics, University of Pretoria  
Lynnwood Road, Pretoria, [u13006194@tuks.co.za](mailto:u13006194@tuks.co.za)*

## ABSTRACT

This paper investigated the stakeholder participation trends in South African green building from 2009 – 2016 to describe the market share trends of major stakeholders. SA green building is less than 10 years old and firms and stakeholders are still in process of establishing themselves.

A total of 106 new Green Star SA certified office buildings from 2009 – 2016 indicated clear market share trends. The combined market share of the three largest role players in every discipline differed significantly: architects (25%), quantity surveyors (28%), structural engineers (40%), sustainability consultants (61%) and contractors (53%). The number of participating firms also differed widely: architects (69), quantity surveyors (33), structural engineers (39), sustainability consultants (23) and contractors (28).

The study only included new office buildings certified using the Office v1 & v1.1 rating tools and excluded renovated or refurbished green buildings.

Practical implications include to expand the study by including data after 2016, to consider the reasons behind the trends and if the trends will keep changing with time. Organisations such as the Green Building Council of South Africa and professional associations that inform and educate industry stakeholders should consider the findings. Strategy managers of firms should pay attention to trends involving their own firms and that of competing firms.

**Keywords:** Green building, Market share, South Africa, Stakeholders, Trends.

## CLIMATE CHANGE AND CONSTRUCTION

Climate change is a reality of the twenty first century. Rising sea levels, increased likelihood of severe weather events occurring and food and water shortage is an increasing global concern (NASA, 2016a; United States Environmental Protection Agency, 2016). The construction industry contributes extensively towards the problem and accounts for more than 40% of energy consumption, 12% of fresh water consumption, 40% of solid waste generation and one third of greenhouse gas emissions worldwide (GBCSA, 2016a; WGBC, 2016a; Kruse, 2004; Toller et al, 2011). The same scenario is experienced in South Africa (Milne, 2012).

Energy is consumed by buildings during the entire building life cycle – production of building materials, transportation and construction, operation and finally the demolition and recycling of materials. The operational phase consumes the largest portion of energy (Kriss, 2014; Pekka, 2009)

The realization that the earth cannot sustain the current rate of resource exploitation led to the consideration of green building principles (The Economist, 2004). Green building involves energy and resource efficient construction and operating methods exercised with environmental responsibility and without compromising the capacity of future generations to provide for their needs (GBCSA, 2016b; Kerswill, 2007). The implementation of green building practices can rejuvenate the construction industry to be part of a more sustainable future (Lafarge, 2015). Studies suggest that energy consumption in buildings can be reduced by an estimated 30 – 80% on condition that future sustainable practises incorporates all aspects of construction (Pekka, 2009; Lafarge, 2015).

## **GREEN BUILDING SYSTEMS**

To address the global challenge of sustainability international action was required. The World Green Building Council (WGBC) was founded in 1999 (WGBC, 2016b) to encourage the international green building movement and to agree on rating certification systems and benchmarking standards (WGBC, 2016a). Several green building rating systems were launched such as the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom (1990), Leadership in Energy and Environmental Design (LEED) in the United States (2000) and Green Star in Australia (2003) (GBCA, 2016). In 2009 the GBCSA launched the Green Star SA rating tool which is a customisation of the Australian Green Star tool to suit the South African context (GBCSA, 2016c). The GBCSA recently certified the 200th Green Star SA certified buildings within 10 years of its existence (GBCSA, 2016d).

## **STAKEHOLDER PARTICIPATION**

According to Fitch and Laquidara-Carr (2013) architects in green building are concerned with resource conservation, engineers focus on energy efficiency while owners are worried about greenhouse gas emissions and investment returns. The South Africa government focus largely on energy efficiency with little to none financial incentives for owners or tenants (Nelson, 2010). McGraw Hill Construction (2014) found that large and small firms reported higher levels of green building involvement than medium sized firms. Ma and Luu (2013) stated that to appoint a Quantity Surveyor at the earliest possible stage of a green building project, will ensure cost efficiency.

## **GREEN BUILDING CHALLENGES**

### **Lack of information and skills**

According to Milne (2012) South Africa will for some time still lack sufficient data on lower lifecycle costs and increased green rentals due to the age of the industry. Lack of data may cause developers to be hesitant to accept green design alternatives (Montoya, 2011). Seah (2009) stressed that consultants will have to add new skills to support clients with green building needs.

### **Green cost premium**

The perception of a green building cost premium still exists in industry (Morris, 2007; Bond and Perrett, 2012 and Fitch and Laquidara-Carr, 2013). South African green building may experience a elevated cost premium due to being a very young market compared to more mature green industries (GBCSA, 2012). Seah (2009) pointed out that social and environmental as well as operational benefits should be considered to offset the initial cost premium of a green building.

A recent study on South African green building costs and trends found an average green building cost premium of 5% for Green Star SA certified office buildings (ASAQS, 2017). To minimise the green building cost premium requires for sustainability to be part of conceptual designs (Milne, 2007; Hoffman & Cowie, 2014)

## RESEARCH METHODOLOGY

The purpose of this study was to gain insight into participation trends of the South African green building industry in. No information is available on the number of firms participating in green building and on the extent of market share attained by firms.

The study data was obtained from case studies of Green Star SA certified projects published on the website of the GBCSA. The published case studies included data of firms participating in certified green building projects. The study was limited to new South African office projects certified until the end of 2016 by means of the Office v1 and Office v1.1 rating tools. A total of 106 projects qualified the above criteria and was included in the study.

## THE DATA

The discussion of the data focused on two opposing aspects of green building participation. In the first instance the study described the measure of dispersion - how widely established the participation in green building were amongst SA built environment practitioners and also how this measure of dispersion has occurred and developed from 2009 to 2016. The study also described the contrasting aspect of the measure of green building market share dominance attained by single firms.

### Dispersion of Green Building participation

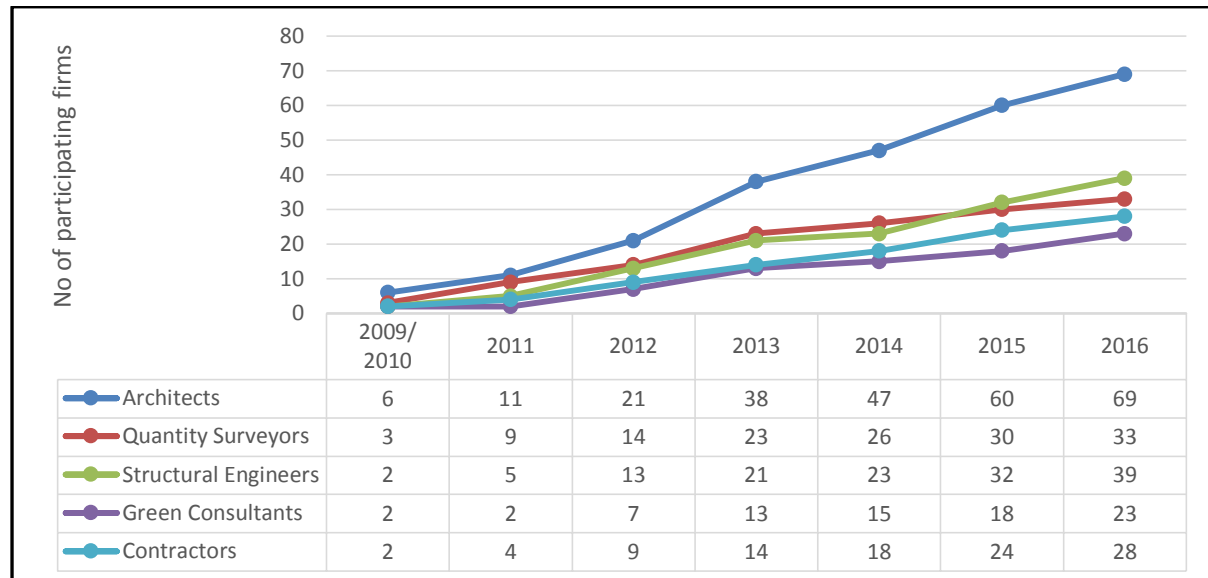
The data revealed a total of 69 Architect firms with green building experience which far exceeds the number of all participating firms from other disciplines. The extent to which participation in green building was evenly spread amongst firms are indicated by the Coefficient of Variation (see Table 1). Architect and Quantity Surveying firms had smaller Coefficients of Variation indicating smaller relative dispersion around the mean and therefore a more even spread of participation/market share. By comparison Structural Engineers, Green Consultants and Contractors had larger Coefficients of Variation indicating less evenly spread green building participation trends. This finding was supported by data in Figures 4, 5 and 6 that highlighted the extent of dominant firms from Structural Engineering, Green Consulting and Contracting disciplines.

**Table 1:** Dispersion of participation in green building

	Architects	Quantity Surveyors	Structural Engineers	Green Consultants	Contractors
<b>Number of participating firms</b>	69	33	39	23	28
<b>Firms with only one Green Building project</b>	51	15	29	14	20
<b>Average market share %</b>	1.58%	3.02%	2.53%	4.35%	3.56%
<b>Market share Standard deviation</b>	1.72	2.75	3.81	6.93	5.78
<b>Market share Coefficient of Variation</b>	1.09	0.91	1.51	1.59	1.62

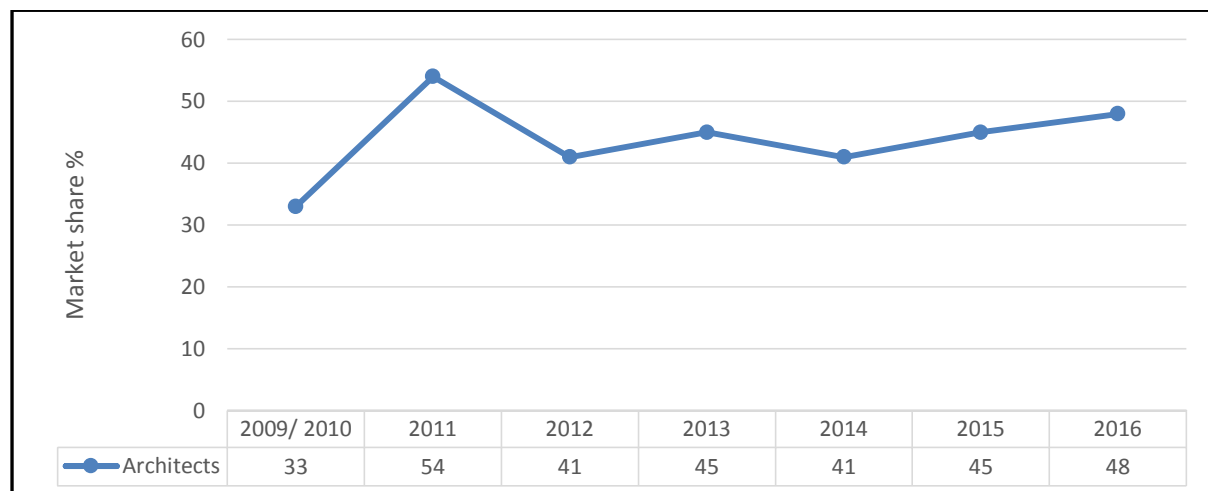
The number of firms of every discipline involved in green building in SA is growing every year (see Figure 1). The growth in the number of firms participating in green building since the first Green Star SA building was certified in 2009, varies between 43% and 51% per annum for the various disciplines.

The study found that 74% of the Architect firms have only been involved with a single green building project. Between 40% and 50% of all green buildings certified since 2012 were designed by Architects with no other green building experience (see Figure 2).



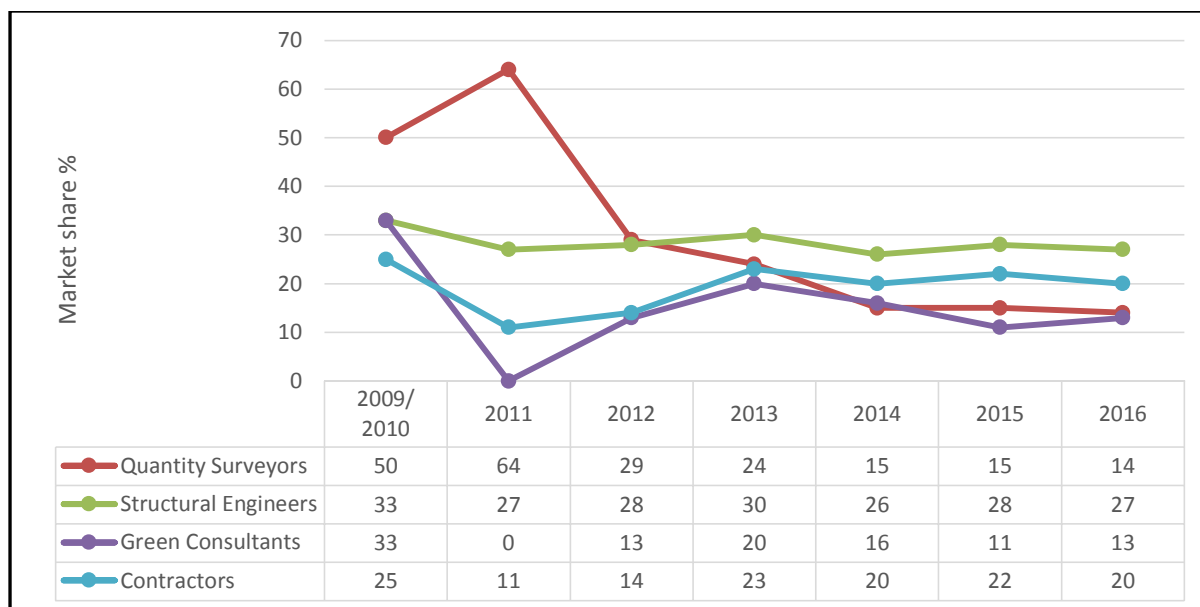
**Figure 1:** Number of participating firms

The percentage of firms from other disciplines and with only single project green building experience were Quantity Surveyors (45%), Structural Engineers (74%), Green Consultants (61%) and Contractors (71%). These percentages were decreasing for the period 2009 – 2016 and by the end of 2016 was as low as 13% for Green Consultants and 14% for Quantity Surveyors, while Contractors (20%) and Structural Engineers (27%) returned slightly higher values (see Figure 3).



**Figure 2:** Market share of Architect firms with experience of only one green building

Construction industry firms from these four disciplines compete against efficient market leaders with strong to dominant market shares. The efficiency of these dominant firms seems to restrict the unhindered growth in participation of firms with little or no green building experience.



**Figure 3:** Market share of firms other than architects with experience of only one green building

### Extent of dominant participants

The market share of every participating firm for each respective discipline were calculated annually from 2009 – 2016. The study indicated that firms from every discipline participating in green building other than Architect firms were operating in industries characterised by strong and established market leaders. The extent of market dominance of firms from the various disciplines, were evaluated and described using a number of different approaches.

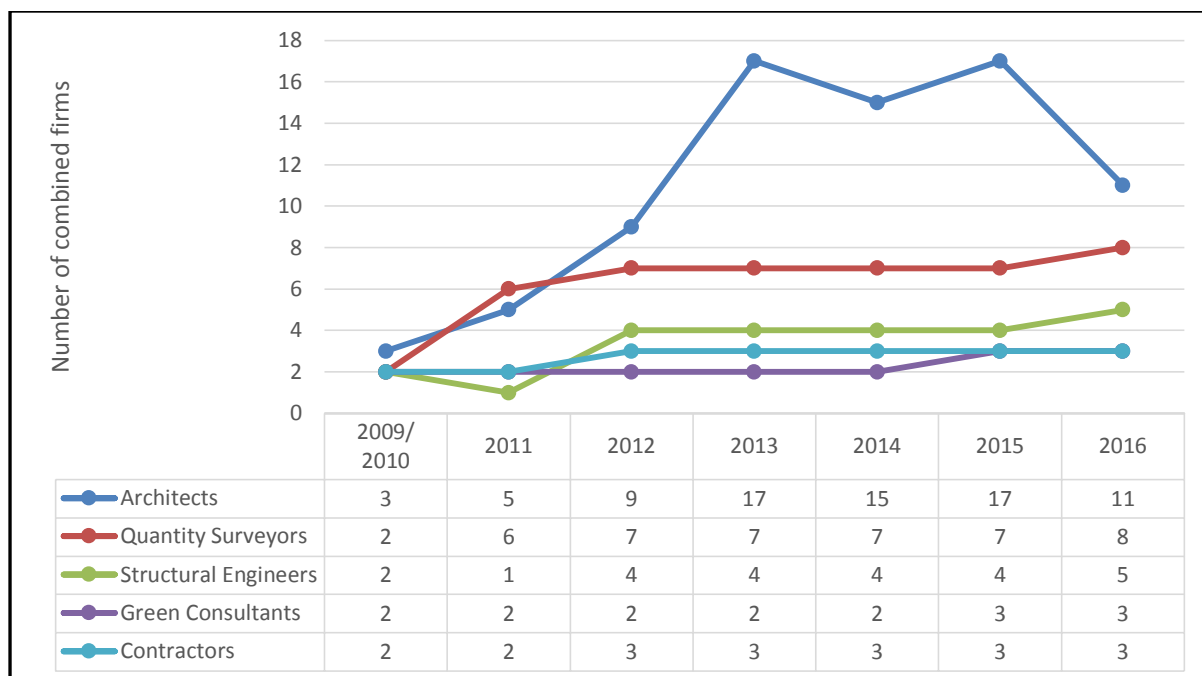
The first approach was to calculate the minimum number of firms for each discipline who together had a combined market share of more than 50%. A small number of firms indicated by the above analysis confirmed the existence of strong and dominant market players. A large number of indicated firms confirmed the absence of dominant market players for the specific industry.

During the first two to three years of green building in South Africa the small number of projects implicated a correspondingly small number of firms. A small number of participating firms will result in relatively large market share each, thereby creating the resemblance of dominance. By 2012 – 2013 however a more accurate trend started to establish itself (see Figure 4).

The comparatively larger number of Architect firms who participated in green building typically resulted in smaller market share for each individual Architect firm. During the period 2013 – 2015 as many as 15 to 17 of the Architect firms with the largest market share had to be combined to exceed a combined market share exceeding 50%. This finding confirmed the absence of large or dominant participants amongst Architect firms for the period 2013-2015.

The data from 2016 however indicated that the Architect firms most established in Green building were starting to more successfully increase their market share. The number of Architect firms with a combined market share of 50% therefore reduced to 11 for 2016 (see Figure 4).





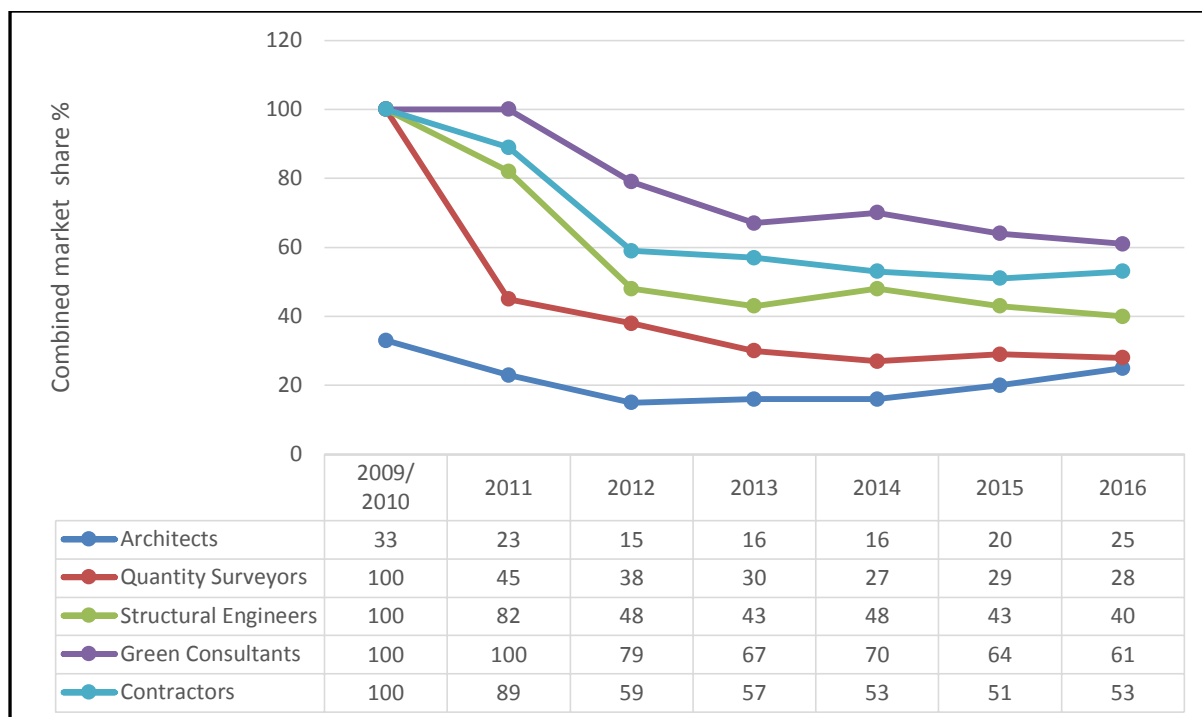
**Figure 4:** Smallest number of firms with a combined market share of >50%

Larger market share for the dominant firms from disciplines other than Architects resulted in much smaller number of firms required to exceed a combined market share of 50%. For Quantity Surveyors 7 firms typically exceeded the combined 50% market share threshold although by 2016 a total of 8 firms were required. Structural Engineering followed a similar trend, requiring only 4 firms to exceed the combined 50% market share threshold although by 2016 a total of 5 firms were required. This may indicate that more Quantity Surveying firms and Structural Engineering firms started to participate in the green building industry in 2016.

The Green Consultants and Contractors were all operating in green building industries with even more dominant participants compared to Quantity surveyors and Structural Engineers. Figure 4 indicated that the 2 or 3 firms with the largest market share from both these disciplines were sufficient to exceed the combined 50% market share threshold. This supported the previous finding indicating a limited number of firms from these two disciplines participating in green building and also that dominant firms with significant market share have established themselves in these industries.

The second approach to describe the extent of market dominance was to consider the combined market share of the three firms from each discipline with the largest individual market share. A discipline with dominant participants will typically return a combined market share of 50% or more. Strong participants will result in a combined market share of around 40% and relatively weaker participants will have a combined market share of around 20%.

The data detailed in Figure 5 described the findings of this analysis. The three most dominant Architect firms only managed a combined market share of 15% – 16% for 2012 – 2014. The general lack of dominant Architect firms was corroborated by this finding. During 2015 the combined market share of the three most dominant Architect firms started to increase and in 2016 reached 25%. This finding of a changing trend for Architect firms supported the previous finding indicating that specific Architect firms were starting to more successfully increase their green building market share.



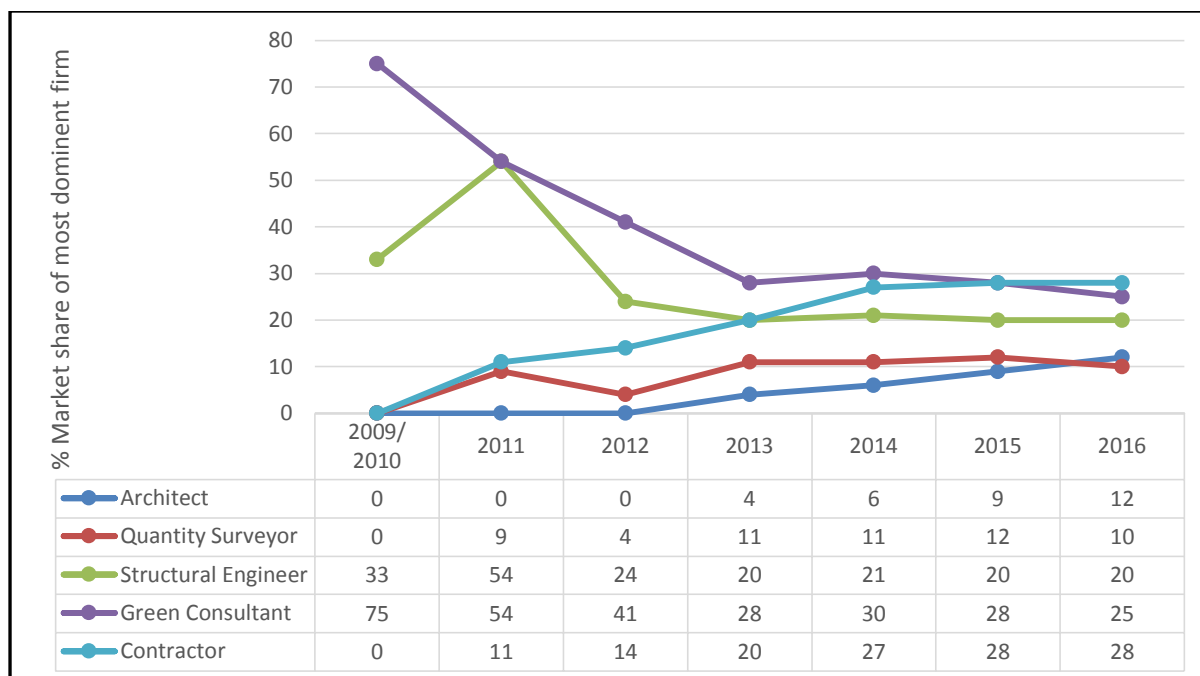
**Figure 5:** Combined market share of three most dominant firms

The Quantity Surveying firms revealed a different scenario. By 2013 when the green building industry was starting to mature from the initial fledgling stage, the combined market share of the three most dominant Quantity Surveying firms levelled off at just under 30%. This scenario confirmed the existence of strong but only partially dominating participants. This finding also supports and upholds the previous finding that more Quantity Surveying firms are starting to engage with green building thereby constraining the likelihood of dominance by a few firms.

Structural Engineering firms again displayed a similar trend to Quantity Surveying firms but with slightly higher levels of dominance. The combined market share of the three most dominant Structural Engineering firms levelled off at just above 40%. A downward trend was displayed from 2014 to 2016 in the combined market share of 48%, 43% and 40%. This finding also supports and upholds the previous finding that more Structural Engineering firms are engaging with green building thereby constraining the likelihood of further dominance by a few firms.

Figure 5 again confirmed the previously identified dominance by leading Consultant and Contracting firms. Both disciplines revealed dominating levels of combined market share of the three most dominant firms of more than 50% for Contracting firms and more than 60% for Green Consultants. The dominance established by a few firms in these industries will probably be maintained on the short to medium term.

The third measure to describe dominance was to consider the market share of the most dominant firm from each discipline. The analysis described each respective firm's relative measure of dominance and also how and when their positions of dominance were assumed. A firm with 10% market share was considered to have attained some measure of dominance, strong dominance was confirmed by a market share approaching 20% while a market share of 25% - 30% was considered as a very dominant position.



**Figure 6:** Market share trend of the most dominant firm per discipline

Since green building certification in SA only started from 2009, the first four years until 2013 can be regarded as years of establishment of the industry. The market shares of firms during this period also tend to vary a great deal as reflected by Figure 6. From 2013 to 2016 much more consistent market share patterns and trends started to emerge.

The most dominant Architect firm (12% market share) was a late starter in with a first green building only in 2013. Since then the firm has increased its market share every year from 4% in 2013 to a level of some dominance of 12% in 2016. This market share trend seems likely to continue in the immediate future. The current scenario of some dominance also confirms the previous findings that the green building market share of Architect firms is widely dispersed with only some level of dominance by market leaders.

The Quantity Surveying firm with the largest market share (10%) was involved with green building since 2011. The firm's market share has been relatively stable at between 10% and 12% from 2013. This market share trend also seems likely to continue in the immediate future. The current scenario of some dominance also confirmed previous findings of only some level of dominance by market leaders that the green building market share of Architect firms is reasonably widely dispersed with.

The Structural Engineering firm with the largest market share (20%) was involved with green building since 2010. Until 2012 the firm's market share varied between 24% and 54%, but since 2013 has stabilized around 20%. The current dominant market share is very likely to be continue into the immediate future.

The Green Consulting firm leading that industry with a strong dominating market share of 25% has been involved with green building from the start. The firm's initial market share of 54% - 75% has stabilized between 25% and 30% since 2013. The Contracting firm with the largest market share started in 2011 with a strong position of 11% and has consistently expanded its market share to the strong dominating position of 28% in 2016.

## CONCLUSION AND RECOMMENDATIONS

This study identified a much wider spread of participation in green building amongst Architect firms when compared to the other four disciplines included in the study. This finding may indicate a stronger willingness from Architects to face the risk and uncertainty of the new challenge presented by green building. The study however also revealed that few Architect firms developed into experienced practitioners. By comparison fewer firms from other disciplines accepted the green building challenge, but more of the firms from other disciplines have developed and expanded their green building competencies into another business line that may offer a competitive advantage over their peers.

This study has identified that firms leading the different segments of industry have attained market shares of between 10% and 28%. The reality of firms who have established positions of such dominance, holds the potentiality of assistance to the expanding of the green building industry. The same scenario of dominating firms can however also be a threat or present a challenge to the growth of the green building industry.

Firms who did establish dominant market share positions probably understood the context and complexities associated with green building, they were able to translate the new challenge into an opportunity and were successful in their subsequent response. Firms who were less successful or have not yet participated in green building can gain much value from the lessons learnt and the new competencies developed. The green building industry will greatly benefit if mechanisms of transporting and sharing this knowledge can be established.

A scenario of a few dominating firms in segments of the green building industry may also present a challenge to growth of the green building industry. Dominating firms may be able to significantly influence and control the awarding of future green building commissions and contracts through effective marketing of their skill sets and previous record. The result of this may be the development of bottlenecks in the supply chain due to the limited capacity offered by a small number of leading firms.

Organisations such as the GBCSA, professional and industry associations and institutions of higher learning should take note of the findings of the study, should consider the potential effect of the findings on the future of the industry and respond appropriately.

In conclusion it is recommended that several aspects identified by the study should be explored in more depth to be able to describe the dynamics of the developing scenario of green building in more detail. Important stakeholders such as building owners and developers and the other engineering disciplines should be added to the study. Consideration should be given to develop a regularly published report on participation in green building and to include the actual details of participating firms. The assumptions made with regards to the underlying causes of the participation trends identified, should be explored as this will provide vital information on how to approach and package future efforts to educate and inform industry stakeholders.

## REFERENCES

- Association of South African Quantity Surveyors, 2016. *Green building in South Africa: Guide to Cost and Trends*. [Online] Available from [http://www.asaqs.co.za/page/free\\_publications](http://www.asaqs.co.za/page/free_publications). [Accessed 1 May 2017]
- Bond, S. & Perrett, G., 2012. The key drivers and barriers to the sustainable development of commercial property in New Zealand. *The Journal of Sustainable Real Estate* 4(1), pp. 48-77.
- Fitch, E. & Laquidara-Carr, D (eds.), 2013, *World green building trends: Business benefits driving new and retrofit market opportunities in over 60 countries*, McGraw-Hill Construction.

GBCA, 2016. *GBCA*. [Online] Available at: <http://www.gbca.org.au/green-star/> [Accessed 30 April 2016].

GBCSA. 2016a. Evidence of Global Warming. Available from: <https://www.gbcsa.org.za/about/about-green-building/> [Accessed 28 April 2016]

GBCSA, 2016b. *About Green Building*. [Online] Available at: <https://www.gbcsa.org.za/about/about-green-building/> [Accessed 11 June 2016].

GBCSA. 2016c. *Green Star SA Overview*. Available from: <https://www.gbcsa.org.za/green-star-sa-rating-system/> [Accessed 28 April 2016]

GBCSA. 2016d. *GBCSA news*. Available from: [https://www.gbcsa.org.za/news\\_post/green-building-council-celebrates-milestone-200-green-star-sa-certifications/](https://www.gbcsa.org.za/news_post/green-building-council-celebrates-milestone-200-green-star-sa-certifications/) [Accessed 02 October 2016]

Hoffman, D.J., & Cowie, D., 2014, '*Factors limiting Green Developments in South Africa – Developers comments*'. ASOCSA 2014. The 8<sup>th</sup> Built Environment Conference – Reflection on Direction in Construction. Durban, South Africa, 27-29 July 2014.

Kerswill, B., 2007. *Green Buildings*. [Online] Available at: [http://www.enviropaedia.com/topic/default.php?topic\\_id=282](http://www.enviropaedia.com/topic/default.php?topic_id=282) [Accessed 29 April 2016].

Kriss, J., 2014. *What is green buildings?*. [Online] Available at: <http://www.usgbc.org/articles/what-green-building> [Accessed 31 May 2016]

Kruse, C., 2004. *IIGCC Briefing Note: Climate Change and the Construction Sector*. UNEP, Paris.

Lafarge Holcim Foundation, 2015. *Understanding Sustainable Construction*. [Online] Available at: <https://www.lafargeholcim-foundation.org/AboutPages/what-is-sustainable-construction> [Accessed 18 September 2016].

Ma, T. & Luu, H. T., 2013. *The changing role of quantity surveyors in the green building development in South Australia*. s.l., 38th AUBEA International Conference, pp. 1-10.

McGraw-Hill Construction, 2014. *Canada Green Buildings Trend: Benefits driving the New and Retrofit Market*, s.l.: Canada Green Building Council.

Milne, N. 2012. *The Rands and Sense of Green Building: Re-visited. Building the Business case for Green Commercial Buildings in South Africa*. Green Building Council, Cape Town, South Africa. pp.16

Montoya, M. 2011, *Green building fundamentals*, 2<sup>nd</sup> ed., (Prentice Hall New Jersey)

Morris, P. 2007, '*What does Green Really Cost?*' The Green Issue Feature, [Online] Available from: <http://www.davislangdon.com/upload/images/publications/USA/Morris%20Article.pdf> [Accessed: 15 March 2016]

NASA. 2016a. *Evidence of Global Warming*. Available from: <http://climate.nasa.gov/evidence/> [Accessed 28 April 2016]

Nelson, A., 2010. *Green buildings, niche becomes mainstream*, Frankfurt, Germany: Deutsche Bank Research.

Pekka, H. E. A., 2009. *Buildings and Climate Change*, Paris: United Nations Environmental Programme.

Seah, E. 2009. *Sustainable Construction and the Impact on the Quantity Surveyor*: 13<sup>th</sup> Pacific Association of Quantity Surveyors Congress. [Online] Available from: [http://www.academia.edu/1160074/sustainable\\_construction\\_and\\_the\\_impact\\_on\\_the\\_quantity\\_surveyor](http://www.academia.edu/1160074/sustainable_construction_and_the_impact_on_the_quantity_surveyor) [Accessed 8 May 2016]

The Economist, 2004. The rise of the Green Building. *Technology Quarterly*, 2 December. Volume Q4.

Toller, S., Wadeskog, A., Finnveden, G., Malmqvist, T. & Carlsson, A. (2011). Energy use and Environmental Impacts of the Swedish Building and Real Estate Management Sectors. *Journal of Industrial Ecology*. 15(3). pp.394 – 404

United States Environmental Protection Agency, 2016. *Climate Change: Basic Information*. [Online] Available at: <https://www3.epa.gov/climatechange/basics/> [Accessed 14 September 2016].

WGBCa. 2016b. *WGBC history* [Online]. Available from: <http://www.worldgbc.org/index.php/worldgbc/history/> [Accessed 01 October 2016]

WGBCb. 2016. *World Green Building Council Members* [Online]. Available from: <http://www.worldgbc.org/worldgbc/members/> [Accessed 01 October 2016]

# Sustainable Development & BIM –

## The Role of the 5D Quantity Surveyor

Dr. Peter Smith

*Associate Professor – University of Technology Sydney (UTS)*  
*Secretary General – International Cost Engineering Council (ICEC)*  
*peter.smith@uts.edu.au*  
*University of Technology Sydney*  
*PO Box 123, Broadway NSW 2007, Australia*

---

### ABSTRACT

BIM and its allied digital technologies provide enormous opportunities for project cost management professionals to dramatically improve the quality, speed, accuracy, value and sophistication of their cost management services. This is particularly the case during the design development stages when various design options are being proposed and evaluated. The ability of the quantity surveyor to use these digital technologies to provide quick and accurate cost advice throughout the design simulation process provides an enormous opportunity for the profession to play a key leading role in sustainable design development. BIM technologies facilitate the rapid simulation of a large number of sustainable design possibilities and the ability of the quantity surveyor to provide accurate and fast cost advice on these simulations is critical. The purpose of this paper is to explore the issues faced by firms in realizing these opportunities and to identify successful practices, procedures and strategies that firms are implementing. The research methodology for the paper is based on detailed interviews with Quantity Surveying firms and case studies of quantity surveying firms that are leading the way. The results show that there is a consistent pattern in relation to the main issues and problems and what was needed to be successful. The greatest issues related to the quality/comprehensiveness of the BIM models, difficulties with designers not providing full access to the models and software/standards compatibility issues. Successful strategies were clearly based on strong commitment and leadership from company directors and positive approaches to dealing with the issues and challenges faced.

**Keywords:** Existing Buildings, Retrofitting Business Case, Sustainable Retrofitting.

### INTRODUCTION

This paper explores the opportunities and practical issues and constraints faced by quantity surveying professionals in the implementation and effective utilization of the various software, technologies and tools that are now available in the Building Information Modeling (BIM) sphere with a particular focus on the important link between the utilization of these tools by quantity surveyors to provide critical cost services to the design and contracting project teams to optimise sustainable development and design project outcomes.

Building Information Modelling (BIM) provides both opportunities and challenges for the project cost management profession. As quantification increasingly becomes automated and BIM models develop the role of the project cost manager will need to adapt accordingly to provide more sophisticated cost management services that incorporate 4D time and 5D cost modelling and sharing cost information/data with the project team as part of the BIM integrated project delivery approach. The RICS (2014) contend that BIM provides project cost managers with the opportunity to spend more time on providing knowledge and expertise intensive advice to the project team - the automation of processes such as quantification will substantially reduce time spent on technical processes and will provide more time

and the digital tools for higher value-added and more sophisticated cost management services. Mitchell (2012) describes the importance for the project cost management professional to embrace the 5th dimension and become key players in the BIM environment – the ‘5D Project Cost Manager’.

However, the profession has generally been slow to embrace and evolve with the full potential that these technologies can provide. There is now considerable momentum building as firms realize they have to embrace these technologies and their competitors seize market advantage through developing expertise in the field. Momentum for change in the industry generally and via the use of digital technologies in particular has been slow but there has been a real acceleration for change across the globe in the past few years. It is important that quantity surveyors are not left behind. The World Economic Forum (2016) make the following comments that have been receiving global attention. *“While most other industries have undergone tremendous changes over the last few decades, and have reaped the benefits of process and product innovations, the Engineering & Construction sector has been hesitant about fully embracing the latest technological opportunities, and its labour productivity has stagnated accordingly. This unimpressive track record can be attributed to various internal and external challenges: the persistent fragmentation of the industry, inadequate collaboration with suppliers and contractors, the difficulties in recruiting a talented workforce, and insufficient knowledge transfer from project to project, to name just a few. The industry has vast potential, however, for improving productivity and efficiency, thanks to digitalization, innovative technologies and new construction techniques. Consider the rapid emergence of augmented reality, drones, 3D scanning and printing, Building Information Modelling (BIM), autonomous equipment and advanced building materials – all of them have now reached market maturity. By adopting and exploiting these innovations, companies will boost productivity, streamline their project management and procedures, and enhance quality and safety. To capture all this potential will require a committed and concerted effort by the industry across many aspects, from technology, operations and strategy to personnel and regulation”* (World Economic Forum 2016, p. 3).

## **5D BIM IMPLEMENTATION**

In line with these changes, the development of 5D (Cost) capabilities is gaining considerable momentum and leading edge project cost management firms are starting to realize the competitive advantages by embracing this ‘new-age’ approach to cost management. A major catalyst for the profession using this technology occurred in 2008 in the United States. The Association for the Advancement of Cost Engineering International (AACE), the American Society of Professional Estimators (ASPE), the United States Army Corps of Engineers, the General Services Administration (GSA) and the National Institute of Building Sciences (NIBS) formed an agreement to work together to solve cost engineering related problems for the facilities industry under the buildingSMART Alliance. The purpose was to develop systems and protocols for collaboration and coordination of cost engineering and estimating through the project lifecycle. *“The consortium continues to adjust to, and coordinate with ever-changing standards, so that the process of extracting and processing the 5D (cost) information from the BIM model is clearly defined, especially as the design evolves”* (ConstruchTech 2013, p.1).

In 2012 the Royal Institution of Chartered Surveyors (RICS) published new guidelines known as the Black Book (Quantity Surveyor and Construction Standards) and New Rules of Measurement (NRM). The Black Book is a comprehensive suite of documents that defines good technical standards for Quantity Surveying and Construction. The New Rules of Measurement suite provides a common measurement standard for cost comparison through the life cycle of cost management. *“The suite has been developed as a result of industry collaboration to ensure that at any point in a building’s life there will be a set of consistent rules for measuring and capturing cost data, thereby completing the cost management life cycle and supporting the procurement of construction projects from cradle to grave. A better understanding of costs during the construction process will increase certainty for business planning and support a reduction in spending on public and private sector construction projects in the long run”* (Property Wire 2012, p.1).



The New Rules of Measurement are integrally linked with BIM and enables a consistent approach to estimating and cost planning within BIM platforms. The RICS are currently looking at developing international standards in collaboration with other kindred associations and industry. The RICS have also recognized the need for global guidance for companies in terms of BIM implementation. They recently published a comprehensive 'International BIM Implementation Guide' for construction professionals and contractors that includes specific guidance for project cost managers (RICS 2014). They note that *"as the industry takes hold of this new future it is essential that organisations and individuals are not flying blind but have information to plot out a change plan and BIM implementation trajectory both for now and indeed a 'future wise' longer term digital strategy"* (RICS 04, p.1 )

The RICS (2015) have also recently developed a global 5D BIM implementation guide for cost managers. The guide focuses on the cost manager's requirements from the BIM model to be able to effectively incorporate 5D BIM processes in project design and development. The main objectives of the guide are to: The main objectives of this guidance note are to: *"i. Assist the QS/cost manager in deriving benefits from delivering cost consultancy services in a BIM environment, by utilising model data rather than traditional manual measurement in the production of quantities, and ii) Inform the team in the needs of the QS/cost manager in performing their measurement role in a BIM environment"* (RICS 2015, p.3).

The extent of firms effectively implementing 5D technology is difficult to gauge. An innovative project cost management firm in Australia provides a good example of what is starting to happen. Mitchell Brandtman are a medium sized quantity surveying firm in Australia that market their firm as '5D Quantity Surveyors and BIM Advocates and Specialists'. Their Managing Director, David Mitchell, contends that the modern day cost manager should be a 5D cost manager utilising electronic models to provide detailed 5D estimates and living cost plans in real time. Mitchell believes that the cost manager provides greatest value through their cost planning role at the conceptual front end stages of a project by providing cost advice and estimates on various design proposals and then refining those estimates as the design evolves. Using traditional 2D approaches this cost planning advice takes considerable time and inhibits rigorous comparative analysis within the allocated time frame for the design development process (Mitchell 2012).

Mitchell argues that the *"5D Cost Manager can do this extremely quickly, an endless number of times and in a complexity of combinations. A 5D Cost Manager can also re-estimate the developing design an endless number of times providing feedback on the estimate variances and corrective suggestions"* (Mitchell 2012, p.4). Mitchell (2012) refers to this as the 5D 'Living Cost Plan'. He argues that these modern techniques can be used within traditional frameworks but that it is the behaviour and how the technology is used that is more important than the software.

## **5D BIM & SUSTAINABLE DEVELOPMENT**

5D BIM provides enormous opportunities for project cost management professionals to dramatically improve the quality, speed, accuracy, value and sophistication of their cost management services and therein ensure their future as key players in the BIM world. This is particularly the case during the design development stages when various design options are being proposed and evaluated. The ability of the quantity surveyor to use BIM models and other digital technologies to provide quick and accurate cost advice throughout the design simulation process will enable the profession to play a key leading role in sustainable design development. BIM technologies facilitate the rapid simulation of a large number of sustainable design possibilities and the ability of the quantity surveyor to provide accurate and fast cost advice on these simulations is critical.

Arnav (2015) contends that the greatest value of BIM lies in computer simulation that enables the project team to develop optimum design solutions for the project through the exploration of a number of design and construction options that are simply not feasible using conventional approaches.

BIM also enables the project team to simulate how the building will behave long before it is constructed – this has enormous benefits in developing sustainable development solutions as the long term operation of the building can be simulated many times. *“BIM has especially helped to enable sustainable design – allowing architects and engineers access to higher tech tools than ever before to carefully integrate and analyze things like heat gain, solar, ventilation, and energy efficiency in their designs”* (Arnav 2015, p.1)

He further highlights the importance of the economic (cost) analysis of sustainable design simulations and the ability to provide timely and accurate cost advice. *“The two most important considerations are the environmental and the economic impacts. While sustainability is important, it has to be feasible. Sustainable design is achieved only when it has a positive impact on both of these areas”* (Arnav 2015, p.1). Accordingly, the project cost manager/quantity surveyor has a key role to play in sustainable development by providing this economic analysis. Proficiency and expertise in 5D BIM is fundamental for the project cost manager/quantity surveyor to provide this analysis at the level required and which BIM technology now provides.

The 5D BIM project cost manager also has an important role to play in the measurement and costing of the operational and environmental performance of buildings. The Global Alliance for Buildings and Construction (GABC 2015, p. 8) note that *“Measurable, Reportable and Verifiable (MRV) information is pivotal to accelerating energy-efficiency in the buildings and construction sectors. In order to finance, construct, and renovate low-carbon, sustainable buildings, decision-makers in the building sector require high quality data to drive, motivate, finance, and require prudent policy action. At present, despite increasingly globalized building and construction markets, measurement and evaluation tools to track and monitor building performance, continue to vary considerably across the globe. However, it is important to calculate the energy savings’ multiple benefits, also towards the local market”*.

The lack of consistent measurable data provides opportunities for the project cost management profession to address this issue and become key players in the measurement and analysis of building operational performance. The GABC (2015, p. 8) stress that *“transparency and comparability rely on consistent data. Yet the way buildings are currently measured varies dramatically, this significant variability introduces high uncertainty in valuation and project-cost estimation”*. They highlight the need for the development of “international standardized and vertically integrated (inter-governmental) measurement and reporting to enhance the understanding and international comparison of energy efficiency data and relevant resource flows for reduced GHG emissions” and the “development of international data, measurement, and standards” in the built environment sector.

The project cost management profession is making the first steps towards addressing this issue through the development of ‘International Construction Measurement Standards’ (ICMS 2017). The development of an international construction measurement standard was initiated by the Royal Institution of Chartered Surveyors (RICS) and the European Council of Construction Economists (CEEC) in 2014. They were soon joined by the International Cost Engineering Council (ICEC) in support of the venture. Using their extensive international networks, these associations set about informing the project cost management profession about the initiative and inviting participation. The author was integrally involved and continues to be involved in this global industry consultation and development of the standard (ICMS 2017).

At the core of the development of the International Construction Measurement Standards (ICMS) is collaboration between the project cost management profession and their representative professional associations on a global scale. The ICMS coalition and support for the measurement standards has grown quickly. The coalition has now grown from a foundation membership base of 17 professional associations in mid-2015 to a membership of 41 associations by mid-2016. There are well over one hundred national associations as well as regional/international associations representing the profession around the world. The project cost management profession has traditionally been fragmented with a lack of global recognition – this is largely due to the different cost management approaches and various

cost management professional title descriptors used in various countries. This initiative is bringing the profession (be they quantity surveyors, cost engineers or other project cost management professionals) together to work on a global standard that has great potential to be recognised and endorsed by major global entities such as the World Bank, the International Monetary Fund and the United Nations as well as major multi-national corporations. These organisations are increasingly requiring global standards - gaining recognition and working with these types of organisations (and gaining their support) can provide the global platform for further standards to be developed, recognized and adopted around the world. The intention is for these international measurement standards to incorporate BIM measurement standards and, in time, environmental measurement standards. This presents tremendous opportunities for the profession to be key global players in the measurement and analysis of the environmental performance of buildings.

## **RESEARCH METHODOLOGY**

The research methodology adopted for this study was detailed industry interviews with medium to large quantity surveying firms in Australia. The quantity surveying firms interviewed comprised five firms (three medium sized firms with 20-30 employees and two large firms with 30 plus employees). The firms were located in NSW and Queensland. Four of the firms had experience with the use of BIM and automated quantities whilst the other firm, who primarily produces bills of quantities, interestingly had undertaken a considerable amount of research and trialling of BIM/automated quantities but has currently decided to remain using traditional approaches until the core issues surrounding the technology are addressed. This provided a good contrast to the other firms who are utilizing this technology. The interviewees were asked a range of questions relating to the issues, problems and benefits associated with the implementation of BIM and automated quantities. The following provides a summary of the main findings.

## **RESEARCH FINDINGS – INDUSTRY INTERVIEWS**

### **Collaboration With Designers & Development of Trust**

Architects, engineers and other design consultants are typically reluctant to provide full versions of their models to quantity surveyors, contractors and the like. There are a range of reasons with the main one being what will be done with the models and the potential liability of the designer. Many designers will only provide limited versions of their models to contractors and quantity surveyors for ‘information only’. Some cite intellectual property reasons but this flies in the face of the concept of BIM (sharing information as effectively and efficiently as possible) – the underlying reason is typically potential liability. A common thread from the interviewees was the importance of establishing strong collaborations with designers, gaining their trust over time and showing the value that that collaboration can provide for all parties. For example, as more detail is provided quantity surveyors have more scope to properly interrogate the model and identify errors/omissions/clashes which can be reported back to the designer for rectification. This has always been one of the traditional roles of the quantity surveyor in the 2D world and there is no fundamental difference in the BIM world. This collaboration should extend to explaining to designers the information/data that the quantity surveyor needs, in what form and how the model can be improved. It is important that the quantity surveyor can clearly articulate what they want and explain the benefits to the designer in providing such. Ideally the quantity surveyor needs the native files from the model. These requirements will change as the project evolves. For example, the information that the quantity surveyors requires from the model will vary considerably between the conceptual design stage, the cost planning stage, the detailed estimating/Bill of Quantities stage, the construction stage and the facility management stage of a project. One firm described their practice of a ‘brainstorming interrogation’ of BIM models for new projects. This may typically range from a few hours to a few days. They compile their team of experts to interrogate the model to identify issues, problems and information required. The results are then fed back to the designers/modelers for attention. The objective is to identify issues early and address them early.

## **BIM Data & Information**

To fully encapsulate the potential benefits of BIM models, the models need to be information rich with comprehensive and accurate data. This requires considerable time and expertise on the part of the BIM modelers and BIM team. On many projects the BIM model falls well short of its potential due to incomplete/inaccurate data. The reasons for this are numerous but the main reasons evolve around whether the design fees include allowance for the input of fully comprehensive data and whether the BIM team have the expertise/knowledge/information to input the necessary information into the model. Many clients do not see the value in paying the necessary fees for comprehensive models or may not have sufficient knowledge/advice to know whether this has been achieved. One quantity surveyor noted that he knew of an informal BIM forum for young BIM modelers sharing information on how to develop 'dumb' BIM models quickly that give the appearance that they are workable models and can quickly satisfy their clients' requirements. Then it will typically be the rest of the project team (contractors, subcontractors, quantity surveyors and the like) that need to work with the inadequate models and develop the further information required for construction.

## **Quantification**

Four of the firms interviewed used automated quantities software to prepare quantities on their projects – two firms used this software extensively particularly in the cost planning stages whilst the other two firms used such software in a limited capacity. The other firm, who primarily prepares Bills of Quantities at tender stage, rarely used automated quantities software as they felt that the quality and the accuracy of the BIM/3D models provided to contractors at tender stage was not sufficient to be able to rely on the quantities that may be automatically generated. The firms utilizing automated quantities used both proprietary and in-house software with the CostX program the most commonly used program. The CostX program is now the most widely used software of this type in Australia and is now used in over 40 countries around the world (Exactal 2017). The CostX program and the in-house programs were all capable of linking in with BIM models. The firms all agreed that they were on the 'automated quantities' path and that this would continue to develop as their own expertise and the software improved. The main issue that they found was in the quality of the electronic documentation (be it 2D, 3D or BIM models). The quality of documentation is critical to the development of accurate quantities and this issue has existed long before the introduction of electronic documentation. In the traditional 2D paper based days interrogation of the drawings and queries to correct design and information errors and inconsistencies was a normal part of the measurement process. The firms stressed that nothing has changed in the new electronic environment. The documentation still needs to be checked.

The new problem though is that it is more difficult to check the documentation accuracy despite advances in clash detection in BIM models. In the 2D days measurers would spend days and weeks measuring and 'absorbing' the project information in great detail. In the electronic 3D environment far less time is spent measuring and 'absorbing' and understanding the documentation details. There is also a new breed of young quantity surveyors who don't have that solid fundamental training in 2D paper-based measurement and may lack the experience and expertise to identify problems in CAD/BIM models as they might have done in the 2D environment. This leads to the major problem of not trusting the automatic quantities produced due to quality issues with the model. Problems may also occur where quantity surveyors are not fully conversant with the automated quantities software. This requires experience, expertise and intuition to be able to identify problems with the quantities produced. The firms only use automated quantities to the extent that is feasible – whilst ideally suited to cost planning measurement there are still limitations with more detailed measurement for Bills of Quantities, Builders Quantities and other detailed estimating requirements. Automatic quantities will also only reflect what is detailed in the model – the need to identify information and quantities not in the electronic model is critical. It is also of note that with all of the interviewed firms a considerable amount of measurement is still done via traditional means (i.e. not automated quantities) particularly with respect to detailed measurements for Bills of Quantities and Contract/Claims Administration. All firms saw automated quantities as a 'journey' as they evolve with the technology and use it where practical and useful.

## **Quantity Surveying BIM Analysis & Deliverables**

Mitchell (2013) contends that the 5D objective during design is to create a living cost plan that provides a transparent framework for making early cost decisions that have most impact on the final project outcomes. This is particularly the case with sustainable design simulations and proposals that have long term operational impacts. The living cost plan must be able to be revised and shared (on a weekly / fortnightly / or monthly cycle) using the current model information. The 5D objective during construction is to also provide a transparent framework for letting and administering construction contracts. The model map which created the cost plan becomes more detailed as the model Level of Development (LOD) progresses to become the basis for quantity take-off for letting and tendering, the valuation of variations, change orders and progress payments during construction and replacement work during operation of the building. The 5D objective on completion is to create a cost integrated 'as built' model that can be synchronised with the FM system to transfer replacement costs, base dates, expected and effective lives, estimated running and maintenance costs.

## **Clients**

All interviewees felt that there is a need for clients, both private sector and public sector, to drive the development of consistent modelling standards. The public sector has a key role to play to provide the necessary leadership for effective implementation. However, the interviewees consistently cited the lack of national government leadership in the field in Australia. Many felt that government were largely not interested and preferred to leave it to the private sector to move the industry forward. Some also cited the lack of expertise within government client bodies due to the now long-standing practice of outsourcing services to the private sector.

## **Education & Training**

Education and training requires substantial time and cost commitment from quantity surveying firms. Many interviewees identified the need for universities to help supplement this training so that graduates enter the industry with at least foundation knowledge in the BIM sphere and use of associated software and digital tools. The interviewees described a range of approaches to education and training in their workplace. One firm noted their practice of peer review at the end of each project. The work of the team on each project is reviewed by peers at the end of the project to identify BIM issues/problems, success factors, failure factors and lessons learnt. Most interviewees expressed concern about the issue of younger staff that may be proficient in the use of BIM models and associated software but lack fundamental knowledge and experience in the core competencies of the profession (construction/services technology knowledge, measurement principles and the like). Conversely, experienced older staff that struggle with this new technology. One firm cited their practice of teaming up younger/older staff members wherever possible so that they can work together and help overcome their respective deficiencies in knowledge/expertise and ultimately lead to long term continual improvement amongst their staff.

Certification was also raised. Certifications such as the 'Certified Practicing BIM Professional' will also help to develop professional understanding, skill and knowledge. This could involve certification of both individuals and companies. Examples cited included CanBIM from Canada. The CanBIM Certification Program for individuals is a tiered certification program providing a benchmark for individuals to be certified to nationally standardized and recognized levels of BIM Competency and Process Management (CanBim 2015).

## FUTURE STRATEGIES & DIRECTIONS

### Main Issues

The RICS (2014, p. 62) highlighted the following main issues facing project cost managers:

- QS professionals receive models developed by other project team members and are expected to perform their tasks using these models.
- Given that the models are developed by other project team members, the first important task that QSs have to undertake is to review the model for accuracy and information richness. Many instances have been reported where the model does not have the required information to allow model-based measurements and quantity take-off.
- It is important for the QS to ensure that the automatic model-based measurements and quantity take-off are compliant with locally accepted standard methods of measurements.
- Classification systems adopted by the project team may have an impact on the work processes of the QS. Commonly adopted classification systems are RICS' NRM, OmniClass Construction Classification System, ICE CESMM, MasterFormat, UniFormat and CPIC Uniclass.
- The LOD of the model must be clearly understood by the QS so as to ensure that cost planning is in accordance with the level of information that is available in the model.
- Models can change frequently in the BIM environment. This has both positive and negative connotations. QS professionals/firms are able to provide better cost planning information to clients due to the model-based measurement and quantity take-off. However, frequent changes may disrupt the workflow normally expected by QSs.

In addressing these issues the RICS (2014, p. 64) suggest that following broad structural changes may be needed: *“broader vision and behavioural changes from all stakeholders to collaborate on the BIM platform with a ‘whole of system’ and a ‘whole of industry’ approach; capacity building, education and training for BIM implementation; better value proposition for all stakeholders (including the articulation of the value proposition); development of national standards and guidelines; investment in research and development; participation of the academic community in updating curricula; process- and people-driven change and not technology-driven change; and a life cycle view for BIM implementation with strong integration with supply chain and asset management”*.

As outlined earlier in this paper, the RICS have recently developed a global guide ('BIM for Cost Managers: Requirements from the BIM model) to assist with this process. The global guide focuses on the development of standard protocols that can be adopted by quantity surveyors/cost managers. The RICS (2015) point out that *“the QS/cost manager needs to understand how a model, its attributes and other data will be created and conveyed at different stages of the project life. This will enable the QS/cost manager to make suitable adjustments to quantities, rates and other ancillary costs and modifications, at each work stage as appropriate. It is possible to link models to cost databases, and we expect this to evolve and develop in the future to provide a fully integrated BIM environment”* (RICS 2015, p. 5).

They then emphasise the need for the QS/Cost Manager to work with the design team to ensure that they get BIM information in the form that suits their processes. *“The different members of the design team may use different BIM authoring tools. Secondary tools may also be used for other purposes such as clash detection, data validation and 4D sequencing/programming (which can be used to review phasing – but this may be dependent on procurement route and contractor involvement). These should all be defined in the BIM Execution Plan (BEP). The exchange formats need to be agreed between the parties and the QS/cost manager (as a recipient of data) needs to state what formats and versions they require (such as IFC, DWF, DWFx, DWG, PDF)”* (RICS 2015, p.5).

## **BIM Modelling Standards for Measurement**

The variance in modelling standards remains a big issue for project cost managers. The lack of consistent modelling standards requires quantity surveyors to adapt to a range of approaches – this leads to obvious inefficiencies and wasted time. Project cost managers attempt to reduce this problem by developing collaborative relationships with designers as outlined earlier but this is a small piecemeal approach to an industry wide problem.

The development of national BIM modelling standards was viewed by interviewees as one of the most important factors in terms of successful long term BIM implementation. Ideally, the development of a global BIM Modelling Standard for Project Cost Managers/Quantity Surveyors would be the best approach. As outlined earlier, the International Cost Engineering Council (ICEC), the RICS, the European Council of Construction Economists (CEEC) and other professional associations are in the early stages of the development of a global International Construction Measurement Standard (ICMS). The purpose is to develop international standards through input and ownership by professional cost management associations around the world that are recognized by world bodies and national governments. There is much potential for this initiative to extend to the development of global BIM Measurement Standards and Environmental Measurement Standards. These global initiatives should have considerable influence on BIM software vendors and the industry generally. A few firms cited the UK BIM Standard 1192 (UniClass 1.4) as a good model that could form the basis of a global standard. Currently BIM software vendors largely determine modelling standards.

## **Level of Development (LOD) Specification Standards**

BIM specification standards during the various stages of development of a project are important for project cost managers and other construction professionals to assist them in defining their information requirements during these various stages. The BIM Forum (2013) have developed a Level of Development (LOD) Specification that has potential global application. It is a reference that enables professionals to specify and articulate with a high level of clarity the content and reliability of Building Information Models (BIMs) at various stages in the design and construction process. The LOD Specification utilizes the basic LOD definitions developed by the American Institute of Architects. It defines and illustrates characteristics of model elements of different building systems at different Levels of Development. This clear articulation allows model authors to define what their models can be relied on for, and allows downstream users to clearly understand the usability and the limitations of models they are receiving (BIM Forum 2013, p.8). The intent of this Specification is to help explain the LOD framework and standardize its use so that it becomes more useful as a communication tool. It does not prescribe what Levels of Development are to be reached at what point in a project but leaves the specification of the model progression to the user of this document. To accomplish the document's intent, its primary objectives are to help teams, including owners; to specify BIM deliverables and to get a clear picture of what will be included in a BIM deliverable; to help design managers explain to their teams the information and detail that needs to be provided at various points in the design process and to provide a standard that can be referenced by contracts and BIM execution plans. (BIM Forum 2013, p.8).

## **Modeling Existing Buildings**

New buildings only account for approximately 1 – 1.5% of the total building stock. Considerable work is being done on the modelling of existing buildings. This has important ramifications for the facility management and refurbishment/retrofit markets. Project cost managers need to get involved with this. The RICS (2014, p. 25) comment that 'with the proliferation of BIM there is now a need to capture as-built information, especially for large-scale retrofit and renewal projects. In these situations it is useful to start with the base digital model of the facility as it exists on site. This is now possible by linking laser scanning and 360-degree video or camera vector technology'.

## **Data Management**

The RICS (2014, p. 25) also contend that the large volumes of data that can be created in the BIM process need to be adequately managed. “To succeed in large-scale BIM projects, data management software should be used. Data management technology allows the modelling process to be connected with extended, dispersed and remote team members. Access control and security along with version control on the model and associated files is ensured through this technology”.

## **Evolving With Digital Technologies Generally**

Big Data is also an area that project cost managers should also embrace and evolve with. The ‘Internet of Things’ shows that in 5 years there will be a 30 fold increase in devices connected to the internet. The future explosion in the number of intelligent devices will create a network rich with information that allows supply chains to assemble and communicate in new ways and will significantly alter supply chain leader information access and cyber-risk exposure (Gartner 2014). The information from these devices will be fundamental to Big Data and what can be done with this information. These transitions will affect how professionals behave in the future. Knowledge/possession of the data will have no value – the real value will lie on how this data is interrogated and interpreted.

Project cost managers are increasingly dealing with more connected, intelligent and demanding clients. The ‘Internet of Things, cloud computing, cloud-based collaboration, crowd sourcing, robotics, prefabrication, sustainability and the like are all areas that professionals in the industry need to evolve with and be part of.

## **CONCLUSION**

The full potential of BIM models is generally not being achieved. Objects in models commonly lack the substantive data that is required for project cost managers and other construction professionals to fully reap the benefits the model has the capacity to provide. This requires comprehensive and accurate data to be input by sufficient personnel with the necessary knowledge, experience and expertise and for adequate fees to be provided to ensure that this occurs. The key parties that need to invest in this data input are clients, developers and contractors. National and/or global object libraries and modelling standards also need to be developed to facilitate this. These remain big issues for the industry and impact directly on the ability of project cost managers to fully harness the potential of BIM.

The role of the 5D BIM project cost manager/quantity surveyor in the measurement and analysis of the economic impacts of various sustainable design and construction proposals put forward during the course of a project is very much dependent on the quality/comprehensiveness of the BIM model.

Ultimately, quantity surveying firms need to adopt proactive and innovative approaches that engage closely with the project design and construction teams to ensure that they get information from the BIM model in the forms that they require for their particular company processes and procedures. Rather than just accepting BIM information in the form that is just given to them at the whim of the design team, quantity surveying firms need to be able to clearly articulate their information requirements (and formats) and, perhaps most importantly, clearly demonstrate the value that this will provide for the design development and project success. This will typically also require the development of long term relationships between designers and contractors to foster levels of trust between the parties and the significant cost benefits that can be realised.

This has the very real potential to place quantity surveyors at the core of the design development process. Effective sustainable development and design relies on solutions that not only reduce environmental impact but can do so as economically as possible. Quantity surveyors should therefore be crucial to sustainable development via this economic input to the design team.



## REFERENCES

- Arnov, P. (2015), What is BIM and How Can It Lead To Sustainable Development? <https://indiansustainability.wordpress.com/2015/07/03/> (accessed 14 May 2017)
- BIM Forum (2013), Level of Development Specification, [www.bimforum.org/lod](http://www.bimforum.org/lod) (accessed 3 May 2017)
- ConstrucTech (2013), Defining the 5D of Bim, [http://www.constructech.com/news/articles/article.aspx?article\\_id=9229](http://www.constructech.com/news/articles/article.aspx?article_id=9229) (accessed 25 June 2013)
- Exactal (2017), CostX, [www.exactal.com](http://www.exactal.com) (accessed 10 May 2017)
- Frei, M., Mbachu, J. & Phipps, R. (2013), Critical success factors, opportunities and threats of the cost management profession: the case of Australasian quantity surveying firms, *International Journal of Project Organisation and Management*, February 2013, Volume 5, Number 1
- GABC (2015), Global Alliance for Buildings and Construction Report, London, UK
- ICMS (2017), Internal Reports and Documents, International Construction Measurement Standards Coalition, <https://communities.rics.org/connect.ti/icmscoalition/view?objectId=14279365> (Viewed: 10 May 2017)
- Mitchell Brandtman (2013), 5D Cost Planning, <http://www.mitbrand.com>
- Mitchell, D. (2012), 5D – Creating Cost Certainty and Better Buildings, RICS Cobra Conference, Las Vegas
- Mitchell, D. (2013), 5D Quantity Surveyor – Here & Now, JCT News, pp 4-6, Thomson Reuters
- Muzvimwe, M. (2011), 5D BIM Explained, <http://www.fgould.com/uk/articles/5d-bim-explained/>
- Olatunji, O., Sher, W., Gu, N. (2010), Building information modeling and quantity surveying practice, *Emirates Journal for Engineering Research* Vol. 15, Issue 1, p. 67-70
- Property Wire 2012, p.1), RICS launches landmark new guidance to the construction sector, <http://www.propertywire.com/news/europe/rics-construction-industry-guidelines-201204246452.html> (accessed 5 April 2015)
- RICS (2014), International BIM Implementation Guide, 1st Ed, RICS Guidance Note, September 2014, Royal Institution of Chartered Surveyors, London, UK
- RICS (2015), BIM for Cost Managers: Requirements from the BIM Model, 1st Ed, RICS Guidance Note, August 2015, Royal Institution of Chartered Surveyors, London, UK
- Smith, P. (2015), Professional Standards For Quantity Surveying & Cost Engineering – Global Issues & Strategies, 19th Pacific Association of Quantity Surveyors (PAQS) Congress, June, Yokohama, Japan
- Wong, A., Wong, F. & Nadeem, A. (2009), Comparative Roles of Major Stakeholders for the Implementation of BIM in Various Countries, Hong Kong Polytechnic University
- World Economic Forum (2016), Shaping the Future of Construction - A Breakthrough in Mindset and Technology, World Economic Forum, Zurich, Switzerland

# THE VIABILITY AND SUSTAINABILITY OF AERATED AUTOCLAVED CONCRETE IN SOUTH AFRICAN CONSTRUCTION

Mr. J.J.A. Jansen <sup>1</sup>, Mr. U. Erasmus <sup>2</sup>, Mr. M. Gomes <sup>3</sup>, Mr. Z. Pelzer <sup>4</sup> and Mr. A. Yared <sup>5</sup>

<sup>1</sup> *Lecturer, [riaan.jansen@up.ac.za](mailto:riaan.jansen@up.ac.za)*

<sup>2</sup> *Post Graduate Student, [ulierasmus@hotmail.com](mailto:ulierasmus@hotmail.com)*

<sup>3</sup> *Post Graduate Student, [mgomes0702@gmail.com](mailto:mgomes0702@gmail.com)*

<sup>4</sup> *Post Graduate Student, [zehanpelzer@yahoo.com](mailto:zehanpelzer@yahoo.com)*

<sup>5</sup> *Post Graduate Student, [antyared11@gmail.com](mailto:antyared11@gmail.com)*

*Department of Construction Economics, Engineering, Built Environment and Information Technology  
Faculty, University of Pretoria, Corner Lynnwood and University Road, Hatfield, Gauteng, South  
Africa, 0002*

## ABSTRACT

The environment is in need of serious rescuing as natural resources are becoming scarcer and more expensive. The construction industry is one of the largest culprits in this regard. There is a need and a desire to build sustainably, but the perceived high cost remains the defining factor that prevents the construction industry of developing sustainable buildings. This treatise investigates the viability of using a building material known as Aerated Autoclaved Concrete (AAC) in South Africa- a developing country. AAC has been used with great success in first world countries. The aim of the investigation is to determine whether or not the success of this material can be introduced and replicated in South Africa to produce sustainable and cost effective high-rise buildings with regard to construction costs and whole-life costing. Through a mixed method of research using both qualitative and quantitative methods, results exceeded expectations in proving that AAC is far superior to that of conventional building materials, which leads to a vast decrease in costs all round. AAC's properties allows for more economical designs which plays a further role in decreasing construction costs. AAC proves to be both feasible and viable within developing countries, although some limitations do exist.

Keywords: aerated autoclaved concrete, sustainable, cost effective, whole life costing, high-rise buildings

## INTRODUCTION

The world population is growing at a rapid rate. This exponential growth is directly proportional to the growth experienced in the construction industry worldwide (PWC, 2016). This growth means that cities have limited land on which buildings can be constructed and as a result more and more high rise buildings are being constructed. There is no questioning the fact that the environment is in need of serious rescuing and the natural resources are becoming scarcer on a daily basis. The construction industry is one of the major culprits in this regard (The world counts, 2016). Drastic measures have to be taken to reduce the footprint that the construction industry has on the planet. Apart from that, new and innovative construction methods are constantly being implemented in an effort to reduce building costs and to increase the speed with which buildings can be constructed. A relatively unknown building material in South Africa is Autoclaved Aerated Concrete, also known as AAC. This material has been successful in European countries and more recently there have been a massive boom of AAC

production in Asia (Xella International, 2016). This material have various advantages in terms of both sustainability and cost saving.

## **MAIN BODY**

To better investigate the viability of AAC in the South African construction industry, it is important to first understand what exactly the material is made up of. The raw materials used and the relevant proportions of each material, will influence the properties of the building material, as well as the possibility of producing it in South Africa. According to Ropelewski and Neufeld (1999). Aerated Autoclaved Concrete consists of sand, fly ash, a binding agent, a rising agent and water. The binding agent is usually a mixture of lime and cement and the rising agent is generally aluminium powder. In terms of mass, the solid components account for about 67% of the materials, with water accounting for the other 33%. The materials and the proportions of each, differ slightly based on both availability and specific project requirements. In some countries the mix proportion might be altered slightly due to the fact that certain raw materials, such as fly ash, are not readily available. Alternative materials such as lime may then be used. The proportions might also be altered in order to strengthen or weaker certain physical properties. AAC is produced to meet specific requirements, which differ from project to project.

The required properties of the blocks are determined by studying the density of the blocks. Generally pores account for anything between 30% and 90% of the volume of the blocks (Stoyan and Kadashevich, 2005). The porous nature of the material means that the finished product can be up to 5 times the volume of the sum of the raw materials (Saiyed et al., 2014). All the raw materials are mixed together to form a slurry and then poured into a specifically sized mould, to create blocks of a certain shape, size and thickness. It is then autoclaved under heat and pressure to create the properties of AAC in the specified proportions. A cellular structure known as calcium silicate hydrate is formed. A chemical reaction takes place forming a structure known as tobermorite which is extremely stable (Xella building solutions, 2016). As the mixture sets it expands and voids are formed within the structure. Once it has hardened, the porous and aerated nature makes it very lightweight.

### **Physical properties:**

The structure consists of a solid micro-porous matrix with macro pores. The system is classified in terms of the distribution and size of the pores. The structure influences the properties of the block considering permeability and density. The fact that AAC does not contain any coarse aggregate, (as is the case with regular concrete) means that it is relatively homogenous in nature. Regardless of that, the properties still vary (Narayanan and Ramamurthy, 2000). According to Yang and Lee (2015) AAC is classified as having a high porosity which means that it has a relatively low density. Due to the low density, it is a very lightweight material that weighs as little as 20% of the weight of regular concrete. The typical density of AAC blocks ranges between 460 and 750 kg/m<sup>3</sup> whereas medium density concrete blocks are between 1350 and 1500 kg/m<sup>3</sup>. High density concrete blocks are between 2300 and 2500 kg/m<sup>3</sup> (Sayied et al., 2015).

### **Mechanical Properties**

Compressive strength is defined in the Oxford dictionary as the resistance of a material to breaking under pressure. The strength of AAC increases when the density of the block is increased at production stage. Using fly ash has been proved to increase the strength to density ratio. The pressure and duration of autoclaving affects the strength of the material. High temperature and pressure lead to a more stable form of tobermorite (Narayanan and Ramamurthy, 2000). According to Beall (2000) AAC has an excellent strength to weight ratio, the compressive strength is suitable for use in single-storey, low rise load-bearing structures and without the need for steel reinforcing.

According to Yankelevsky and Avnon (1998) AAC is not commonly used as a structural element. However, it does have a high in-plane shear capacity and is therefore commonly used in infill walls as

it significantly increases the structural stiffness of the building. The resistance against lateral loads that may be encountered such as wind and earthquakes is increased.

### **Functional properties**

Straube and Schoch (2014) state that it is both the tobermorite content and the distribution of the pores that influence the durability. The more uniform the distribution of the pores is, the higher the durability of the blocks will be. The thermal conductivity of AAC is a crucial factor which may determine how well the product performs, in the varying South African weather conditions. Yang and Lee (2015) argue that due to the high porosity and low density of the blocks it will have a lower thermal conductivity than conventional concrete. According to (Wakile et al., 2015) this is an advantage as the units will offer greater thermal insulation. Structures built using AAC will have a more constant room temperature throughout the day and the thermal comfort experienced by the user will be higher, without having to alter room conditions. AAC has a thermal insulation five times that of bricks of the same thickness and this may reduce heating or cooling costs by up to 60% (Xella building solutions, 2016). The amount of thermal conductivity of the units can be altered for specific requirements. By increasing the density of the units, the thermal conductivity is increased and the units offer less thermal insulation.

AAC is one of the highest rating building materials in terms of hourly fire resistance according to Saiyed et al. (2014:24). This makes it suitable for use in walling as well as other structural elements, assuming it has the appropriate bearing capacity to support the specific load. The relatively low thermal conductivity makes the material superior in terms of fire resistance. Due to the excellent fire characteristics displayed by AAC it is commonly used in lift shaft walls, corridors, around columns and for protection as fire walls. The transient heat transfer is much lower and therefore the fire spreads significantly slower (Wakili et al., 2015). In areas of high fire risk, the blocks can thus be produced with a lower density that will make them more resistant to fire. The units are much bigger than ordinary masonry units such as bricks, meaning that there is considerably less joints, through which fire can spread.

The acoustical performance of AAC depends on the application of the blocks within the structure. According to Laukaitis and Fiks (2006) the sound absorption coefficient of AAC is low unless it has been specifically treated. Sound absorption has a large effect on the acoustical performance of a wall, floor or roofing system. The sound absorption coefficient might even be as low as 0.25. However, when AAC is treated it might be increased up to 0.6. Sayied et al. (2014:26) disagree, stating that AAC has excellent noise reduction properties. They go on to state that the noise reduction coefficient is twice that of standard concrete blocks, and up to seven times higher than that of standard concrete walls. According to Sayied et al. (2014), AAC has various other properties such as a high breathability, which discourages the growth of mould and other bacteria. Due to the fact that it is pre-fabricated in large blocks, it is very easily workable and requires little mortar and no curing. The construction period is reduced drastically which also has a positive influence on construction cost. AAC is attractive and no form of finishing is required. Furthermore AAC has been described as being pest resistant

### **The process of Autoclaved aerated concrete block construction**

According to Bhavan (2005:13) when storing the blocks, it should be stacked on top of planks and covered to protect in absorbing moisture. In specific climatic conditions it may be advisable to wet the edges in order to induce a better bond with the mortar. Bhavan (2005:14) states that the mortar shouldn't be spread too much ahead of the units that are being laid. The mortar stiffening and losing its plasticity would have a negative impact on the process. When the mortar starts hardening it should be struck off and compressed, by using a rounded 'U' shaped tool. The first course of masonry is laid with great care to ensure the correct level and plumb. A builder's line is pulled from corner to corner and the blocks are set out. The positions of the blocks are then marked out on the damp proof course. The two corner blocks are set onto a bed of mortar and the builder's line is then moved. The line is

tightly fixed, so that the rest of the course coincides with the corner levels. The rest of the course may then be set in place. After every fourth block, alignment should be checked. According to Bhavan (2005:15) the corners of the walls should be built up four or five courses high in order to establish a uniform bond and alignment intended for the wall. When placing a 'closure block' all four edges of the unit will have a mortar batter. Care should be taken to place the block into the correct position with no opening gaps. Door and window frames can be built into the wall as it would for conventional methods. Frames can also be fixed directly to the masonry with 200mm long flooring nails. These nails should be spaced between 200-400mm from each other. When two load bearing walls meet the two skins should be bonded and tied so that at least 50% of the units are intersecting. Bhavan (2005:15). These masonry units can receive many types of finishes, including a direct coat of primer and paint, cement based plaster and coats of paint. All exposed wall surfaces should be inspected on a yearly basis. Cracks can be sealed with a cement grout and finished with cement based paint (Bhavan 2005:15)

### **Sustainability of AAC:**

(Zhang et al. 2005) describes the concept of sustainable development as the capability to meet current needs without affecting the ability of future generations to meet their needs. To understand this definition one has to look at aspects such as supply of raw materials, energy consumption, environmental impact, and potential recycling and reuse.

#### ***Raw material supply***

Fly ash (FA) makes up the largest part of the raw materials required to produce AAC. Fly ash is one of the naturally-occurring by-products from the coal combustion process ([www.flyash.com](http://www.flyash.com)). According to van der Merwe et al (2014:77) in South Africa coal-fired power stations are the most common means of producing power, it produces 25 million tons of FA per annum. Van der Merwe et al (2014:78) also notes that only 5% of the FA produced in South Africa is reused, mostly as a cement extender and can be included in the mixture of concrete. Lime is the second largest component that is used to create AAC. According to the MM Invest Holding (2016) in South Africa there are 27 limestone quarries, 4 limestone mining setups and 4 lime producers. "South Africa's share of the world lime and cement output is about 0.8% and 0.7% respectively".

#### ***Energy Usage***

When considering the sustainability of a building product, it is important to look at the energy usage of a building that makes use of a specific building product. According to Drochytka et al. (2012) 40% of the energy produced in Europe is used within the building sector. If AAC is to be a sustainable option for the construction of commercial and residential buildings, then it would have to be more energy efficient than the conventional building methods that are used today. In a study about improving the energy efficiency in buildings Drochytka et al. (2012:321) found that energy usage in the residential buildings can be reduced by 7% if AAC walls are used. Drochytka et al. (2012) also found that a square metre of AAC walling saves 350kg of carbon dioxide emissions during the life cycle. If the construction of new buildings and renovation projects are carried out using AAC, there would be a decrease in the amount of energy used and CO<sub>2</sub> produced. A study on the viability of AAC for the residential sector by Radhi (2011:2087) states that AAC, a green construction material, offers energy savings because of the thermal mass and insulation properties of the material. Thermal bridging control and air-tightness are positive green building indications that AAC comprise of. The EAACA ([www.eaaca.org](http://www.eaaca.org)) states that AAC remains energy efficient over the life cycle.

#### ***Environmental Impact***

According to Yusof et al. (2015:66), the construction industry is the main source of air, water and noise pollution. In 2008 the European Union recorded a total of 859 million tons of waste generation from construction activities. It is more than one-third (37.56%) of all waste produced by economic

activities (Eurostat, 2016). According to Saiyed et al (2014:23), AAC is environmentally friendly. The process of manufacturing AAC uses materials that are natural and yields no pollutants or by-products. AAC is free from harmful and toxic substances. There is minimal impact from the processing of raw materials to the disposal of AAC waste.

### ***Recycling and Reuse***

The recycling of demolished AAC still remains a challenge. According to Bergmans et al (2015:9) AAC aggregate has lower compressive strengths than other materials used in construction components and demolition waste. Bergmans et al (2015:11) notes that it is possible to use AAC aggregate as a replacement for the sand portion in the manufacturing of new AAC. This replacement is limited to 20% of the sands fraction. Recycling of AAC is not limited to construction. Renman et al (2012:2) did a study on the use of crushed AAC as filter medium in reactive bed filter technology. Crushed AAC filter medium is a new lightweight aggregate (LWA) that can be used in several wastewater treatment applications.

### **Construction costs:**

Larger size of AAC Blocks lead to faster construction and less mortar requirements for joining. No curing is required, hence labour costs are saved. As stated by Saiyed et al, (2014:26) AAC is porous, and must have plaster or cladding of sort, on the exterior to keep out water. According to (Pytlik et al, 1992:41), the cost benefits from AAC during and after construction include lower transportation costs, condensed construction time, lower energy bills and lower maintenance costs.

A Swedish firm manufacturing AAC conducted comparative building costs in Florida. Siporex compared the cost of residential, office warehouse and commercial buildings constructed with AAC with traditional construction materials. Based on the cost per square foot of a wall surface, the cost of a traditional wall in a single-family or multi-family house would be about \$3.92. In comparison, the cost per square foot for an eight inch thick Siporex (AAC) panel was \$3.48. In this investigation, direct and indirect costs were not taken into account as well as finishes, fenestration, etc. (www.lccsiporex.com) According research conducted Bansal et al. (2013:261), states that “construction costs varies between US \$62/m<sup>2</sup> and US \$91/m<sup>2</sup> with different construction materials and it is found lowest with AAC block masonry based constructed houses.”

## **IMPORTANCE OF THE RESEARCH**

This research is important in determining the viability of AAC in the South African construction industry and whether it is a viable alternative to the traditional masonry units. Also if it could become the preferred building material within the next couple of years. The first aim was to investigate the existence of the AAC product within South African boundaries. The second aim was to determine the viability of the product. The third aim of the research was to investigate whether or not a new material product (AAC) can be brought onto the South African construction market due to the properties AAC possesses and whether it can be classified as a ‘green building material’ enabling sustainability within the construction industry. AAC consists of simple, widely available raw materials. This should make production in South Africa possible.

## **THE RESEARCH METHOD**

A mixed research method - a combination of qualitative and quantitative research have been considered. Questions were answered through analysing and understanding unstructured data; ranging from academic journals to market research and interviews with competent professionals. The quantitative research took into account the structured data in a systematic approach and was analysed. A case study was also used, comparing the cost of the Autoclaved Aerated Concrete with a conventional brick & mortar building. The case study was also used to assist with proving the other factors in terms of the viability of AAC.

## RESULTS

### **The Cost Implications of AAC concrete compared to traditional masonry.**

#### ***Manufacturing***

In South Africa “Everite” has taken the initiative to set up an AAC production plant and are currently the only producers of AAC on the continent. It was advantageous for them to set up the plant because they already had a fibre cement production plant in place. The cost to purchase equipment and to convert the existing fibre cement plant into an AAC production plant was R80 million, due to majority of the production process being the same. Everite did not purchase the most sophisticated and developed production machinery available, thus there is still a human (labour) component required. (de Klerk, 2016) The cost associated with setting up a new plant is R330 million, which is a large initial capital expenditure, which would not be affordable for most companies in South Africa. This capital saving made it financially possible for “Everite” to produce the AAC building blocks. (de Klerk, 2016) In order to pay off the initial investment of R330 million, the selling price of one block would be much higher than what it is currently for Everite. The price increase on each block would vary according to how fast one wants to pay back the initial investment made. (de Klerk, 2016). All the raw materials used to produce the AAC blocks are stored at the production plant. The factory owns its’ own sand mine and the cement is delivered to the plant via a train. Both are critical long term cost saving strategies. The Aluminium powder in South Africa is of substandard quality; therefore it is the only raw material that is imported in order to produce this product.

#### ***Construction***

In terms of AAC, a large share of the cost savings has to do with the time saved during the construction process. AAC allows for labourers to lay bricks at a faster rate than conventional South African methods of brick-laying. This is mainly due to the size and weight of the AAC component. One block of AAC (600 x 250 x 110mm) replaces 18 conventional bricks (220 x 110 x 75mm) for a one brick wall. An AAC block is approximately a quarter of the weight of an equivalent sized number of bricks. (de Klerk, 2016). This reduction in weight will reduce the required strength needed from the supporting structural components. The case study site (Hatfield Square), the use of AAC instead of conventional masonry has resulted in a saving on reinforcement in the region of 30%.

The building rate is faster due to the glue which is used to bond the blocks, it is supplied pre-made in bags and just requires water. It is a lot less labour intensive to mix and apply the glue, versus the mortar used for conventional brickwork. (de Klerk, 2016). Minimal training is required for already trained brick-layers in order to acquaint themselves with the new building methods. (de Klerk, 2016).

Workability and labour differs between conventional masonry and AAC. Chasing of services within the walls is relatively easy with AAC compared to that of brickwork. This is because the equipment used for chasing in AAC is merely tungsten tipped hand saw, whereas for brickwork one would need a grinder. The process of chasing AAC is sped up when one makes use of mechanical equipment. Once the service pipes are installed a problem arises with AAC. The voids cannot be easily closed up with the application of the glue specified. On the case study site (Hatfield Square), workers have been forced to apply a layer of conventional mortar to close up the chased section. Another issue arising with chasing is that when chasing in 110mm thick AAC blocks, the structural integrity and fire properties are influenced negatively. This requires chasing to be done in 220mm AAC blocks, this increases the price substantially, and will be more expensive than a one brick wall. AAC have designed and manufactured their own standard lintels which coincide with regular construction regulations. However, these lintels are unable to span over long distances, therefore instead, requiring the use of steel lintels over these longer spans.

A cost comparison was done by Quantity Surveyors for a student housing development consisting of a few different blocks, the highest one going up to three storeys. Two bills of quantities were created,

one with AAC and the other with conventional brickwork. From these bills the cost differences were carefully analysed. Due to the lighter structure of AAC, the foundations did not need to be as big and there is a saving of over R 500 000.00 in the foundations bill. The masonry totals were very similar with AAC being about R 150 000.00 cheaper. The total cost for the project with regular brickwork is R 72 145 937.40 and with AAC it is R 71 418 690.38. This shows a significant saving in the total building cost by choosing AAC over conventional brickwork.

### ***Operations***

The cost related to the operations of the building refers to “running costs” acquired after construction is completed. AAC has an impressive technical performance that can compete with other forms of masonry. The costs associated with making provisions for fire resistance, thermal and sound insulation are important to consider in the design stage of the building. This is due to the fact that over the life cycle of a building operations form part of a direct expense, that is acquired by the building, in order to provide an environment that is comfortable and safe. (de Klerk, 2016) Everite claim that the insulation performance is 5 times better than that of a brick of the same thickness. Since the AAC building block has a very good thermal performance rating, this allows for an opportunity in saving costs required to keep the building warm in winter and cooler in summer. Due to the fact that AAC blocks are great insulators, it can provide up to 60 per cent reduction in heating and cooling costs. (de Klerk, 2016) Although fire protection is put in place regardless of its resistance properties, one could save with insurance costs. Due to the fact that AAC blocks can withstand direct fire for up to 6 hours, insurance premiums can be lowered, thus improving operation costs to it. (de Klerk, 2016)

### **Sustainable and availability of South African resources**

The sustainability of AAC will have a significant impact on the viability thereof in the South African construction industry over the long run.

### ***Manufacturing***

Availability of raw materials is the biggest factor in determining whether the continued production of AAC in South Africa will be possible. All of the raw materials needed to produce AAC are readily available in South Africa with the exception of Aluminium powder, which has to be imported from Germany. This is due to the fact that the locally produced Aluminium powder is not of the correct grade and consistency. Sand and cement are both locally produced and there is an abundant supply thereof. Quick lime is also available locally. It is a by-product of the mining industry, so as long as mining takes place in South Africa, there will be a sufficient supply of quick lime. (de Klerk, 2016)

All the off-cuts which happen in the wet state fall onto a conveyor belt and are added back into the mix. The formula for the next mix is then adjusted according to the amount of off-cuts which are put back into the mix. In the autoclave, steam is moved from one cylinder to the next in order to prevent the steam from escaping when the baked cakes are removed. This results in a large energy saving, because new steam doesn't have to be generated every time. (de Klerk, 2016)

### ***Construction***

AAC blocks are very easy to build with and due to the size of the blocks, it is much easier to build straight, plumb walls. There is a significantly lower wastage factor on site than there is for traditional masonry. AAC units can be recycled. Construction using AAC leaves a much tidier site, because minimal mortar has to be mixed. Only the adhesive needs to be mixed with water. The recycled product has various uses. One of the most prominent uses is in water filtration systems. (de Klerk, 2016)



## ***Operations***

The thermal resistance value (R-value) of a 150mm AAC block is 1.17 compared to 0.35 for a one brick (220mm) wall. The finished product of a building constructed of AAC is therefore 4 times more energy efficient than brickwork, due to the fact that AAC has superior insulation properties compared to traditional masonry. With the recent focus on green building solutions, AAC proves to be a very good alternative solution. (de Klerk, 2016)

## **Impact on the duration of the construction process**

The reduction of time during the manufacturing and construction process is believed to be one of AAC's greatest attributes.

## ***Manufacturing***

The process of creating an AAC block within South Africa has a number of limitations and benefits. AAC gains its attributes through the various raw materials used in producing the block. Each material has several properties which provide AAC with all its characteristics. These include fire resistance, thermal & sound insulation, ease of use and workability, low carbon footprint, low heating and cooling costs, and lightweight and strength. (de Klerk, 2016) It is therefore imperative to attain the highest quality and efficient supply of raw materials to ensure these qualities are met. Everite have their own sand plant as well as contractual agreements in place with other high-profile local suppliers in order to supply them the highest grade materials via rail services straight to Everite's batching plants. This leads to a quick, reliable supply of materials which drastically reduces waiting-time from other, non-efficient suppliers. This allows Everite to have a more productive initial stage within the manufacturing process. (de Klerk, 2016)

Unfortunately, the Aluminium powder is imported from Germany due to quality and cost factors. Delivery of the powder can be delayed due to various aspects which can hamper the manufacturing process. (de Klerk, 2016) Due to the high initial start-up cost of the plant, Everite could only afford one production line. The current production line is able to produce 8 640 blocks of AAC per day. This comprises of 108 pallets (80 blocks) of AAC on average. This is a limiting factor as there are only 8 640 blocks of AAC available for retail per day. The production of AAC blocks may be increased by adding another production line. (de Klerk, 2016) Another limiting factor is that currently they have to unpack the AAC blocks from the production line and palletise manually by hand. This may be rectified by means of specific machinery, which can complete this process; however this system has not yet been commissioned. (de Klerk, 2016)

The AAC cake is baked by means of an autoclave furnace. The factory has 4 autoclave furnaces which are a total of 40m in length. During this process, the autoclaves spend a total time of 10hours baking. This is a major time constraint as the autoclave process limits the amount of blocks that can be produced as there is a limited amount of blocks that can go through the autoclave per day. This waiting period will also delay the mixing of the following batch as the pre-baked mix cannot wait be exposed to the 'outdoor' environment longer than the 30minutes of the production line.

Once baked, the cakes are removed from the autoclaves. The entire process of manufacturing the product, unpacking, curing and preparing for delivery can be estimated to take 24hours. At this stage, AAC is ready for use and is fully capable of meeting construction needs. (de Klerk, 2016) In comparison, concrete can take up to 28 days just to cure and meet the required strengths. This very short manufacturing time allows for rapid production and stockpiles can be increased rapidly.

## ***Construction***

The larger size of AAC blocks leads to a huge saving in construction time. Two different sizes of AAC blocks are produced, namely a 600 x 250 x 110mm block and a 600 x 250 x 150mm block. In

South Africa, they currently only produce the 150mm wide block, this is due to production constraints at the Everite factory. (de Klerk, 2016)

The speed of construction using the AAC blocks is proclaimed to be two times faster than that of a half brick wall and four times faster than a one brick wall, when compared to conventional masonry. The reason for this increased speed of construction is mainly due to the dimensions of the AAC block. One AAC block equates to 9 bricks in a conventional half brick wall and 18 bricks in a one brick wall. (Ravid, 2016). The blocks are also of a light weight nature and allow for easy handling and building. The mortar used in conventional brickwork is replaced with a special glue adhesive, which is applied quickly and with minimal effort.

The building method used is of very similar nature to conventional masonry. The major difference between the two is the different application of the mortar or glue adhesive. Current brick-layers have been trained within a day to acquaint themselves with the 3-4mm thick glue adhesive layer. Great accuracy is needed in doing so as there is very little tolerance available.

## CONCLUSION

AAC has only recently entered the South African construction industry. In the past it was not a feasible building material due to the fact that it had to be imported and this obviously had made it relatively expensive. It is now being locally produced by Everite and this has resulted in a drastic reduction in the cost of the unit to contractors. There are plans in place to set up a few more production plants within South Africa. This will facilitate the growth in popularity of the building material. The vast majority of the feedback received from the various parties involved in the Hatfield Square student housing development has been positive. The only negative feedbacks are due to the fact that it is the first time the product is being used in South Africa; therefore nobody has any prior experience using the product. There are no SABS standards for the use of AAC as yet and this proved problematic. Small problems were encountered on site with regards to items such as chasing and wall heights. The more the product is used the more familiar engineers, contractors and architects will become with it and as soon as SABS standards are put in place, most of these problems will be a thing of the past.

Everite, however, are releasing the product only to approved contractors in order to ensure that they can monitor that the product is used correctly. Incorrect use can result in various failures and this could tarnish the reputation of the product. The product will be systematically made available until a point where it will be available to the public. AAC has all of the potential to become the next big thing in high-rise, commercial and residential construction within South Africa. However, with AAC being new to the industry, it does not prove feasible in low-rise construction. This is due to the fact that extensive testing has been conducted with high-rise buildings whereby the demand for advanced building technologies is far greater.

The management of the introduction thereof into the industry will be the determining factor of its success. The properties and advantages of AAC speak for themselves and there is undoubtedly a demand for such a product. Therefore it is safe to say that AAC is a feasible and sustainable as a building material in the South African construction industry.

## BIBLIOGRAPHY

1. Bansal, D., Singh, R., & Sawhney, R.L. 2014. *Effect of construction materials on embodied energy and cost of buildings-A case study of residential houses in India up to 60m<sup>2</sup> of plinth area*. Journal of Energy and Buildings. 60: 260-266.
2. Beall, C. 2000. *New masonry products and materials*. Prog. Struct. Engng Mater. 2: pp.296.

3. Bergmans, J., Nielsen, P., Snellings, R., & Broos, K. 2016. *Recycling of autoclaved aerated concrete in floor screeds: Sulfate leaching reduction by ettringite formation*. Journal of Construction and Building Materials. 111: 9-14.
4. Bhavan, M. 2005. *Code of Practice for Construction of Autoclaved Cellular Concrete Block Masonry*. Indian standard.
5. CSR Hebel. *Design and Build with Hebel*, [Online] Available: <<http://hebel.com.au/design-and-build-with-hebel>> [Accessed 2 June 2016].
6. De Klerk. *Everite*. 2016. [Interviewed October 2016].
7. Design. [Online]. Available :< [www.lccsiporex.com](http://www.lccsiporex.com) > [Accessed 26 June 2016].
8. Drochytka, R., Zach, J., Korjenic, A., Hroudova, J. 2012. *Improving the energy efficiency in buildings while reducing the waste using autoclaved aerated concrete made from power industry waste*. Journal of Energy and Buildings, (58): 319-323.
9. Economics. [Online] Available < <http://www.aerconaac.com/technical-manual-economics.html>> [Accessed 10 April 2016].
10. Eurostat [Online] Available < <http://ec.europa.eu/Eurostat/statistics> > [Accessed 10 April 2016].
11. Laukaitis, A. and Fiks, B. 2006. *Acoustical properties of aerated autoclaved concrete*. Applied Acoustics. (67) pp. 295
12. Limestone. [Online] Available: <<http://mminvestholding.co.za/limestone#tab-id-11>> [Accessed 28 April 2016].
13. Mminvestholding. [Online] Available < <http://www.mminvestholding.co.za>> [Accessed 15 April 2016].
14. Narayanan, N. & Ramamurthy, K. 2000. *Structure and properties of aerated concrete: a review*. International Journal of Cement Composites and Lightweight Concrete, 22(5): 321-329.
15. Oxford dictionary. *Compressive Strength*. [Online] Available: <[www.oxforddictionary.com](http://www.oxforddictionary.com)> [Accessed 13 July 2016].
16. PwC. 2016. *Global Construction 2030: A Global Forecast For The Construction Industry To 2030*. [Online] Available: <<http://www.pwc.com/gx/en/industries/engineering-construction/publications/pwc-global-construction-2030.html>>. [Accessed 14 August 2016].
17. Pytlik, E.C., Saxena, J. 1992. *Autoclaved Cellular Concrete: The building material for the 21<sup>st</sup> century*. *Advances in Autoclaved Aerated Concrete*. Proceedings of the 3<sup>rd</sup> rilem International symposium on Autoclaved Aerated concrete, Zurich, Switzerland.
18. Radhi, H. 2011. *Viability of autoclaved aerated concrete walls for the residential sector in the United Arab Emirates*. Journal of Energy and Buildings, 43: 2086-2092.
19. Ravid, M. *Paragon Architects*. 2016. [Interviewed October 2016].
20. Renman, G., Renman, A. 2012. *Sustainable use of crushed autoclaved aerated concrete (CAAC) as a filter medium in wastewater purification*. KTH Royal Institute of Technology, Department of Land and Water Resources Engineering: Stockholm, Sweden.
21. Renman, G., Renman, A. 2012. *Sustainable use of crushed autoclaved aerated concrete (CAAC) as a filter medium in wastewater purification*. Wascon 2012 Conference proceedings.
22. Resource & Environment. [Online] Available: <<http://www.eaaca.org/index.php/aac/resources-environment>> [Accessed 27 April 2016].
23. Ropelewski, L. and Neufeld D.N. 1999. *Thermal Inertia Properties of Autoclaved Aerated Concrete*. Journal of Energy Engineering. 125 (2) p. 59.
24. Saiyed, F.M., Makwana, A.H., Pitroda, J. Vyas, C.M. 2014. *Aerated Autoclaved Concrete (AAC) Blocks: Novel Material for Construction Industry*. International Journal of Advanced Research in Engineering, Science & Management, 1(2): 21-32.
25. Schnitzler, S. 2006. *Applied research paper. Autoclaved Aerated Concrete as a Green Building Material*.
26. Straube, B. and Schoch, T. 2014. *The durability of autoclaved aerated concrete*. Mauerwerk 18 (¾), pp.240.
27. Stoyan, D., Kadashevich, I. 2005. *Stochastic Modelling of the Geometrical Microstructure of AAC*. Autoclaved Aerated Concrete, pp. 229-234.

28. The World Counts. *Consequences Of Depletion Of Natural Resources*, Accessed 5 November, [Online] Available: <<http://www.theworldcounts.com /stories/ consequences of depletion of natural resources>>. [Accessed 19 June 2016].
29. Van der Merwe, E.M., Prinsloo, L.C., Mathebula, C.L., Swart, H.C., Coetsee, E., Doucet, F.J. 2014. *Surface and bulk characterization of an ultrafine South African coal fly ash with reference to polymer applications*. Journal of Applied Surface Science, 317: 73-83.
30. Wakile, K.G., Hugi, E., Karvonen, L., Schnewlin, P. and Winnefeld, F. 2015. *Thermal behaviour of autoclaved aerated concrete exposed to fire*. Cement & Concrete Composites. 62, pp. 52.
31. What is flyash. [Online] Available:< <http://flyash.com/about-fly-ash/>> [Accessed 28 April 2016].
32. Xella Building Solutions. [Online] Available <http://www.xellabuildingsolutions.com/AAC-blocks.php> [Accessed 18 June 2016].
33. Xella International, *The Hebel Brand*, [Online] Available <<http://www.xella.com /en/hebel.php>> [Accessed 21 July 2016].
34. Yang, K. and Lee, K. 2015. *Tests on high-performance aerated concrete with a lower density*. Construction and Building Materials. pp. 109.
35. Yankelevsky, D.Z. and Avnon, I. 1998. *Autoclaved aerated concrete behavior under explosive action*. Construction and Building Materials 12: pp. 359.
36. Yusof, N., Abidin, N.Z., Zailani, S.H.M., Govindan, K., Iranmanesh, M. 2016. *Linking the environmental practice of construction firms and the environmental behaviour of practitioners in construction projects*. Journal of Cleaner Production, 121: 64-71.
37. Zhang, Z., Provis, J.L., Andrew, R. & Wang, H. 2005. *Geopolymer foam concrete: A emerging material for sustainable construction*. Journal of Construction and Building Materials, 56: 113-127.

# THE VIABILITY OF USING ALTERNATIVE BUILDING SYSTEMS IN THE GOVERNMENT SUBSIDISED HOUSING ENVIRONMENT

Mr. J.J.A. Jansen<sup>1</sup> and Mr. A.C. Fourie<sup>2</sup>

<sup>1</sup>Lecturer, [riaan.jansen@up.ac.za](mailto:riaan.jansen@up.ac.za)

<sup>2</sup> Post Graduate Student, [armandleg.4e@gmail.com](mailto:armandleg.4e@gmail.com)

Department of Construction Economics, Engineering, Built Environment and Information  
Technology Faculty, University of Pretoria, Corner Lynnwood and University Road,  
Hatfield, Gauteng, South Africa, 0002

## ABSTRACT

South African government subsidised housing programmes have become synonymous with slow service delivery, poor fund management and poor quality housing units. Although aimed to increase production capacity and to meet the basic needs of people, these programmes do not allow for increases in budget. The study investigates the viability of selected alternative building systems in government subsidised housing units for a typical lower income residential area. A case study approach was followed where a comparative cost analysis was conducted with the use of bills of quantities for a typical government subsidised housing unit. Three different alternative building systems' construction costs for a single housing unit were compared to the conventional building system. The study found that the conventional method of building was the cheapest, followed by a composite framed system which was 5 % more expensive, followed by a rammed earth system which was 5.9% more expensive and lastly a light steel framed system which was 14% more expensive. The conventional building system used to build the government subsidised housing units are the most cost effective alternative from the systems considered for this study. However, one should ask if the higher construction cost justifies higher life cycle costing and unsustainability.

*Keywords: Alternative building systems, Government subsidised housing, Rammed Earth systems, Composite Systems, Framed Systems*

## INTRODUCTION

The South African government initiated its government subsidised housing (GSH) programmes in 1994 in an effort to meet its new social responsibility mandates. These mandates included housing procurement, among other services deemed to be basic necessities. Government aimed to increase the productive capacity of its workforce by providing basic necessities, thus allowing previously disadvantaged citizens to be more active in the upliftment of the country's economy (Simons, J.A., Irwin D.B. & Drinnien B.A., 1987). Since their inception, GSH programmes have experienced numerous shortcomings and issues. In a bid to improve service delivery, these problems have been addressed in an attempt to make GSH programmes as efficient as possible (Bond & Tait, 1997). The increasingly difficult economic climate coupled with limited funding only allows for consistently declining service delivery while GSH programmes are continuously mismanaged.

Considering that funding is the limiting factor, to increase the amount of housing units that can be delivered the cost per unit needs to be decreased. The current deliverable however, does not conform to national habitable requirements (SANS 10400 XA building code, 2011) which leads to marginal savings on initial capital outlay at the cost of substantial life cycle and reconstructive expenditure (Van Rensburg, 2015). This study aims to investigate whether a housing unit built with alternative

building methods with superior quality can be constructed at the same expenditure level as the current conventional construction methods.

This study also aims to contribute to the field of viability of alternative building systems (ABS), with particular focus on their application in the GSH sector in South Africa. The relationship between additional expenditure and a superior housing unit in the GSH sector will also be introduced. This study aims to offer a practical solution to the issue of dysfunctional service delivery in the GSH sector in South Africa.

### **Available literature and most important previous studies.**

In research conducted by Perry (2012), Cheng, X., Zhao, X., Chen, Y. & Li, Z. (2012), Boaden (1990) and Ngowi (1997), correlations can be drawn between structural aesthetics and a recipient's willingness to accept a given dwelling. This phenomenon originates from an underprivileged mind-set. As a result, people desire a standard of housing that aesthetically conforms to the visual equivalent of the typical upper class masonry residential structure and the connotation to status that is still prevalent (Boaden, 1990). Hughes & Burton (2004) proved a direct correlation between younger, better educated people and their willingness to accept alternative means of construction for their homes. People that did not fit into this demographic however, required an average saving of 15,100 British pounds to consider a steel frame house as opposed to the conventional masonry house.

### **Important gaps, inconsistencies and controversies**

In research conducted by Perry (2012), Cheng et al (2012), Boaden (1990) and Hughes & Burton (2004), there is a strong correlation, internationally, between education and age, which are generally closely linked due to South Africa's political history.

This study aims to establish the viability of using ABS in the GSH sector in South Africa, investigating whether a superior housing unit can be produced at the same capital expense per unit. This will be determined by way of comparative cost analysis, using a typical 52m<sup>2</sup> GSH unit layout and corresponding Bills of Quantities document (BOQ). The final cost of each building system will be estimated and compared to establish whether it is indeed viable to replace the current building practice in favour of one of the selected ABS's.

## **MAIN BODY**

The Bill of Rights in the Constitution of the Republic of South Africa grants basic human rights to all legal citizens of the country, adequate housing being one of these basic human rights. (South Africa, 1996). The realisation of these rights is enforced through regulations and legislation, which the government must abide by (South Africa, 1996).

The National Housing code of 2000 set policies by the government to assist households in obtaining adequate housing through various housing assistance programmes introduced since 1994 (South African Government Gazette, 1996). The main function of the National Housing Act (No 107 of 1997) is primarily for the provision of adequate housing through housing schemes and programmes such as the integrated residential development programme (IRDP), upgrading of informal settlements programme (UISP) and community residential units (CRU) (Department of Human settlements, Government of South Africa, 2009). The need to increase the minimum standard in quality of delivered government funded housing was identified as early as 1998, as stated by May & Govender (1998).

The Department of Human Settlements has reported that between 1994 to December 2013, 2.8 million housing units were delivered. In 2013, Financial and Fiscal Commission (FFC) Chairman, Bongani

Khumalo, estimated that it would cost the government approximately R 800 Billion to eradicate the housing backlog by 2020 (Van Rensburg, 2015). The South African government has realised that its roll out, over the past 18 years, of RDP houses based on conventional building methods is not sustainable in terms of expenditure, time and maintenance. As a result, alternative means of delivering government subsidised housing needs to be investigated. Van Rensburg (2015) stated that state agencies such as the National Home Builders Registration Council (NHBRC) and the Construction Industry Development Board (CIDB) have stated that where the RDP houses were provided, their beneficiaries were not satisfied with the quality of housing they received, hiring these units out and, in severe cases, simply not taking up residence in these units.

Issues experienced with GSH units range from leaks to structural cracks and even total collapses during severe weather. The CIDB identified weaknesses in the procurement process to be a major problem in the construction process of GSH projects. The estimated cost to make these homes structurally sound and compliant to NHBRC minimum technical requirements is approximately R400 million according to the NHBRC (Van Rensburg, 2015). The Department of Housing in the Eastern Cape estimated that it would cost approximately R 360 million to rectify structural issues in 20 000 housing units previously provided to recipients (Van Rensburg, 2015).

Possible difficulties such as design, building specifications and procurement structures, have been proven inconsistent and unreliable as pointed out by the Parliamentary Monitoring Group. This is evident in the poor quality of housing units that pass the current screening and quality controls that may be in place, and are given to recipients. In most cases, recipients wait years to receive an ultimately substandard housing unit that is not in compliance with the relevant SABS and NHBRC standards adhered to in terms of the conventional housing construction. These standards have been made even more stringent with the introduction of the SANS 10400-XA standards governing the minimum standards for green design (SANS 10400 XA building code, 2011). This study aims to investigate the viability of ABS being implemented in the GSH sector in South Africa. Viability will be determined by means of a comparative desktop study. Project viability will be explored with rammed earth bricks, space frame construction and light steel frame construction against the conventional building system, concrete cinder blocks.

### **Alternative construction methods**

As stated by Muhammed & Hayatuddeen (2007), “Provision of appropriate housing at an affordable cost has remained a nagging problem despite major developments in modern building techniques”. In 1886 Charles Booth first implemented the idea of social responsibility. This saw state supplying housing to citizens in the lowest income bracket in the country who are not capable to do so for themselves. Since the inception of social housing, the main concern has been how best to spend taxpayers’ money to benefit the largest possible group of people with an adequate housing unit. This issue revolves around spending as little as possible per housing unit whilst maintaining conformity to whichever building standard is applicable in the area concerned (Himmelfarb, 1991).

In South Africa there are requirements by the NHBRC and NBR as well as SANS regulations, with the SANS 10400-XA being the newest addition. Arguments are prevalent in the market place that Innovative Building Technology (IBT’s) are an effective way to manage quality, by manufacturers’ specifications for installation, as well as their potential to save on capital costs. The potential saving per unit is dependent on the size and scope of the project based on economies of scale (Investing Answers, 2013).

### **Construction cost**

Construction cost is one of the most important and determining factors in the construction industry (Stats SA. 2016). A project developer’s main goal is generally to minimise expenditure whilst maximising the quality of the unit being constructed. The components that affect the construction cost are material price, project duration, labour rates, transport prices, inflation, insurances, etc. An

increase in the price of these items means an increase in the price of the project. The project developers for low cost housing therefore need to determine what the expenses is, how to cut back on costs, to determine what type, quality and quantity of certain materials and methods can be used. By using different methods or materials in low cost housing, the objective is to optimise the cost to project quality ratio as far as possible for both initial capital outlay and life cycle costing purposes (Stats SA, 2016). By using alternative building systems, it allows for alterations to the standard design in terms of elements required from various systems which allow for potentially lower cost / quicker design requirements, such as raft foundations, integrated steel roof structures, etc.

### ***Light Steel Frame (LSF)***

LSF construction in the residential construction sphere is much faster than the conventional masonry approach to construction. This time saving offers savings in both project duration and the use of manual labour. The rate of erection and cost savings are a major selling point used by many manufacturers, as stated by Barnard (2012). Due to the specialised nature of manufacture, LSF construction may not be feasible in smaller scale projects (Jansen, 2015). Because of the varying size of projects of this nature, potential savings that may be negotiated based on economies of scale cannot be quantified. The design process for LSF construction allows for the installation of services in the structural panelling and as a result, services are installed without the need for chasing and fixing of completed works. This in turn decreases operational time on services being chased and installed afterwards. Items, including the wall cladding (acoustic, water-resistant and fire rated) and wall finishes affect capital expenditure. Items such as roof cladding, ceilings and raft foundations remain the same as for conventional masonry housing units (Innosteel, 2015).

### ***Space Frame (SF)***

SF construction is based on the placement of standard 3D structural wire mesh insulated panels, which are fixed to a raft foundation, tied together, and finally plastered for aesthetics. SF is a more standardised system in comparison to LSF, where standard panels are supplied and panels are augmented on site to fit their placement (doors, windows, corners, etc.). Due to ease of placement and relatively simple installation, minimal skilled labour is required. Savings in labour and a comparatively quick establishment of panels offer a faster and cheaper alternative to masonry construction. This saving again is dependent on the scale of the project in question, with compounded savings on increased project scale (Graca and Gaspari Associates, 1982). SF panels offer far greater savings in terms of operational and future costs due to the superior thermal and acoustic performance as well as durability, leading to a saving in the overall lifecycle operational costs (Graca and Gaspari Associates, 1982).

### ***Rammed Earth Brick (REB)***

REB construction requires mechanised equipment in order to extrude and compress the soil and cement into a brick. Mechanisation of REB results in a reduction in labour requirements and an increase in the use of plant, machinery, fuel and capital. The mechanisation process drastically decreases construction time assuming that brick production had commenced at the required time to ensure that the daily unit requirements can be met and maintained (Treloar et al., 2001).

On site production of REB units eliminates logistic requirements, replacing them with space and materials management. REB in terms of GSH applications will necessitate on site preproduction and stockpiling as opposed to mass orders masonry units, creating community involvement and job creation. REB production can also be managed to suite required material quantity, allowing for cash flow management and minimising fixed capital, which allows contractors increased control over their project liquidity, which in turn affords them the luxury of increased leeway in their financial planning.



## RESEARCH DESIGN AND METHODOLOGY

The aim of this study is to determine the viability of the building systems that are being considered in this study for comparative cost analyses. Analysis will be based on a typical GSH unit as used by Jansen (2011) by means of adapting the BOQ to cater for the ABS in question.

BOQ's will be based on a standard design of a 52m<sup>2</sup> typical GSH unit. Provision will be made for design variances between systems that allow for competitive advantages over other systems. Material rates will be sourced from manufacturers and competitive market tenders. Unit cost will then be determined per construction system for comparative cost analysis.

The viability analysis will be completed by determining the most cost effective building system by comparing priced BOQ's for the standard 52m<sup>2</sup> GSH unit, this data will be used to conduct a comparative cost analysis to determine the most cost effective building systems.

## RESULTS

Each building system's comparative cost was established by applying it to the construction of a typical RDP house design. The cost involved only entails the physical construction of the housing unit as bulk services, land acquisition and so forth are factors dealt with on a project wide scale and not per unit. This maintains comparative integrity; only the cost of construction of a single unit will be involved per building system in question.

### Building system costing

#### *Concrete Cinder Block (CCB)*

- The cost to deliver a CCB house per unit is R 378 198.71
- Design variations (Concrete, Building Envelope, Roofing & Plaster) account for R51 100.00 (39.95% of total construction cost)

#### *Space Frame (SF)*

- The cost to deliver a SF house per unit is R 397 137.64
- Design variations (Concrete, Building Envelope, Roofing & Plaster) account for R167 713.10 (42.23% of total construction cost)

#### *Earth Brick (EB)*

- The cost to deliver a EB house per unit is R 400 545.56
- Design variations (Concrete, Building Envelope, Roofing & Plaster) account for R170 702.50.00 (42.62% of total construction cost)

#### *Light Steel Frame (LSF)*

- The cost to deliver a SF house per unit is R 431 148.00
- Design variations (Concrete, Building Envelope, Roofing & Plaster) account for R195 564.00 (45.36% of total construction cost)

In conclusion, this data forms the basis of the comparative analysis that will be handled in the discussion chapter. Quantitative principals will be applied to ascertain which construction system is the most viable system to be used in the construction of GSH programmes and what percentage of their construction costs can be attributed to system specific costs.

## **RESULTS - SUPPORTING DATA**

This study focuses on the viability of implementing alternative building systems in the GSH sector. A comparative cost analysis has been conducted based on the findings generated from the Standardised BOQ's of a typical 52m<sup>2</sup> low cost housing design.

### ***Concrete Cinder Block (CCB)***

CCB construction is the cheapest system at R 378 198.71 per unit. This can be attributed to the extremely low cost of materials (concrete cinder blocks). Due to this factor, we observe the lowest cost assigned to design variance, 39.95%, due to the ratio between the standard finishes and a comparatively lower envelope cost.

### ***Space Frame (SF)***

The second cheapest building system is SF construction at R 397 137.64 per unit. SF is 5.01% more expensive per housing unit in comparison to CCB construction. This cost difference however, does not reflect the cost and time savings presented by SF construction. Design variation cost accounts for 42.23% for SF construction, slightly higher due to increased material costs in comparison to the internal fixed costs, but still in the same general region as CCB construction.

### ***Earth Brick (EB)***

The third cheapest building system is EB construction at R 400 545.56 per unit. EB is 5.91% more expensive per housing unit in comparison to CCB construction. Design variation cost accounts for 42.62% for EB construction, also slightly higher due to increased material costs in comparison to the internal fixed costs.

### ***Light Steel Frame (LSF)***

The most expensive building system is LSF construction at R 431 148.00 per unit. LSF is 14.00% more expensive per housing unit in comparison to CCB construction. Design variation cost accounts for 45.36% for LSF construction, also slightly higher due to increased material costs in comparison to the internal fixed costs. As hypothesised, design variable elements consist of more than 25% of the cost of building a typical government subsidised housing unit, this proves the impact that choosing the right material of construction can have on the costing of a residential housing programme.

### ***Case Study Application***

Also as hypothesised, the most viable system for the construction of GSH units is the concrete cinder block system. This supports the South African government's choice to implement this building system purely from a viability point of view. Unfortunately, construction is only the means to an end, this end being the provision of housing units to an acceptable standard. Taking Van Rensburg's case study of 20 000 units that requires an additional R 360 000 000 budget to obtain a liveable standard. The total cost for the conventional concrete cinder block method, consisting of the original construction cost of R 7 563 974 200 and the additional R 360 000 000 restoration cost amounts to R 7 923 974 200. The proposed budget for restoring these dwellings comes to 4.76% of the initial cost for the dwellings. However, should these housing units have been constructed from the next most viable construction system from this study, Space Frame, it would have had a construction cost of R 7 942 752 800.00, indicating a sizable 5.01% increase in construction costs in comparison to the original construction cost of the conventional concrete cinder block system. This percentage is drastically decreased to 0.25% when the additional expenditure of 4.76% of the initial cost is required to restore these dwellings (CCB construction) to an inhabitable condition. Whilst an additional R 378 955 107 to build these units from a superior material (spaceframe) seems a sizable figure, but is warranted by the potential benefit? These benefits include reduced maintenance, increase in quality and durability and maintaining structural integrity. The effective additional capital is 0.25% of the project value, which equates to R 18 778 600.00 (the cost of building roughly 50 of the Concrete Cinder Blocks housing

units). Diminishing public faith in the dwellings procured by government aside, when the same tender process is employed to restore these housing units, it is arguable that the same issues will resurface with time. Incurring another sizable amount of money for restoration.

While R 18 778 600.00 is still a considerable amount, it is miniscule in comparison to the initial capital expenditure required to fund this GSH programme for example. Government should evaluate what the cost of effectively meeting their mandate is and what the trust of the impoverished lower class is worth to a democratic government, which is effectively failing to meet the mandates promised to their electing populous over 20 years ago.

## **CONCLUSIONS AND RECOMMENDATIONS**

This study aimed to determine whether it would be viable to make use of alternative building systems in the construction of government subsidised housing with a supplementary interest in the contribution towards net construction cost. The viability of three alternative building systems were investigated and compared to the current system used to build GSM housing.

This study determined that the current system used in the construction of government-subsidised housing in South Africa is still the most financially viable alternative. Design dependant variables was also proven significant.

A notable observation is that the potential cost for restoring sub-par housing units back to a liveable standard and the processes followed in the procurement of these remedial works may simply restart a broken process, requiring additional funding to restore dwellings again. The assumption that the funding to restore these dwellings is approved in the first place, given the rather tedious bureaucratic route to the approval of funding. This may render alternative building systems viable in terms of life cycle costing as a whole.

### **Limitations**

Construction time, system durability and performance factors (thermal, acoustic, fire rating, etc.) were not considered in the calculation of viability, but their importance was noted in the discussion and conclusion.

### **Contributions**

Although this study has affirmed that the current method of construction for GSH units may be the most viable in terms of initial capital outlay, it does not necessarily hold true for the lifecycle costing of these units. With the building system, specific cost items make up a sizable amount of the total construction costs. This sizable impact that the specified building material has on project budgets is irrefutable.

While the scope of this study does not look into all of the aspects required to ensure the efficient production, management and delivery of government subsidised housing, it has offered unique findings. While these findings do not offer the solution to immediate improvement to the government service, it is the intention of this study to catalyse improvement in the sector. This catalyst comes in the form of the systems viability data, which will hopefully inspire a more in depth consideration of all factors that realistically affect the quality of life of the average government subsidised housing recipient.

## REFERENCES

- Barnard, J. 2012. *Alternative building materials: Light Steel Frame Building in SA*. Lecture to the Building Science 320 class. 2014-08-19.
- Boaden, B. 1990. *The myths and the realities of shack upgrading*. Urban Forum, 1(1):75-84.
- Bond, P. & Tait, A. 1997. *The failure of housing policy in post-Apartheid South Africa*. Urban Forum, 8(1):19-41.
- Cheng, X., Zhao, X., Chen, Y. & Li, Z. 2012. *A model study on affordable steel residential housing in China*. Front Structural Civil Engineering, 6(3):288-296.
- Department of Human settlements, Government of South Africa, 2009. *National Housing Code*. A simplified guide to the national housing code, 1, 13-59.
- Graca and Gaspari Associates. 1982. *Space frame*. [Online] Available from: <http://www.space-frame.co.za>. [Accessed 12-05-2016].
- Himmelfarb, G., 1991. *Poverty and compassion: The moral imagination of the late Victorians*. Alfred a Knopf Inc.
- Hughes, T. & Burton, M. 2004. *Consumer Response to Steel Frame Housing: A Choice Modelling Experiment*. [Online] Available from: <http://www.innosteel.co.za/process/> [Accessed: 19-03-2016].
- Innosteel. 2015. *Process*. [Online] Available from: <http://www.innosteel.co.za/process/> [Accessed: 2015-09-19].
- Investing Answers. 2013. *Economies of Scale*. [Online] Available from: <http://www.investinganswers.com/financial-dictionary/economics/economies-scale-1008> [Accessed 15-05-2016].
- Jansen, J.J.A. 2011, *A Grounded Theory To Systems Criteria Development For Innovative Building Systems Implementation*. University of Pretoria.
- Jansen, J.J.A. 2015. *Light steel frame, lecture notes distributed in Building Sciences 320*. The University of Pretoria, Pretoria on 22th August 2015.
- May, J. and Govender, J., 1998. *Poverty and inequality in South Africa*. Indicator South Africa, 15, pp.53-58.
- Muhammed, U.F., Hayatuddeen, A. 2007. *Earth Brick Construction: Cutting down the cost of walling in buildings*. [Online] Available from: [http://www.academia.edu/3682295/Earth\\_Brick\\_Construction\\_Cutting\\_Down\\_The\\_Cost\\_Of\\_Wall\\_In\\_Buildings](http://www.academia.edu/3682295/Earth_Brick_Construction_Cutting_Down_The_Cost_Of_Wall_In_Buildings) [Accessed 10-11-2016].
- Ngowi, A.B. 1997. *Improving the traditional earth construction: a case study of Botswana*. Construction and Building Materials, 11(1):1-7.
- Perry, A.F. 2012. *Sustainable and informal: a case study in the shadows of housing policy in Masiphumelele, Cape Town, South Africa*. Indilinga: African Journal of Indigenous Knowledge Systems, 11(1):114-127.

SANS 10400 XA building code. 2011. *Republic of South Africa: Edict of Government*. [Online] Available from: [www.home.gil.com.au/~jandi/harvard/Harvard\\_v.2.02.pdf](http://www.home.gil.com.au/~jandi/harvard/Harvard_v.2.02.pdf) [Downloaded: 05-07-2016].

Simons, J.A., Irwin D.B. & Drinnien B.A. 1987. *Maslow's Hierarchy of Needs*. [Online] Available from: [http://eznow7jgmenpjz.pic3.eznetonline.com/upload/MASLOW\\_YQfG.pdf](http://eznow7jgmenpjz.pic3.eznetonline.com/upload/MASLOW_YQfG.pdf) [Accessed 04-09-2016].

Stats SA. 2016. *Construction: what are the costs per square metre?* [Online] Available from: <http://www.statssa.gov.za/?p=7974> [Accessed 12-11-2016].

South African Government Gazette. 1996. *The Bill of Rights of the Constitution of the Republic of South Africa, No. 108 of 1996*. Government Gazette, 17678(2083):1-177. [Online] Available from: [http://www.saflii.org/za/legis/consol\\_act/cotrosa1996423.pdf](http://www.saflii.org/za/legis/consol_act/cotrosa1996423.pdf) [Accessed 10-11-2016].

Treloar, G.J., Owen, C. & Fay, R. 2001. *Environmental assessment of rammed earth construction systems*. Structural survey, 19(2):99-106.

Van Rensburg, D, 2015. *How urbanites can invest in virtual cattle*. City Press, 18 October. [Online] Available from: <http://city-press.news24.com/Personal-Finance/How-urbanites-can-invest-in-virtual-cattle-20151018> [Accessed 09-08-2016].

# WHOLE LIFE CYCLE COSTING FOR SUSTAINABLE FACILITY MANAGEMENT

Noor Azeyah Khiyon

Undergraduate Programme Lead, School of the Built Environment,  
University of Reading Malaysia, Johor, Malaysia, n.a.khiyon@reading.edu.my

## Abstract

Buildings are long term investment and associated with environmental concerns over its life span. Thus, more projects have been procured using Public Private Partnership and Private Finance Initiatives (PPP/PFI). Likewise, in Malaysia, PPP/PFI projects are escalating which render the importance of Whole Life Cycle Costing (WLCC) and sustainable facility management. However, PPP/PFI projects in Malaysia are still young and tend to focus more on the value for money rather than its environmental impacts. The research seeks to examine the importance of WLCC for SFM as well as to investigate the barriers and drivers of SFM of PPP/PFI projects in Malaysia. Quantitative approach is adopted and questionnaires are distributed to all members of Malaysian Association of Facility Management (MAFM) accordingly. Collected data is analysed by means of Severity Index (SI) and Relative Importance Index (RII). Findings revealed that lack of guidance documentation is the main barrier while the reduction of life cycle costing is regarded as the main driver of SFM for PPP/PFI projects in Malaysia. This research recommends that further research is essential in order to integrate WLCC and SFM for PPP/PFI projects in Malaysia so that not only value for money projects can be achieved but also sustainable projects.

## INTRODUCTION

Buildings are long term investment and associated with environmental concerns over its life span (Ristimaki et al., 2013). Hence, it is significant to value the importance of environmental concerns and its impact towards early design decisions over a life span of a building. Nowadays, in order to address the concerns surrounding long term investment and environmental, more projects have been procured by using PPP/PFI scheme (Cartlidge, 2006). Likewise, in Malaysia, PPP/PFI projects are growing since its introduction which resulted in the importance of Whole Life Cycle Costing (WLCC) and facility management. This is justifiable because WLCC is one of the key principles of PPP/PFI projects whereby usually, projects are awarded based on the lowest total cost over the concession period which is typically between 20 to 30 years. Also, PPP/PFI projects enhance 'maintenance culture' because concessionaires will be accountable to maintain the building and its assets over the long concession period. Sarpin et al. (2016) accentuated that operation and maintenance are significant because it is capable of influencing WLCC of a building. Apparently, Robinson et al. (2009) pointed out that most of the proportion of WLCC in a building is contributed by the operation and maintenance costs rather than the initial costs which represents only a minor proportion.

In relation to this, there is a relationship between WLCC and operation and maintenance because any decision made without taking into account WLCC will cause issues during the operation and maintenance of a building (Wang, 2011). Hence, it is fundamental that WLCC to be implemented at the very early stage when decisions are still open. Also, at this stage, it is appropriate to address and incorporate sustainability concerns. The typical view of sustainability will impose additional costs to PPP/PFI projects in Malaysia have to be diminished. This could be done by the incorporation of sustainability at the very early stage of a project so that it can be quantified in monetary terms over the whole life cycle of the project. The nature of PPP/PFI projects which are long term contracts are suitable to allow for incorporation of sustainability as one of the objectives of the projects. However, PPP/PFI projects in Malaysia are still very young and progressing as well as tend to focus more on the value for

money rather than its environmental impacts although it has been pointed out by Abdullah et al. (2014) that PPP/PFI projects have the potential to enhance sustainable facility management implementation. Many researches have been conducted in the area of PPP/PFI projects but the focus is only on the value for money. For instance, a framework of value for money assessment for PPP/PFI projects is proposed by Takim et al. (2009) which covers economy, efficient and effectiveness. Likewise, PPP guideline in Malaysia outlined that WLCC and value for money is one of the key principles of PPP/PFI projects in Malaysia but none of the sustainability concerns is discussed. Globally, it is reported by the National Audit Office that \$2.6 billion per annum is still wasted through various reasons which include WLCC and sustainability. Hence, the research seeks to examine the importance of WLCC for SFM as well as to investigate the barriers and drivers of SFM of PPP/PFI projects in Malaysia.

## **THE IMPORTANCE OF WLCC FOR SFM**

According to Sarpin et al. (2016), there is a need for sustainability to be incorporated within facility management for PPP/PFI projects in Malaysia. In other words, there is a growing concern on the need for SFM. For that purposes, facility managers play significant role. Facility managers have the capacity to define, analyse and examine sustainability concerns over the whole life cycle of a building. This is because they are in critical position to view a project entirely (Hodges, 2005). Typically, they are involved in operation and maintenance of a building, hence, having them at the very early stage of PPP/PFI projects in Malaysia allow various inputs to be contributed particularly in selecting the best available alternatives of building elements and services that will render efficient facility management in the later stage of the projects. In the UK and the US, robust guidelines of sustainability have been published but in order for Malaysia to adopt such guidelines, there is a necessity to investigate and develop appropriate sustainability indicators (Ros et al., 2011) so that the guidelines will more practical and appropriate in meeting local needs. In term of research, many researches have been carried out in the area of WLCC and sustainability. For example, Wong (2010) carried out a research about WLCC for different types of sustainable alternatives of a building. However, he recommended in his research that there is a need to develop an approach of WLCC that is capable in assisting decision making in relation to which sustainable alternatives are best value for money.

Additionally, in a research conducted by Zhou et al. (2005), they pointed out that incorporation of sustainability into PPP/PFI projects is essential. Also, they mentioned that in order to ensure that sustainable PPP/PFI projects can be successfully achieved, it is beneficial to investigate WLCC of sustainability in regards to PPP/PFI projects. It is apt to address the concerns for PPP/PFI projects because of the long concession period of the projects. If facility managers are involved in the very early stage of the projects to deal with WLCC and SFM, both economic and environmental benefits can be expected. Boussabaine and Kirkham (2008) emphasized that sustainability achievement is feasible only with the consideration of long term operational and maintenance costs as well as performance of building elements and services. Also, it has been highlighted by Zeiler et al. (2013) and Alnaser et al. (2008) that economic viability is considered to the most significant factor in decision making to select the best value for money sustainable alternatives in a building. It is obvious that WLCC and SFM have to be considered for PPP/PFI projects in Malaysia in order to ensure that economic and environmental aspects of alternatives of building elements and services are considered before their selection.

Munteanu and Mehedintu (2016) explained that WLCC and facility management are interrelated in the sense that facility management is able to improve the processes of the whole life cycle of a project whilst reducing the WLCC particularly operation and maintenance costs. As stated earlier, most of the proportion of WLCC in a building is contributed by the operation and maintenance costs rather than the initial costs which represents only a minor proportion. WLCC acts as a tool to assist facility managers in making decisions based on a systematic assessment of the whole life cycle of a project. Integration of WLCC and SFM is significant because it is worth noting that over the whole life cycle of a project, operation and maintenance costs will surely exceed the initial construction costs. Indirectly, integration of WLCC and SFM provide facility managers with the capability to make informed decisions with consideration of both costs and environmental concerns over the long concession period of PPP/PFI projects in Malaysia. Relevantly, other than value for money, the projects will be running in good

conditions, avoiding early deterioration whilst keeping the operation and maintenance costs at the optimum level. In other words, the integration of WLCC and SFM for PPP/PFI projects in Malaysia will enhance the entire value of the projects.

## **BARRIERS OF SFM**

Although the benefits of WLCC and SFM are recognized but, as mentioned earlier, in Malaysia, PPP/PFI projects are focusing only on the value for money but not on the environmental concerns. Hence, there is a need to investigate the barriers that hindered the SFM implementation. Based on the research conducted by Elmualim et al. (2010), it is revealed that the three main barriers of SFM include lack of knowledge, lack of commitment from senior management and time constraints. Additionally, Finch and Clements-Croome (1997) added that SFM are facing with technical barrier particularly on the lack of professional training among the facility managers. Apart from that, based on the research by Massoud et al. (2010), they pointed out that SFM is stalled by the lack of support and incentive from the government. Also, the benefits of SFM can only be seen over a period of time which render it to be uncertain is also another barrier of SFM implementation.

In relation to that, Massoud et al. (2010) emphasized that lack of law and regulation is also impeding the SFM implementation. Other typical barriers of SFM as accordance as Finch and Clements-Croome (1997) include customer constraints, physical and historical constraints, financial constraints, lack of awareness, lack of tools and organizational engagement. Additionally, in a research conducted by Lee and Kang (2013), SFM implementation is hindered by the lack of guidance documentation and lack of capabilities and skills among the facility managers. Limited data of local consumption which include energy, water and etc. is also another barrier of SFM implementation (Nielsen et al., 2009). Lastly, Sarpin and Yang (2013) added that unwillingness to implement sustainability, lack of competence in managing the changing attitude process of people and organisations, lack of resources, lack of guidance documentations and the fact that SFM increase the liability of facility managers are impeding the SFM implementation.

## **DRIVERS OF SFM**

Due to the various barriers of SFM, many researchers have suggested drivers of SFM implementation. Elmualim et al. (2010) suggested that SFM implementation could be enhanced by having robust legislation and regulation, pressure from clients, employees and shareholders, the need and emphasis on life cycle reduction and to show corporate image as well as organisation ethos. In context of economic, Ikediashi et al. (2014) listed that financial gain, investment drive, again, life cycle cost reduction, profitability and market expansion are able to drive the SFM implementation. Additionally, they also suggested that organisation should implement SFM to remain competitive. While, in term of social, the drivers of SFM implementation as indicated by Baaki et al. (2016) include job creation for local communities, pressure from senior management, enhance relation with stakeholders and market competition. Apart from that, Baaki et al. (2016) and Ikediashi et al. (2014) stated that environmental factors have the potential to drive SFM implementation. The factors include reduction of energy consumption, waste reduction, elimination of oil and air pollution, increase productivity, sustainable urbanisation, reduction of deforestation and reduction of carbon dioxide emissions. In a nutshell, all the listed barriers and drivers of SFM are globally researched and it is essential to investigate the barriers and drivers of SFM particularly for PPP/PFI projects in Malaysia in order to reveal the current state of the SFM implementation for PPP/PFI projects in Malaysia.

## **RESEARCH METHODOLOGY**

Quantitative approach is adopted in this research and questionnaire survey is used as research instrument to collect all the required data from the population of the research. The population of the research is the members of Malaysian Association of Facility Managers (MAFM). In total, there are 107 members of MAFM. However only 71 of them are currently practicing facility management. Hence, the total population of the research is 71 only. Fellow and Liu (2008) pointed out that if the population of the research is relatively small, the entire population must be considered as the sample size for the research. Additionally, Awodele (2012) explained that the main purpose of sampling



technique is to allow for practical data collection to be carried out while at the same time, ensure that the sample size of the research is able to represent the entire population. Hence, the entire population of the research is regarded as the sample of the research. In term of response rate from the respondents, 63% response rate has been received from the respondents. Yong and Mustaffa (2011) and Akintoye (2000) added that 30% response rate is acceptable for subsequent analysis in construction research. Subsequently, collected data is analysed by means of statistical analysis and presented accordingly.

As for the barriers of SFM for PPP/PFI projects in Malaysia, they are ranked based on SI calculations. SI calculations have been used in many previous researches, for instance, Assaf and Al-Hejji (2006) used SI to rank the causes of delay in large construction projects based on the severity rank indicated by the respondents. Similarly, Le-Hoai et al. (2008) ranked the factor that caused cost overruns in Vietnam by means of SI calculation. With reference to the past researchers that used SI as an analysis technique in their research, SI can be calculated by using the following formula (Assaf and Al-Hejji, 2006; Le-Hoai et al., 2008):

$$SI = \sum \frac{a\left(\frac{n}{N} \times 100\right)}{5}$$

where a = constant weightage given to each response (ranges from 1 to 5), n = frequency of the responses, N = total number of responses. The SI enables the researcher to rank the barriers of SFM for PPP/PFI projects in Malaysia according to their level of severity.

While, the drivers of SFM for PPP/PFI projects are ranked based on RII calculations. RII calculations are also famously used by many researchers, for example, Enshassi et al. (2009) used RII to determine the perceptions of the various respondents of their research towards factors of performance of construction projects in Gaza. Additionally, Odusami (2002) calculated RII to rank the important skills that should be acquired by the construction project leaders based on the indication of rankings provided by the respondents of the research. based on the past researchers, RII can be calculated by using the following formula (Enshassi et al., 2009; Odusami, 2002):

$$RII = \sum \frac{W}{A * N}$$

where W = weightage given to each response (ranges from 1 to 5), A = the highest response integer (5), N is the total number of responses. The RII allows the researcher to rank the drivers of SFM for PPP/PFI projects in Malaysia according to their level of importance.

Prior to the analysis, reliability tests is conducted and this is necessary in order to ensure the internal consistency of collected data in a research (Memon et al., 2011). Cronbach alpha is the reliability tests that is widely used in measuring the internal consistency. Typically, if the Cronbach alpha value is less than 0.30, the reliability is regarded as low and unacceptable. While, Cronbach alpha value of more than 0.70 is considered as high and acceptable (Memon et al., 2011). Similarly, Tavakol et al. (2011) pointed out that Cronbach alpha value has to be as minimum as 0.70. Therefore, in order to ensure that the collected data in this research is reliable, Cronbach alpha is calculated. Moreover, statistical analysis are basically based on the assumption that collected data are normally distributed. Field (2009) agreed that normality of collected data should be taken seriously or else, it would be impossible for accurate and reliable conclusions to be drawn. Hence, for collected data for both barriers and drivers of SFM, normality is calculated by means of Skewness, Kurtosis and Shapiro-Wilk tests. Chua (2013) pointed out that collected data is normally distributed if the values of Skewness and Kurtosis are within -1.96 to +1.96. Additionally, he added that based on Shapiro-Wilk test, p-value (sig.) of the collected data must be more than 0.05. In relation to that, Shapiro-Wilk test is adopted in this research to test the normality of the data because according to Shapiro and Wilk (1965), the test is appropriate to investigate the normality of data for a small sample of research. Royston agreed that the test is suitable to be use for small sample of research of more than 3 but not more than 5000.

## RESULTS AND FINDINGS

The main aim of the research is to investigate the barriers and drivers of SFM for PPP/PFI projects in Malaysia. The investigation is carried out by means of statistical analysis based on the responses received from the respondents. As for the barriers of SFM for PPP/PFI projects in Malaysia, they are ranked based on SI calculations. While, the drivers of SFM for PPP/PFI projects are ranked based on RII calculations.

### BARRIERS OF SFM FOR PPP/PFI PROJECTS IN MALAYSIA

Prior to SI calculations, the normality of collected data in regards to the barriers of SFM is tested. The normality tests include Skewness, Kurtosis and Shapiro-Wilk test. The results of the normality tests are illustrated in table 1 below.

**Table 1:** Normality of barriers of SFM for PPP/PFI projects in Malaysia

Normality of data	Skewness	Kurtosis	Shapiro-Wilk
Barriers of SFM for PPP/PFI projects in Malaysia	-0.170	0.746	0.959

Obviously, table 1 reveals that the collected data in regards to the barrier of SFM for PPP/PFI projects in Malaysia is normally distributed as Chua (2013) pointed out that collected data is normally distributed if the values of Skewness and Kurtosis are within -1.96 to +1.96 and the values of Shapiro-Wilk test are more than 0.05. Moreover, in order to determine whether items in the questionnaire survey that represent barriers of SFM for PPP/PFI projects in Malaysia are internally consistent and reliable, Cronbach's alpha is calculated. Based on the calculation, it is verified that the items of SFM for PPP/PFI projects in Malaysia are consistent and reliable with a Cronbach's alpha value of 0.908. This is justifiable because according to Tavakol et al. (2011), Cronbach's alpha value of more than 0.70 is considered as acceptable. Next, SI calculations are computed for each of the barriers of SFM for PPP/PFI projects in Malaysia and the results are as tabulated in table 2.

**Table 2:** Severity of barriers of SFM for PPP/PFI projects in Malaysia

No.	Barriers of SFM for PPP/PFI projects in Malaysia	SI	Rank
1	Customer constraints	0.8533	2
2	Physical / Historical constraints	0.7733	16
3	Organizational engagement	0.7956	10
4	Lack of training	0.8267	5
5	Lack of tools	0.8222	6
6	Lack of awareness	0.7822	15
7	Financial constraints	0.7911	13
8	Lack of senior management commitment	0.8311	4
9	Lack of knowledge	0.7867	14
10	Time constraint	0.8089	7
11	Lack of capabilities / skills	0.8000	9
12	Unwillingness to implement sustainability	0.7867	14
13	Lack of competence in managing the changing attitude process of people and organisations	0.8133	8
14	Lack of guidance documentation	0.8622	1
15	Limited data of local consumption	0.8489	3
16	Increasing liability	0.8089	7
17	Lack of resources	0.8222	6
18	Lack of government support and incentive	0.8311	4
19	Uncertainty of outcomes and benefits	0.7956	11
20	Lack of relevant laws and regulations	0.7956	12

Based on table 2, lack of guidance documentation has been ranked as the most severe barrier of SFM for PPP/PFI projects in Malaysia with SI value of 0.8622. This barrier is followed by customer constraints and limited data of local consumption with SI value of 0.8533 and 0.8489 respectively. In relation to lack of guidance documentation, as mentioned earlier, PPP/PFI projects in Malaysia focus only on the value for money aspect rather than the environmental aspect. Hence, Malaysia is lacking of a guideline or reference that could be referred by the facility managers in order to implement SFM. Accordingly, SFM has not been emphasized as one of the principles of PPP/PFI projects in Malaysia (Unit PPP, 2009). Ros et al. (2011) pointed out that in other countries, for instance, in the UK and the US, sustainability guidelines are published to assist in sustainability implementation. The fact that Malaysia is lacking of such guideline has render difficulties for facility managers to implement SFM and thus, it is essential to investigate and develop appropriate sustainability parameters so that a guideline that is practical and appropriate in meeting local needs can be developed and published. Moreover, SFM are continuous processes that should be initiated during the early stage of the PPP/PFI projects and it covers the entire phases of the projects until the end of the concession period of the projects. Hence, having a guideline that showing in details how the processes should be conducted would definitely ease the roles of the facility managers. However, as discussed earlier, the absence of such guideline has hindered the SFM implementation.

Apart from that, although SFM provides many benefits to PPP/PFI projects, most of the benefits can only be seen towards the end of the projects or in other words, after a period of time. Hence, customers are typically unaware of the benefits and tend to focus only on initial costs savings rather than long term costs savings. Due to this, customer constraints are ranked as the second most severe barrier of SFM for PPP/PFI projects in Malaysia. Actually, customer constraints have been regarded as one of the main barriers of SFM since years ago (Elmualim et al., 2008). The low interests of customers in SFM will cause it to be less significant to be implemented. As the main source of investments, customers need to motivate facility managers to implement SFM because SFM will usually require additional initial investments from the customers. However, if customers are not willing to invest on SFM implementation, this will totally impede the facility managers from implementing SFM for PPP/PFI projects in Malaysia. Moreover, as discussed earlier, SFM are continuous processes and during the processes lots of data is required. Most of the data deals with local consumption such as energy consumption, water consumption and etc. This is another serious issue to deal with in Malaysia whereby most of the data is unavailable or inaccessible. The absence of the required data is critical and it is essential for facility managers to have reliable databases of the required data to ease the implementation of SFM for PPP/PFI projects in Malaysia.

### **DRIVERS OF SFM FOR PPP/PFI PROJECTS IN MALAYSIA**

Similar to the research analysis techniques of barriers of SFM for PPP/PFI projects in Malaysia, prior to RII calculations, the normality of collected data in regards to the drivers of SFM is tested by using Skewness, Kurtosis and Shapiro-Wilk test. The results of the normality tests are illustrated in table 3 below.

**Table 3:** Normality of driver of WLCC and SFM for PPP/PFI projects in Malaysia

Normality of data	Skewness	Kurtosis	Shapiro-Wilk
Drivers of SFM for PPP/PFI projects in Malaysia	0.753	0.587	0.938

Obviously, table 3 reveals that the collected data in regards to the drivers of SFM for PPP/PFI projects in Malaysia are normally distributed as the values of Skewness and Kurtosis are within -1.96 to +1.96 while the values of Shapiro-Wilk test are more than 0.05 (Chua, 2013). Moreover, in term of consistency and reliability, based on the Cronbach's alpha calculation, all items for drivers of SFM for PPP/PFI projects in Malaysia are consistent and reliable with Cronbach's alpha value of 0.931. Next, RII calculations are computed for each of the drivers of SFM for PPP/PFI projects in Malaysia and the results are as tabulated in table 4.

**Table 4:** Importance of drivers of SFM for PPP/PFI projects in Malaysia

No.	Drivers of SFM for PPP/PFI projects in Malaysia	RII	Rank
1	Reduction in energy consumption	0.8578	3
2	Waste reduction	0.8578	3
3	Increase productivity	0.8444	5
4	Elimination of oil and air pollution	0.7956	7
5	Sustainable urbanisation	0.7911	8
6	Reduction of deforestation	0.7644	12
7	Reduction of carbon dioxide emissions	0.8533	4
8	Legislation and regulation	0.8622	2
9	Corporate image	0.7289	18
10	Organisation ethos	0.7378	16
11	Service management / Director's leadership	0.7689	11
12	Pressure from clients	0.7333	17
13	Pressure from employees	0.7333	17
14	Pressure from stakeholders	0.7556	13
15	Job creation for local communities	0.7333	17
16	Pressure from senior management	0.7867	9
17	Enhance relation with stakeholders	0.7733	10
18	Market competition	0.7556	13
19	Financial gain	0.7556	13
20	Investment drive	0.8133	6
21	Life cycle cost reduction	0.8844	1
22	Profitability	0.7689	11
23	To remain competitive	0.7467	15
24	Market expansion	0.7511	14

Based on table 4, life cycle cost reduction has been ranked as the most important driver of SFM for PPP/PFI projects in Malaysia with SI value of 0.8844. This driver is followed by legislation and regulation, reduction in energy consumption and waste reduction with SI value of 0.8622, 0.8578 and 0.8578 respectively. In relation to the most important driver identified, life cycle cost and SFM are interrelated in the sense that facility management has the potential to improve the entire processes of a project whilst reducing life cycle costs particularly operation and maintenance costs (Munteanu and Mehedintu, 2016). It is worth noting that most of the proportion of WLCC in a building is contributed by the operation and maintenance costs rather than the initial costs which represents only a minor proportion. Typically, life cycle costing acts as tool to assist facility managers to make decision based on a systematic process. Furthermore, legislation and regulation has been argued by many researchers as one of the main drivers of SFM (Shiers et al., 2007; Casals, 2006). For instance, Shiers et al. (2007) revealed in their research that the existence of legislation and regulation in regards to energy efficiency have enhanced the obligations towards the energy efficiency.

Therefore, in Malaysia, government plays significant role in imposing legislation and regulation in regards to SFM particularly for PPP/PFI projects so that its implementation can be enhanced. Evidently, due to the long nature of concession period of PPP/PFI projects, Abdullah Hashim et al. (2016) pointed out that PPP/PFI projects have the potential to enhance SFM implementation. In relation to this, the availability of legislation and regulation requiring SFM to be implemented for PPP/PFI projects in Malaysia will unquestionably drive the SFM implementation among the facility managers. It is agreed by Elmualim et al. (2010) that government have the authority to influence the SFM implementation and this could be done by means of imposing legislation and regulation in regards to SFM. Apart from that, high consumption of energy is correlated with high costs of utility and maintenance. Due to this, many organisations are now committed with sustainability (Walker et al., 2007). Facility managers are at the

forefront in dealing with utilities consumption. Hence, if the mission of reducing energy consumption and waste is incorporated within the PPP/PFI projects at the very early stage, this could be the driver to enhance the SFM implementation. In fact, similarly, in a research conducted by Elmualim et al. (2010), two main concerns of SFM are reducing energy consumption and waste.

## CONCLUSIONS

In conclusion, it is essential to integrate WLCC and SFM particularly for PPP/PFI projects in Malaysia. These principles are basically interrelated and consideration of both principles during the early stage of PPP/PFI projects in Malaysia will enhance the entire value of the projects in context of economic and environmental. However, the research reveals that SFM implementation in Malaysia particularly for PPP/PFI projects are hindered due to the lack of guidance documentation, customer constraints and limited data of local consumption. In relation to this, the research suggested that the emphasis of life cycle cost reduction could enhance SFM implementation for PPP/PFI projects in Malaysia. Also having robust legislation and regulation imposed by the government could also influence the implementation. In context of environmental, the need to reduce energy consumption and waste can also drive the SFM implementation for PPP/PFI projects in Malaysia. Further, the research recommends that it is essential to integrate WLCC and SFM for PPP/PFI projects in Malaysia so that not only value for money projects can be achieved but also sustainable projects. However, before this is possible, it is significant to first investigate the parameters of SFM particularly for PPP/PFI projects in Malaysia that are to be integrated with the parameters of WLCC for PPP/PFI projects in Malaysia.

## REFERENCES

- Abdullah Hashim, H., Sapri, M., Low, S., (2016). Sustainable Initiatives for Facilities Management in Public Private Partnership (PPP) Projects. *International Journal of Real Estate Studies*, 10(1), pp. 45-52.
- Akintoye, A., (2000). Analysis of factors influencing project cost estimating practice. *Construction Management & Economics*, 18(1), pp.77-89.
- Alnaser, N.W., Flanagan, R. and Alnaser, W.E., (2008). Model for calculating the sustainable building index (SBI) in the kingdom of Bahrain. *Energy and buildings*, 40(11), pp.2037-2043.
- 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.
- Awodele, O.A., (2012). *Framework for managing risk in privately financed market projects in Nigeria* (Doctoral dissertation, Heriot-Watt University).
- Baaki, T.K., Baharum, M.R. and Ali, A.S., (2016). A review of sustainable facilities management knowledge and practice. In *MATEC Web of Conferences* (Vol. 66, p. 00075). EDP Sciences.
- Boussabaine, A. and Kirkham, R., (2008). *Whole life-cycle costing: risk and risk responses*. John Wiley & Sons.
- Cartlidge, D., (2006). *New aspects of quantity surveying practice*. Routledge.
- Casals, X.G., (2006). Analysis of building energy regulation and certification in Europe: Their role, limitations and differences. *Energy and buildings*, 38(5), pp.381-392.
- Elmualim, A., Shockley, D., Valle, R., Ludlow, G. and Shah, S., (2010). Barriers and commitment of facilities management profession to the sustainability agenda. *Building and Environment*, 45(1), pp.58-64.

Elmualim, A.A., Czwakiel, A., Valle, C.R., Ludlow, G. and Shah, S., (2008), September. Barriers for implementing sustainable facilities management. In *World Sustainable Building Conference September 2008, Melbourne, Australia*.

Enshassi, A., Mohamed, S. and Abushaban, S., (2009). Factors affecting the performance of construction projects in the Gaza strip. *Journal of Civil engineering and Management*, 15(3), pp.269-280.

Fellows, R.F. and Liu, A.M., (2008). *Research methods for construction*. John Wiley & Sons.  
Field, A., 2009. *Discovering statistics using SPSS*. Sage publications.

Finch, E. and Clements-Croome, D., (1997). University courses in intelligent buildings-new learning approaches. *Facilities*, 15(7/8), pp.171-176.

Hodges, C.P., (2005). A facility manager's approach to sustainability. *Journal of Facilities Management*, 3(4), pp.312-324.

I. Ikediashi, D., O. Ogunlana, S. and O. Ujene, A., (2014). An investigation on policy direction and drivers for sustainable facilities management practice in Nigeria. *Journal of Facilities Management*, 12(3), pp.303-322.

Lee, S.Y. and Kang, M., (2013). Innovation characteristics and intention to adopt sustainable facilities management practices. *Ergonomics*, 56(3), pp.480-491.

Le-Hoi, L., Lee, Y.D. and Lee, J.Y., (2008). Delay and cost overruns in Vietnam large construction projects: A comparison with other selected countries. *KSCE journal of civil engineering*, 12(6), pp.367-377.

Massoud, M.A., Fayad, R., El-Fadel, M. and Kamleh, R., (2010). Drivers, barriers and incentives to implementing environmental management systems in the food industry: A case of Lebanon. *Journal of Cleaner Production*, 18(3), pp.200-209.

Memon, A.H., Rahman, I.A., Abdullah, M.R. and Azis, A.A.A., (2011). Factors affecting construction cost in Mara large construction project: perspective of project management consultant. *International Journal of Sustainable Construction Engineering and Technology*, 1(2), pp.41-54.

Munteanu, A. and Mehedintu, G., (2016). The importance of facility management in the life cycle costing calculation. *Review of General Management*, 23(1).

Nielsen, S.B., Jensen, J.O. and Jensen, P.A., (2009), January. Delivering sustainable facilities management in Danish housing estates. In *2nd International Conference on Sustainability Measurement and Modelling ICSMM 09© CIMNE, Barcelona*.

Odusami, K.T., (2002). Perceptions of construction professionals concerning important skills of effective project leaders. *Journal of Management in Engineering*, 18(2), pp.61-67.

Piaw, C.Y., (2013). Kaedah dan Statistik Penyelidikan. *Malaysia: Mc. Graw Hill Sdn Bhd*.

Ristimäki, M., Säynäjoki, A., Heinonen, J. and Junnila, S., (2013). Combining life cycle costing and life cycle assessment for an analysis of a new residential district energy system design. *Energy*, 63, pp.168-179.

Ros, M.F.I.C., Ismail, Z., Hassan, F. and Mat, M.C., (2011), September. Sustainable private financing initiative contracts. In *Business, Engineering and Industrial Applications (ISBEIA), 2011 IEEE Symposium on* (pp. 452-457). IEEE.

Sarpin, N. and Yang, J., (2013), May. People capabilities for promoting sustainability in facilities management practices. In *World Building Congress 2013, 5-9 May, Brisbane, Australia* (pp. 1-11). International Council for Research and Innovation in Building and Construction (CIB).

Sarpin, N., Sarpin, N., Yang, J., Yang, J., Xia, B. and Xia, B., (2016). Developing a people capability framework to promote sustainability in facility management practices. *Facilities*, 34(7/8), pp.450-467.

Shapiro, S.S. and Wilk, M.B., (1965). An analysis of variance test for normality (complete samples). *Biometrika*, 52(3/4), pp.591-611.

Shiers, D., Lavers, A. and Keeping, M., (2007). Indicators of the impact of environmental factors on UK construction law: developments in the new millennium. *Construction Management and Economics*, 25(7), pp.821-829.

Takim, R., Ismail, K., Nawawi, A.H. and Jaafar, A., (2009). The Malaysian private finance initiative and value for money. *Asian social science*, 5(3), p.103.

Tavakol, M. and Dennick, R., (2011). Making sense of Cronbach's alpha. *International journal of medical education*, 2, p.53.

Unit, P.P.P., (2009). Public Private Partnership (PPP) Guideline.

Walker, G. and Shove, E., (2007). Ambivalence, sustainability and the governance of socio-technical transitions. *Journal of Environmental Policy & Planning*, 9(3-4), pp.213-225.

Wang, N., (2011). Multi-criteria decision-making model for whole life costing design. *Structure and Infrastructure Engineering*, 7(6), pp.441-452.

Wong, I. L., (2010). Whole life costing: towards a sustainable built environment. Paper presented at the 5<sup>th</sup> International Conference on Responsive Manufacturing – Green Manufacturing 2010 (ICRM 2010). Ningbo, China.

Yong, Y.C. and Mustaffa, N.E., (2011). Clients, Consultants and Contractors' Perception of Critical Success Factors for Construction Projects in Malaysia. *Management*, 735, p.744.

Zeiler, W., Maaijen, R. and Maassen, W., (2013). Life cycle performance costing based building design decision support. *ASHRAE Transactions*, 119, p.P1.

Zhou, L., Keivani, R. and Kurul, E., (2013). Sustainability performance measurement framework for PFI projects in the UK. *Journal of Financial Management of Property and Construction*, 18(3), pp.232-250.

# **A COMPARATIVE STUDY OF THE PERFORMANCE OF GREEN BUILDINGS IN HONG KONG AND SINGAPORE**

Ellen Lau and Lo Chung Hay, Haywood, Birmingham City University

Email: [lhellen@gmail.com](mailto:lhellen@gmail.com)

## **Abstract**

Hong Kong and Singapore are always taken for comparison worldwide for economic, social and education development. However not many studies refer to the organizational development of environmental issues. Therefore this study aims to examine the green building development in Singapore and Hong Kong, thereafter analyze those factors affecting the performance and efficiency of the development of green buildings, and finally, investigate the green building development orientation or architecture which leads a better urban performance to that city. The study contains the following objectives: (i) compare and contrast the green building standard in Hong Kong and Singapore by examining the rating criteria of the two different sets of standards; (ii) compare the environmental performance of two green buildings in these cities; (iii) produce a summary of the benefits that could be brought to the city through the performance of green building design such that recommendations can be made for future development of the performance in green buildings.

**Keywords: green buildings, environmental standards, Hong Kong, Singapore, city development**

## **INTRODUCTION**

Green building development has been a hot topic in the recent years in Asian countries. When green building development is mentioned in Asia, Singapore is remarked as a rising star, whereas Hong Kong is more of known as an Asian Financial Center. According to the Sustainable Cities Index in 2016, Singapore was ranked as 2<sup>nd</sup> out of 100 countries and Hong Kong was ranked as 16<sup>th</sup> (Arcadis, 2016). This research was conducted with three pillars: People, Planet, and Profit. Planet represents environmental, capturing “Green” factors like energy pollution and carbon-emission. In the Planet sub-index, Singapore was ranked 12<sup>th</sup> and Hong Kong was ranked 29<sup>th</sup>. Apart from the above city index, another research also ranked Singapore higher in the Green Aspect than that of Hong Kong. According to the Asian Green City Index (AGCI) 2011 and 2013 which were conducted by Economist Intelligence Unit (EIU:



2011,2013), the overall result showed that Singapore was graded as “Well Above Average” and Hong Kong was graded as “Above Average”. In AGCI, eight categories of green city are taken into account. They are Energy and CO<sub>2</sub>, Land use and buildings, Transport, Waste, Water, Sanitation, Air quality and Environment governance.

Hong Kong and Singapore are always taken for comparison worldwide, but not many publications look at the organization of the environmental development. Therefore, this study aims to explore why Singapore gets higher ranking than Hong Kong, and to examine the main factors that lead Singapore to perform better in green planning direction. It contains the following objectives: (i) to compare and contrast the green building standards in Hong Kong and Singapore via comparing the rating criteria to analyze the differences between the two standards; (ii) to compare the performance of green buildings of the two cities via project examples; and (iii) to summarize the benefits that could be brought to the city through the performance of green building design and make recommendations for future development.

## **LITERATURE REVIEW**

### **Initiative of Green Building**

In the 1970s, countries in US and Northern Europe brought up the issue of energy-efficient buildings and launched the concept of sustainable development. Thereafter, owing to public concern on environmental pollution and energy crisis, there is a need for energy-efficient buildings which then results in the development of green buildings. A number of policy documents for energy-efficiency have been published about the intent to reduce the usage of natural resources (Mao et al., 2009; Retzlaff, 2010). As for Singapore, the government believes that a green city should be free from diseases to attract tourists as tourism has been one of the factors that help in the realization of fast economic growth of Singapore since its independence in 1965. Hence, environmental education and environmental protection are emphasized in Singapore. In the mid-1990s, HKSAR government started to look into energy-efficient buildings and subsequently established the Energy Efficiency Office in 1994. The office at that time was under the Electrical and Mechanical Services Department which emphasized energy conservation. It later leads to the legislation of Energy Efficiency Ordinance Cap 610 which takes effect in 2012 and promotion of Green Buildings by the Business Environment Council in 2013 (Leung, 2013).

A report from *Whole Building Design Guide* (WBDG) stated that buildings use almost a quarter of the energy and more than a half of the electricity in a country. For example, the buildings in the United States use “39% of its energy and 68% of its electricity and buildings emit 38% of the carbon dioxide. Starting from the 1990s, some countries lead the green building movement across the globe. However, it is found that investing just in energy-efficient buildings is not sufficient to achieve the aims of reducing the counter impacts on human health, environment and sustainable development (Chan et al., 2009). It has been mentioned that green building is not only about energy-efficiency, but also the environmental impacts on building’s life-cycle (UNEP, 2010). This concept moves forward the development of green building to include relieving the threats of global warming and achieving sustainable environment for the next generations. Due to the change of the global trend, some countries issued different action plans to innovate the green building development, for example, the US issued green building policy in the mid-1990s and the 2000s; Netherlands published a sustainable construction policy covering green building action plan (Retzlaff, 2010). In the spotlight of international treaties and protocols, the development of green building becomes a hot issue. For example, the Kyoto Protocol treaty issued in 2005 attempts to legally bind various countries to lower their Green House Gas emission. The protocol treaty helps to speed up the green building movement and leads to the creation of different sets of standards in various countries and an innovation of green building policy.

### **Definition of Green Building**

According to the World Green Building Council, a ‘green’ building is a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. It also highlights the consideration of the quality of life of occupants in design, construction and operation. A global online resource for guiding the green living (Ecolife.com Dictionary, 2010) stated that green buildings are designed and built in the trend that have minimal environmental impact and maximum building life-cycle. Designs of green building can be applied to different types of buildings including residential, schools, commercial and industrial. Buildings. This definition is more design oriented which have been taken to include:

- **Energy efficiency:** It concerns the resources for producing and manufacturing building components, the energy used in the working processes and in maintenance; and it also includes the aim to design for renewable energy, such as solar system and wind power etc.

- Eco building materials: Green buildings should take advantage of environmental preferable materials during construction and renovation works, such as local produced materials, recyclable materials, renewable resources and non-toxic materials.
- Water efficiency: A green building should be set up with a comprehensive planning of the water pipe system to achieve water efficiency and endeavor to minimize water pollution, including the re-usage of fresh and sea water, sewage, rainwater and landscape waste.
- Waste reduction: A waste management plan should be set up for green building construction and demolition which aims to reduce the waste as much as possible and classify the waste for recycling or reusing.
- Toxics reduction: Green Building aims to minimize the use of health harming materials by means of constructing a non-toxic building, as the non-toxic construction materials or production are healthier for occupants and planet.
- Indoor air quality: By means of having the exceptional filtration system and air movement, it can reduce the pollution to indoor air, such that better indoor air quality to the occupants can be maintained.

### **Benefits of Green Building Design**

The development of society and construction spend a lot of natural resources and cause different kind of impacts to the environment. Green building is regarded as a solution that brings positive impacts to social, economic and environmental aspect (Western North Carolina Green Building Council, 2013), in which WNCGBC highlights also builder benefits and home-owner benefits.

#### ***Social Benefits***

The design of green building is to address comfort, safety and security to accommodate society changing needs since people spend about 90% of their time inside buildings (OECD, 2003). Moreover, the renewable energy can result in lesser toxic chemicals used in the built environment. The use of natural ventilation and daylighting also provide an internal environment that is thermally and visually comfortable. Obviously, green building can provide a better quality of living and indoor environment to the occupants. (ASTM, 2001; BEAM, 2010; EPA, 2012; CalRecycle, 2014; GBCA, 2013; McGraw-Hill Construction, 2013; UNEP, 2010; WNCGBC, 2013).

#### ***Economic Benefits***

For economic benefits. global studies state that green design are cost efficient over their life-time. The design strategies intend to reduce the demand for artificial lighting and climate control, and when adding up with those efficient appliances, these will further reduce the energy and water consumption of the building. The reduction in consumption

equals to a cost of saving in effectiveness with the energy bills. A green design also means to minimise the cost for intensive future modification and it is widely acknowledged as being attractive to future owners and tenants. (McGraw-Hill Construction, 2013; WNCGBC, 2013). Apart from that, when provided with a healthier and better environment for occupants, it is believed that it can increase their working productivity and result in a positive impact to economy (CalRecycle, 2014; WNCGBC, 2013). In addition, green building can also help to build up the reputation and the corporate image for businesses via increasing the asset value. When a city can provide an outstanding green environment, it can increase their attraction to the investor and hence bring more investment and economic benefits to the country, such as the Singapore famous green spot -- Garden by the Bay (EPA, 2012; WNCGBC, 2013).

### ***Environmental Benefits***

For environmental benefits. Green building can minimize the pollution and waste from adopting re-newsble energy and reduce the carbon footprint to maximise the use of natural energy (ASTM, 2001; BCA, 2011; BEAM, 2010; CalRecycle, 2013; EPA, 2012; GBCA, 2013; HKGBC, 2013a; McGraw, 2013; UNEP, 2010; USGBC, 2013a). It also protects and enhance the biodiversity and ecosystems (EPA, 2012; WNCGBC, 2013). Furthermore, it also solves the issue of limited natural resources by using the clean energy and environmental friendly materials. For example, the design of natural daylighting can contribute to a bright, cheerful or harmonious indoor environment and reduce the needs for electrical lighting, and in turn improve the sustainability of that design. Second, the design of passive cooling system can prevent the area from overheating through blocking the solar gains and promoting natural ventailation to reduce the heating inside the area, and in turn improve the sustainability of that design. Besides, building orientation to north or to south can also enhance the access rate of predominant wind and avoid the powerful sumshine at the mid-noon (EPA, 2012; McGraw-Hill Construction, 2013; WNCGBC, 2013).

## **RESEARCH METHODOLOGY**

This study adopts a qualitative approach to analyze green building via references drawn from books, academic materials, journals, reports, and articles retrieved from internet. By using the desk-top study method, the references related to government and institutional publication and materials from *Green Building Councils* are used to correspond literature or script to analyze green building development in Hong Kong and Singapore. This comparative study looks into three areas: (1) the green building standards; (2) project case of green buildings; and (3) the perceived benefits and recommendation for future development

## **Comparing building standard**

### ***Green building standards for Hong Kong***

Hong Kong Building Environmental Assessment Method (HKBEAM) is the green building standard in Hong Kong. HKBEAM Plus is commonly used in Hong Kong because it is a tailor-made standard for high rise, high density built environment of sub-tropical climate in Hong Kong, and is a voluntary scheme covering New Buildings, Existing Buildings and Interiors. There are six key criterias to rate buildings: i) Innovation and additions, ii) Site Aspects, iii) Marterials and Waste Aspects, iv) Water Use, v) Energy Use, vi) Indoor Environmental Quality, plus Management. Based on the above criteria, the building will be scored and the result will put into four Green Mark rating i) Platinum, ii) Gold, iii) Silver, iv) Bronze, based on the weighting distribution shown in Table 1.

For the criteria “Innovation”, the applicants are free to submit any idea for innovative techniques, performance enhancements that provide environmental benefits additional to those result already covered in the HKBEAM Plus manual. This section is to i) Encourage new technologies and techniques that have not yet applied in Hong Kong; ii) Encourage new technologies and techniques that provide performance enhancements above or over stated performances criteria in the manual; iii) Encourage the building to be an asset to promote environmental performance in society (Provision of Venues or Public Spaces for Environmental Programme); iv) Encourage responsiveness to community needs by involving the people in the community in building operation (Engagement with Neighborhoods); and v) Promote the use of electric vehicles (Provision of Electrical Vehicle Charge).

For the criteria “Site Aspects”, it is focusing on the location of the site and emissions from the buildings to enhance microclimate to the surroundings (Greenery) and the provisions of amenities. “Location of the site” is being assessed about whether the place comprises adequate local amenities and public transport, which can in turn reduce travel needs and reliance on private vehicles to minimize the production of carbon dioxide and enhance the green performance. “Emissions from the building” is being assessed with respect to the level of noise pollution and light pollution. The level of those pollutions can reflect the performances of building management and the design of the project, which can have a negative impact on the neighboring properties. “Greenery” is about the heat island reduction and green roof designed to assure that the microclimate has been considered adequately and mitigation plan are suitably provided to the surroundings. “Provisions of amenities” is about the provisions of facilities and services fulfilling corporate social responsibility, as such as bike parking area, baby care room, free wheelchair common services, barrier free access (BFA). It means to encourage and

promote the social responsibility.

For the criteria “Materials and Waste Aspects”, it is about the waste recycling facilities, materials purchasing plan, selection of materials and waste management so as to reduce pressure on landfill sites, reduce the production of non-renewable resources and reduce the environmental impacts eventually.

For the criteria “Management”, it assesses the overall management system, policies and procedures that are put into the place, the staff and the resources with the involvement of building users. Through the environmental, health, safety and energy management system, operation and maintenance system, indoor air quality (IAQ) management etc., the management system is to ensure buildings are operating in their maximum sustainable potential.

For the criteria “Energy Efficiency” and “Water Efficiency”, it aims to contribute to energy efficiency where the management, operation and maintenance can seek continual improvements in energy performance. Especially for the water efficiency, the scarce supply of water has now become a serious problem even in other parts of the world.

For the criteria “Indoor Environmental Quality”, this section is to consider the indoor quality and ventilation provisions. The building design, operation, management should aim to provide a good indoor environment quality with a minimum usage of energy or resources.

**Table 1:** The weighting distribution of green building standard of Hong Kong

<b>Category</b>	<b>Weighting</b>
Management	24%
Site aspects	10%
Materials and Wastes Aspects	14%
Energy Use	24%
Water Use	14%
Indoor Environmental Quality	14%

### ***Green building standards for Singapore***

For Singapore, the green building standards is the Green Mark Scheme. The Green Mark Scheme was firstly published in January 2005 by the Singapore Building Construction Authority (BCA) as an initiative to spur Singapore’s construction industry to become more environmental friendly to the society, to promote sustainable building environment and to enhance the environmental awareness among the developers and designers when they start to develop their design concept. There are five key criteria to rate buildings, which are i) Energy Efficiency, ii) Water Efficiency, iii) Environmental Protection, iv) Indoor Environmental Quality, v) Other green and innovative features that contribute to better building performance. The scheme is later edited in 2015 and the criteria are then re-structured into five elements, which are i) Climate Responsive Design, ii) Building Energy Performance, iii) Advanced Green Efforts, iv) Resource Stewardship, v) Smart Healthy Building, which are more focused

on building design. Based on the above five criteria, the building will be scored and the result will be put into three Green Mark rating: Green Mark Gold, Gold<sup>Plus</sup> or Platinum Award. Both existing and new buildings are qualified to register with the scheme based on the weighting distribution shown in Table 2.

For “Climate Responsive Design”, it is about the assessment for i) envelope and roof thermal transfer, ii) Air tightness and leakage and iii) bicycle parking, which stated in Green Mark Scheme NRB-2015. This consideration is to maximize the response to the local tropical climate from the variable external climate. These assessments aim to reduce the thermal heat gain and enhance the indoor thermal comfort; reduce energy used by minimizing air infiltration; reduce the energy consumption from vehicular travel by encourage cycling.

For “Resource Stewardship”, it is credited by the Water efficient systems, materials usage, and wastage management. By considering the planning of water efficient, monitoring and potable water replacement strategies, it can reduce the water consumption during building operation. Moreover, by considering the materials usage, it encourages using the sustainable construction design and fit-out system so as to reduce the environmental impact of the buildings. As for the part of waste management, it aims to minimize the waste by control the resources consumed during the construction process, provide adequate facilities to manage waste in the building operations.

For “Advanced Green Efforts”, this is to assess i) where the project can provide a substantial performance or outcome that addresses beyond the Green Mark specified (Enhanced Performance); ii) the project can demonstrate that it can achieve higher level of environmental performance without capital rise to build up a great interest to promote market transformation (Demonstrating Cost Efficient); and iii) the project can demonstrate that it contributes to social sustainability.

For “Building Energy Performance”, this section focuses on how the building demonstrate the optimization of building energy systems through energy efficiency, effectiveness and replacement strategies to reduce the impacts caused by that project.

For “Smart Healthy Building”, it is about the indoor environmental quality (IEQ), which means factors like the air quality, effective daylight, quality of artificial lighting affecting the IEQ. Therefore, through the assessment of indoor air quality, spatial quality and smart building operation, the BCU can identify the quality of indoor environment in that project.

**Table 2:** The weighting distribution of green building standard of Singapore

Section	Weighting
Climate Responsive Design	30/120 (21.4%)
Resource Stewardship	30/120 (21.4%)
Advanced Green Efforts	20/120 (14.4%)
Building Energy Performance	30/120 (21.4%)
Smart Healthy Building	30/120 (21.4%)

### ***Comparison of HKBEAM Plus and Green Mark Scheme***

There are seven criteria items and four awards provided by HKBEAM while there are five criteria items and three awards provided by the Green Mark Scheme (see Table 3). However, it is found the criteria in HKBEAM Plus and Green Mark Scheme are quite similar. They contain the usual aspects about innovation technology, waste management, water and energy efficiency, indoor environmental quality, which aims to reach the reduction of natural resource use, reduction of environmental impact, and benefit to the occupants. From the criteria weightings, Tables 1 and 2 show that the weightings between the two schemes are different. The highest weightings in HKBEAM Plus are ‘Management’ and ‘Energy efficiency’ (each 24%), while the weightings in the Green Mark Scheme are generally averaging out. The weighting distribution reflects that Hong Kong encourages the development of building management system, policies and procedures for the building design based on technology for energy efficiency. It is envisaged that only rules and regulations, supported by incentives would help promoting green building development, while it is considered that social awareness of green building constitutes a behavioural change and is a market-driven process (HKGBC, 2014). Besides, the restrictive space available in Hong Kong limits the launch of renewable energy sources to capture energy efficiency and help slowing down the usage amount of energy. According to the Arcadis report (2016), it stated that the quality of open space within the urban area should be improved.

The average weighting distribution of the Green Mark Scheme shows that the Singapore Building Construction Authority (BCA) would like to encourage a balance for each of the environmental elements to benefit the building occupants. This means that Singapore is adopting an integrative approach towards green building development. According to the report on Green City Index (EUI, 2011, 2013), it stated that the performance of water management and waste management of Singapore is better than Hong Kong. However, the performance of land use is better in Hong Kong than in Singapore. It seems that each city has its own merits in different field.

**Table 3:** Comparing the criteria elements of green building standard

	<u>Criteria in HKBEAM Plus</u> <u>(Hong Kong)</u>	<u>Criteria in Green Mark Scheme (Singapore)</u>
i)	Innovation	Climate Responsive Design
ii)	Site Aspects	Resource Stewardship
iii)	Materials and Waste Aspects	Advanced Green Efforts
iv)	Management	Building Energy Performance
v)	Water Efficiency	Smart Healthy Building
vi)	Energy Efficiency	/
vii)	Indoor Environmental Quality	/



### **Comparing project cases**

The projects are chosen on the basis of similarity while the buildings have been completed for some time and are landmark green buildings of the two cities.

#### ***Zero Carbon Building (ZCB), Hong Kong***

The Zero Carbon Building (ZCB) is the owner of Green Building Award 2012 and BEAM Plus NB V1.1 – Provisional Platinum rating. It is the first zero carbon building in HK constructed in partnership with government to raise the community awareness of sustainable living. ZCB is a 3-storey building in a native urban woodland landscape area. The building has exhibition areas, an eco-home show-flat, an office area and a multi-function hall. The landscape aims to promote biodiversity and provides greenery for reducing the urban heat island effect. ZCB contains the following green features:

i) Eco-Friendly Construction: By using the building information modeling technology to minimize construction material waste and reduce overall energy consumption by 40%.

ii) Landscaped Space: The landscaped outdoor space covers over 50% of the site in surrounding the main building. It contains features of eco-plaza, eco-terrace, eco-garden. Moreover, the woodland houses are planted with 40 native tree species to protect the endemic biodiversity, improve the local micro-climate by reducing the heat island effect, and absorb 8,500kg of carbon dioxide per year.

iii) Net Energy Surplus: The biodiesel tri-generation system incorporates the waste cooking oil and it can produce 70% of energy needs in ZCB and the remaining 30% energy was produced by the photovoltaic solar panels. Besides, there are various measures to reduce the energy usage for cooling and the Eco-Max absorption chillers adopted convert building waste heat to produce energy for the refrigeration and air conditioning needs.

#### ***Tampines Concourse, Singapore***

The Tampines Concourse is awarded with the BCA Green Mark Gold<sup>Plus</sup> in 2009 and constructed in a partnership with the government. It is a 3-storey office building and also the first carbon neutral development in the Asia Pacific region. Beyond sustainable design features such as an energy-efficient building envelope design and eco-friendly fittings for energy and water efficiency, this project also introduces innovative building materials to reduce the usage of natural resources in the construction process. Tampines Concourse contains the following green features:

- i) Designed for energy efficiency: The building is designed with indoor non-compressor fresh air cooling system for smart temperature together with the extensive façade, roof greening with vertical greening area of 2504m<sup>2</sup>, green roof system of 1921m<sup>2</sup> natural

day lighting system for allowing daylight penetration into the building. These innovative design can save around 42,000 kWh per year based on temperature control for the common area, 620,000 kWh per year for the entire building and mitigate solar heat gain and urban heat island effect.

- ii) Designed for water efficiency: The building is designed with waterless urinals and water efficiency labeling system in restroom, with nano-coating applied on water urinals for ease of maintenance, deodorization and sterilization. The design of the water efficiency system can save water around 280 m<sup>3</sup> per year and reduce the operational cost for potable water usage.
- iii) Sustainable Construction and Management: For construction, the building was constructed with extensive use of recycled materials and environmentally friendly materials, such as green concrete, copper slag, recycled concrete aggregates, dry wall partitions, non-chemical anti-termite system and recycled pre-cast concrete kerbs etc. For Management, the project was planned to reduce the usage of natural materials together with targets set to reduce water and energy consumption during construction stage, setting a rainwater recycling system, waste water treatment system for achieving zero potable water purpose. It can eventually reduce CO<sub>2</sub> emissions and promote conservation of natural resources.

### ***Comparing the performance of ZCB and Tampines Concourse***

Referring to Table 4, the performance of ZCB is better in carbon dioxide reduction and less in electrical energy gained. This may be caused by the geography and weather in Hong Kong as the weather in Singapore is hotter and sunnier than Hong Kong, for which benefit to the solar heat gain is obvious in Singapore.

### ***Benefits perceived from the performance of green building***

It is reflected from the project cases that the benefits perceived from the performance of green building are: (1) through the waste management and use of recycled materials during the construction stage, both buildings can minimize the pollution and the waste; (2) the landscape area in ZCB in providing an eco-friendly garden with respect to the biodiversity and ecosystem, it can lower the severity of urban island heat and carbon emission; (3) through the design of water treatment system, solar panel system, solar heat gain system and energy saving plan, it minimizes to reliance on non-renewable natural resource and reduce the production of toxic chemicals. Moreover, the design of

day-lighting, natural ventilation helps to provide thermal comfort, visually comfort, and better indoor air quality to the users and occupants. This altogether demonstrates the environmental and social benefits of green buildings. The economic benefits are not referred here as data are yet to be collected in years to realize the actual financial benefits in comparing to the estimated benefits.

**Table 4:** Comparing the project cases

<u>Item No.</u>	<u>Zero Carbon Building (ZCB)</u>	<u>Tampines Concourse</u>
1	230,000kWh Electrical energy gained yearly and including 99,000kWh surpluses yearly.	620,000kWh energy saved yearly from solar heat gain and urban heat island effect.
2	7,100 tons of carbon dioxide reduction per year.	6,750 tons of carbon dioxide reduction yearly.
3	Minimized construction material waste and reduce overall energy consumption by 40%.	Recycled materials and environmentally friendly materials were used and reduced CO <sub>2</sub> emissions eventually.

## CONCLUSION AND RECOMMENDATIONS

With the comparison of the green building standards and the project case studies above, it is found that the factors affecting green building development are not mainly about the green marking scheme or guide. It is about the involvement of government. Singapore has legislation enacted in 2008 for the Building Control (environmental sustainability) regulations to acquire a minimum environmental sustainability standard equivalent to the Green Mark Certified Level for new buildings and existing buildings; whereas Hong Kong has planning regulations encouraging developers and designers to adopt energy conservation design with compensation on GFA concession. Moreover, the government strategy is another main factor that affects the development of green building. In Singapore, BCA looks after the green building development. In Hong Kong, a separate institution called ‘Green Building Council’ (GBC) is set up in 2009 to look after green building development. HKGBC has devised a gradual development roadmap via providing market-driven incentives for energy reduction for new buildings and existing buildings. As for building control, the Guidelines on Design and Construction Requirements for Energy Efficiency of Residential Buildings takes effect in 2014. It can be seen that the pace is different although the direction is the same for Singapore and Hong Kong. It is believed that the progress of green building development in Hong Kong is hindered by land and housing problems, and political problems in the recent years.

As for Hong Kong, government would face similar problems of environment aspects in facing climate change. Government should set a solid development strategy for

developing a green society and enhancing green concept into the social health issues, not just technical issues. As such, public awareness in Hong Kong has been recently dominated by housing issues and political issues, and less of green building development. Therefore, it is recommended that Hong Kong can firstly start to promote green living style from education, which aims to educate the next generation about the importance of environmental aspect of constructing a green society in the future. Second, government can implement policies to encourage the construction of green buildings or buildings with green elements, such as tax return or rate concession, or more construction exemption allowances to encourage the development of green elements for construction and building projects. Third, there should be a central coordinating authority to take charge of green building development such that integrative policies can be effectively implemented.

As for Singapore, they may already have an all-round origination for green building development due to the government involvement and the public awareness. However, Singapore is facing the environmental issue of natural environment. It is because the rapid development in Singapore has neglected the natural environment. It will affect the balance of the natural ecosystems. Therefore, reducing the impact to the natural environment is needed, as such as the urge to cut down the waste, increase material recycling and the force to reduce carbon emission.

## REFERENCES

- ARCADIS (2016) *SUSTAINABLE CITIES INDEX 2016: Putting people at the heart of city sustainability*. [ONLINE] Available at: <https://www.arcadis.com/media/0/6/6/%7B06687980-3179-47AD-89FD-6AFA76EBB73%7DSustainable%20Cities%20Index%202016%20Global%20Web.pdf>. [Accessed 1 March 2017]
- Building and Construction Authority (2014) *Singapore's Green Building Masterplan Greening 80 % of all Buildings in Singapore before 2030*. [ONLINE] Available at: <http://www.macaomiecf.com/cms2014/fckupload/file/3Tan%20Tian%20Chong.pdf>. [Accessed 12 January 2017]
- BUILDING Journal Hongkong (2012) *The first zero carbon building in Hong Kong*. [ONLINE] Available at: [http://www.building.com.hk/feature/2012\\_0813zcb.pdf](http://www.building.com.hk/feature/2012_0813zcb.pdf). [Accessed 16 December 2016].
- CalRecycle, California Business Portal (2014) Green building basics, available at <http://www.calrecycle.ca.gov/GreenBuilding/Basics.htm>
- Chan, H.W.E., Qian, Q.K. and Lam P.T.I. (2009) The market for green building in developed Asian cities—the perspectives of building designers, *Energy Policy* Volume 37, Issue 8, August 2009, Pages 3061-3070
- City Developments Limited (2012) *SUSTAINABILITY: ADDING VALUE TO BUSINESS CDL's Ideas*,

*Initiatives* & *Impacts*. Available at:  
[http://media.corporateir.net/media\\_files/IROL/60/60774/021012\\_CDL\\_Sustainability\\_Showcase\\_W\\_Singapore\\_Sentosa\\_Cove\\_Presentation\\_S.pdf](http://media.corporateir.net/media_files/IROL/60/60774/021012_CDL_Sustainability_Showcase_W_Singapore_Sentosa_Cove_Presentation_S.pdf) (Accessed: 9 December 2016)

City Developments Limited (2009) *CDL UNVEILS FIRST CARBONNEUTRAL® DEVELOPMENT IN SINGAPORE & ASIA PACIFIC – 11 TAMPINES CONCOURSE*. [ONLINE] Available at:  
[https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=15&cad=rja&uact=8&ved=0ahUKEwis5rqL2tXSAhWGj5QKHc2rB1kQFghpMA4&url=http%3A%2F%2Fphx.corporate-ir.net%2FExternal.File%3Fitem%3DUGFyZW50SUQ9MTQ2MTZ8Q2hpbGRJRD0tMXxUeXBIPtM%3D%26t%3D1&usq=AFQjCNGB6OaeQVbPt0wVVABA7e97\\_JtGRw&sig2=NtyJn9Lz-JDz9FfGNmeNRg](https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=15&cad=rja&uact=8&ved=0ahUKEwis5rqL2tXSAhWGj5QKHc2rB1kQFghpMA4&url=http%3A%2F%2Fphx.corporate-ir.net%2FExternal.File%3Fitem%3DUGFyZW50SUQ9MTQ2MTZ8Q2hpbGRJRD0tMXxUeXBIPtM%3D%26t%3D1&usq=AFQjCNGB6OaeQVbPt0wVVABA7e97_JtGRw&sig2=NtyJn9Lz-JDz9FfGNmeNRg). [Accessed 1 March 2017].

City University of Hong Kong (2012) *Green and Sustainable Buildings Design Criteria and Application in Hong Kong* [ONLINE] Available at:  
[http://personal.cityu.edu.hk/~bswmwong/contents/resources/city\\_env\\_studies/green\\_bldg\\_design.pdf](http://personal.cityu.edu.hk/~bswmwong/contents/resources/city_env_studies/green_bldg_design.pdf). [Accessed 7 January 2017]

Eco-business (2014) *Putting Singapore on the global map for green buildings*. [ONLINE] Available at:  
<http://www.eco-business.com/news/putting-singapore-global-map-green-buildings/>. [Accessed 10 January 2017]

Ecolife (2010) *Definition of Green Building*. [ONLINE] Available at:  
<http://www.ecolife.com/define/green-building.html>. [Accessed 20 January 2017].

Construction Industry Council (2014) *What Is a Zero Carbon Building ?*. [ONLINE] Available at:  
[http://www.cic.hk/eng/main/zcb/ZCB\\_experience/what\\_is\\_zcb/](http://www.cic.hk/eng/main/zcb/ZCB_experience/what_is_zcb/). [Accessed 8 December 2016].

Economist Intelligence Unit (2011) *Asian Green City Index 2011* [ONLINE] Available at:  
[http://sg.siemens.com/city\\_of\\_the\\_future/\\_docs/Asian-Green-City-Index.pdf](http://sg.siemens.com/city_of_the_future/_docs/Asian-Green-City-Index.pdf). [Accessed 1 March 2017].

Economist Intelligence Unit (2013) *Asian Green City Index 2013* [ONLINE] Available at:  
[http://www.macaomiecfc.com/MIECF2013/downloads/forum%20pdf%20for%20KM/S2\\_Stefan%20Denig.pdf](http://www.macaomiecfc.com/MIECF2013/downloads/forum%20pdf%20for%20KM/S2_Stefan%20Denig.pdf). [Accessed 1 March 2017].

Gottfried, D. (2013) *Dodge Construction Outlook: The explosion of green buildings*, McGraw-Hill Construction

HKGBC (2009) *About HKGBC*. [ONLINE] Available at:  
<https://www.hkgbc.org.hk/eng/AboutHkgbc.aspx>. [Accessed 10 January 2017].

Green Building Council Australia (2013) *Green Building Evolution*, available at  
<https://www.gbca.org.au/resources/gbca-publications/green-building-evolution-2013/>

Hui, S.C.M. (2011) *Design of High Performance Green Buildings: Opportunities and Challenges*. Available at: [https://web.hku.hk/~cmhui/111205\\_MARCC\\_Seminar.pdf](https://web.hku.hk/~cmhui/111205_MARCC_Seminar.pdf) (Accessed: 9 December 2016).

Hui, S.C.M (2010) *Zero energy and zero carbon buildings: myths and facts* . [ONLINE] Available at:  
<https://web.hku.hk/~cmhui/ISSF2010-SamHui.pdf>. [Accessed 9 December 2016]

Leung, C.F. (2013) *Green Buildings in Hong Kong*. Available at:  
[http://www.polyu.edu.hk/greencampus/files/CS%20Weeks\\_Seminars%20PDF/Green%20buildings%20](http://www.polyu.edu.hk/greencampus/files/CS%20Weeks_Seminars%20PDF/Green%20buildings%20)

in%20Hong%20Kong.pdf (Accessed: 9 December 2016).

Li, G. (2013) Zero Carbon Building. Construction Industry Council. 2013. *ZCB First Zero Carbon Building in Hong Kong*. [ONLINE] Available at: [http://www.macaomiecfc.com/MIECF2013/downloads/forum%205\\_pdf%20for%20KM/S5\\_Guiyi%20Li.pdf](http://www.macaomiecfc.com/MIECF2013/downloads/forum%205_pdf%20for%20KM/S5_Guiyi%20Li.pdf). [Accessed 16 December 2016]

Mao, X, Lu, H and Li, Q (2009) A comparison study of mainstream sustainable/green building rating tools in the world, in Management and Service Science, 2009. MASS '09. International Conference on 20-22 Sept. 2009, 1-5

McGraw-Hill Construction, Smart Market Report: World Green Building Trends, New York, 2013.

Retzlaff, R. (2010) Developing policies for green buildings: what can the United States learn from the Netherlands? Sustainability: Science, Practice, & Policy 6(1):29–38. Published online Jul 10, 2010

United Nations Environment Programmes (2010) Annual Report, available at <http://staging.unep.org/annualreport/2010/pdfs/UNEP-AR-2010-FULL-REPORT.pdf> (assessed: March 2017)

Western North Carolina Green Building Council (2013) available at <http://www.wncgbc.org/>

World Green Building Council (2013) Definition of Green building, available at <http://www.worldgbc.org/>

# Sustainable Retrofitting – Global Strategies & Implementation Issues

Dr. Peter Smith

Associate Professor – University of Technology Sydney (UTS)  
Secretary General – International Cost Engineering Council (ICEC)  
peter.smith@uts.edu.au  
University of Technology Sydney  
PO Box 123, Broadway NSW 2007, Australia

---

## ABSTRACT

This paper examines the issues related to the implementation of Sustainable Retrofitting in the construction industry and the various initiatives and approaches that are being used in various countries around the world to promote the retrofitting of existing buildings. Whilst existing buildings generally represent approximately 98% of the total building stock sustainable design and construction initiatives have typically tended to focus on new buildings. However, the past decade has seen greater focus placed on existing buildings. The research methodology is based on a literature review of the key global issues in relation to retrofitting and then a detailed investigation of implementation strategies and ‘best practices’ that have been developed in a range of countries and cities around the world. The research reveals that there are considerable implementation issues. The key problems relate to the lack of incentives for existing building owners to retrofit their buildings and the difficulties in adequately communicating the retrofitting ‘business case’ to these owners. Nevertheless, an increasing number of countries are developing successful retrofitting implementation strategies. A key finding was the importance of coordinated government support, leadership and incentives as a critical driver for sustainable retrofitting of the existing building stock.

**Keywords:** Existing Buildings, Retrofitting Business Case, Sustainable Retrofitting

## INTRODUCTION

Existing buildings and the construction sector have an enormous impact on the environment. Globally, buildings account for approximately 40% of energy consumption, 30% of all energy-related greenhouse gas (GHG) emissions, 30% of global resource consumption, 12% of global fresh water use and produces 40% of waste (UNEP 2016). Accordingly, the built environment has been widely recognized as having the greatest potential for addressing global environmental problems and particularly through existing buildings which account for approximately 98% of the total building stock (World Bank 2014). This can be achieved by effective long term sustainable retrofitting of the existing global building stock.

The importance of the retrofit market will continue to grow as the world’s population grows in combination with increased urbanization. The World Economic Forum (2011, p.11) contend that *“together, government and industry stakeholders stand at the apex of a historic opportunity to spark the retrofit market; there is no time to waste. As the world’s urban population continues to swell towards 70% by 2050, existing buildings and infrastructure will be increasingly strained; more urban fabric will be built than ever before; and more of the world’s resources will be used to fuel such growth. When we reach 2050, over 50% of today’s existing building stock will still be in use. Forward-thinking policy will not only ensure that today’s building stock is retrofitted to avoid a country or region’s exposure to the increasing risks of resource scarcity but that the systematic framework is in place to ensure that tomorrow’s generation of buildings will continue to be as efficient as possible, even as they age”*.

This paper will examine the global issues related to sustainable building retrofitting and strategies that are being used around the world to try and achieve this.

## RETROFITTING – GLOBAL POTENTIAL

The IEA (2013) articulate the global potential for retrofitting the existing building stock through utilizing existing technologies and further innovation.

*“The buildings sector, including the residential and services sub-sectors, uses a wide array of technologies. They are used in the building envelope and its insulation, in space heating and cooling systems, in water heating, in lighting, in appliances and consumer products, and in business equipment. The long lifetime of buildings and related equipment presents both challenges and opportunities for the sector. Some of the technologies needed to transform the buildings sector are already commercially available and cost effective, with payback periods of less than five years. Others are more costly and will require government intervention if they are to achieve wide market uptake. Unlike many of the technologies needed in the transport and industry sectors, only a small proportion require major research and development (R&D) breakthroughs. Many could, however, benefit from a combination of additional R&D and economies of scale to reduce costs, enhance performance and improve their affordability” (IEA 2013, p.9).*

The IEA (2013) contend that the global barriers to seizing these opportunities and implementing effective building retrofits are complex and require government leadership to achieve high levels of market diffusion. Integrated and comprehensive policies are needed to overcome the common barriers such as high initial costs. A transformation of the buildings sector could have long term profound effects particularly with respect to the power sector. This is significant as the IEA (2013) note that in a ‘business-as-usual’ scenario energy demand in buildings will increase by 50% globally by 2050.

## RESEARCH METHODOLOGY

The research methodology adopted for this study was a comprehensive literature review and case study analysis of retrofitting trends, policies, best practices and strategies being implemented around the world and the main global implementation issues and challenges.

## GLOBAL COMPARISONS

### Generally

Solidiance (2016) undertook an extensive study of 10 major cities around the world to analyse and rank each on their green building performance. The cities were London, New York, Beijing, Dubai, Hong Kong, Paris, Shanghai, Singapore, Sydney and Tokyo. The cities were assessed on 4 criteria:

- i) Green Building Landscape  
Based on the number of green buildings, % of green buildings out of total buildings, green building ratings and number of green building certified professionals
- ii) Green Building Efficiency and Performance  
Based on CO<sub>2</sub> emissions and energy use.
- iii) Green Building Policies and Targets  
Based on green government policies, building codes and targets
- iv) Green City Culture and Environment  
Based on the sustainability culture of the city

Whilst the study covered both new and existing buildings, the results provide an excellent indication of the relative green ‘maturity’ of these cities which naturally provides a good indicator of the way that they ‘green’ the existing building stock. They also provide a good indicator of green policies and implementation in the countries that they represent.



The overall assessment ranked Paris first followed by Singapore and London. These three cities were found to be the most advanced in the adoption of new and existing green buildings with a high level of green building activity. They were followed by Sydney, Tokyo and Hong Kong and then New York, Dubai, Beijing and Shanghai respectively.

Singapore were observed as a pioneer in the construction industry with a long history of comprehensive and bold policies and targets. The city's target of greening 80% of its building stock by 2030 is considerable more ambitious than the other cities studied. The study also noted that, whilst Beijing, Dubai and Shanghai ranked at the bottom, these cities joined the green building movement much later than their counterparts but are catching up at a remarkable rate (Solidiance 2016)

The most relevant section of this study for this paper was Criteria 3 - Green Building Policies and Targets. Green building policies, codes, incentives and targets form the backbone for sustainable building and retrofitting and are primarily government driven. Government leadership is crucial for effective long term implementation of green building initiatives. Also crucial is certainty that these policies will be implemented over the long term and not be viewed as short-term stop-gap measures. The study found that Tokyo led the way with its Green Building Program in 2002 followed by Singapore with the first of its Green Building Masterplans in 2006.

The following section is drawn from Solidiance (2016, p. 34-48)

### **Tokyo**

The Tokyo government introduced a 'Green Building Environment Plan' in 2002 to provide a clear framework for the design, implementation and evaluation of sustainable buildings – both new and existing. Building Environment Plans are required for new buildings or retrofitting projects where the total floor area exceeds 5000m<sup>2</sup>. The government then introduced the Tokyo 'Cap-and-Trade Program' in 2010 for industrial/commercial buildings that mandates a reduction of CO<sub>2</sub> emissions from these sectors. Targets have been set to establish caps (emission limits) and a mandatory reduction rate has been set for buildings/facilities based on the relevant cap.

Financial incentives adopted by the government include tax incentives through an 'Energy Saving Promotion' scheme targeting small to medium enterprises. These incentives enable building owners to offset enterprise taxes when they incorporate energy efficient equipment and/or renewable energy into their buildings.

### **Singapore**

The Singapore government, through their Building and Construction Authority (BCA), has been a long term leader in promoting sustainable development in the country. They introduced the Green Mark green building rating system in 2005 and this provided the benchmark for evaluating the environmental performance of their buildings. This was followed in 2006 by the introduction of a 'Green Master Plan' that has been subsequently revised twice with the 3<sup>rd</sup> 'Green Master Plan' launched in 2010. The key objectives of the Master Plans were to establish green building as the norm in Singapore, to green both new and existing buildings, develop green technologies and design innovation and to ultimately establish Singapore as a global leader in sustainable development. In 2010 they developed a 'Sustainability Blueprint' that set a very ambitious target of greening 80% of its existing building stock by 2030. This was embraced by the industry and indications are that this goal will be achieved - by 2014 more than 25% of the existing building stock had been 'greened'.

In 2012 the Singapore government introduced further requirements specifically targeted at existing building owners. Existing building owners are required to submit annual reports via a Building Energy Submission System (BESS) that detail information about their building and its energy consumption. Existing building retrofits are required to incorporate stringent energy usage standards and comply with

the minimum environmental standards set by the Green Mark scheme. This includes regular energy efficiency audits.

A number of financial incentives are provided to encourage existing building owners to retrofit their buildings to become more sustainable. This includes a Green Mark Incentive Scheme that provides cash incentives for sustainable retrofits. To help address the issue of the typically high initial costs with sustainable retrofits, the Building Retrofit Energy Efficiency Financing (BREEF) Scheme financing program was established.

## **Paris**

In Paris, a lot of work has been done to encourage large businesses in the city to sign up to the 'Paris Climate Action Charter' to help meet their 'Climate-Energy Plan' objectives. Under this charter, the Paris District Heating Company, which supplies approximately one-third of heating, launched a programme to reduce pollution and promote renewable energies. Over 30 large businesses have now signed up to the Charter.

In terms of encouraging the retrofitting of the existing building stock, Paris has initiated a plan for 1000 buildings to undergo energy-targeted renovations by 2020. This is also supported by the annual investment of approximately US\$44 million to help encourage/finance the retrofitting of residential buildings. In 2015 legislation was introduced requiring the rooftops on all new or refurbished buildings in commercial zones to be partially covered in plants or solar panels to improve energy performance. Authorities also conduct GHG inventory and energy consumption assessments of public/community buildings every 5 years.

## **New York**

New York was an early global leader in policies focusing on improving the energy performance of the existing building stock. In 2009 they developed a 'Greener Greater Buildings Plan' (GGBP) that incorporated benchmarking, energy audits and retro-commissioning and a new energy code. This was supported in 2010 by the establishment of the New York City Energy Conservation Code (NYCEEC) - an independent, non-profit financial corporation to help implement the GGBP. The GGBP requires large commercial buildings to benchmark their energy and water consumption with the Energy Star rating scheme with the data published online. Buildings over 50,000 sq feet must have periodic energy audits and undergo energy retrofits if required.

The have adopted the slogan of 'One City - Built to Last' and have an all-inclusive 10 year plan to target all public/private buildings that need major energy upgrades. Energy performance targets have been developed for existing buildings to be achieved through both voluntary reductions and new regulations. The target is to reduce the city's building emissions by 30% by 2025.

The city also provides considerable financial incentives through funding of approximately US\$ 250 million per annum to support a wide range of program that include direct financial incentives for energy reduction. Tax credits are also provided through the 'New York State Green Building Tax Credit' scheme that provides \$US 25 million in tax credits for owners and tenants of existing buildings that meet established energy benchmarks. Lower interest loans are also provided to owners and tenants for energy reduction retrofits.

## **Hong Kong**

Hong Kong established its Building Energy Codes in 1998 to articulate building compliance standards and this subsequently required mandatory compliance with the Buildings Energy Efficiency Ordinance (BEEO). The BEEO now has a statutory requirement for commercial buildings to have energy audits carried out every 10 years. In 2011, the Hong Kong government introduced a new plan titled the 'Building Design to Foster a Quality and Sustainable Built Environment' (BDF QSBE) for all new

commercial buildings and retrofit projects to promote energy efficiency and green design. The BDF QSBE requires that all new buildings and retrofits be assessed via the Hong Kong Green Building Council BEAM Plus rating system in order to receive concessions for additional gross floor area. In 2013 they launched the HK3030 campaign that included targets of reducing total building electricity use by 30% by 2030.

However, Hong Kong has arguably made its greatest mark by establishing one of the world's largest government funded financial incentive schemes to encourage private sector building owners to invest in environmental retrofits – the Buildings Energy Efficiency Funding Scheme (BEEFS). It has provided US\$ 450 million for this scheme and new matching schemes secured for 2014-18 from two major electricity companies has added approximately US\$100 million to this funding.

## **London**

London has established a Green Organisations Program to encourage building owners to upgrade their buildings to be more energy efficient and to train their staff in the operational aspects. They also introduced an innovative RE:FIT retrofit program for commercial buildings to encourage retrofits and achieve cost savings in operation. The UK government has also set new ambitious national targets requiring all new homes built from 2016 and all new non domestic buildings from 2019 to be zero carbon. They have also established new energy benchmarking and disclosure requirements for both new and refurbished existing buildings. This comprises a sustainability statement (BREEAM or a Code for Sustainable Homes pre-assessment) and an Energy Strategy incorporating a detailed assessment of the energy demand of the building.

Financial incentives include the London Energy Efficiency Fund (LEEF) providing US\$ 50 million in funding for energy efficient building retrofits.

## **Sydney**

Sydney has developed a 'Greening Your Business' sustainability program to help meets its ambitious target of reducing carbon emissions in the city by 70% by 2030. It comprises 4 main pillars: Smart Green Business – assisting program participants, City Switch Green Office – guidance and assistance for office building owners/tenants, Better Buildings Partnership – group of leading commercial property owners and Environmental Upgrade Finance. Sydney has also developed an Energy Efficient Master Plan.

Financial incentives are provided through Environmental Upgrade Finance and Environmental Grants Programs. The Environmental Upgrade Finance involves finance for sustainable retrofits/upgrades that are repaid through the city's council rate collections as an Environmental Upgrade Charge. The Grants Program provides grants with priority given to projects aligned with the city's 'Sustainable Sydney 2030' strategic targets.

## **Dubai**

Dubai introduced their 'Green Building Regulations and Specifications Code' in 2012 for public buildings and in 2014 extended this to cover private commercial buildings. It incorporates the Estimada Pearl Rating System that is adopted widely in the United Arab Emirates. In 2015 their Green Building Council introduced their 'Technical Guidelines for Retrofitting Existing Buildings'. In a relative short space of time Dubai has been able to green nearly 9% of its existing building stock in line with the Estimada and other international rating tools. The Emirates Authority for Standardization & Metrology (ESMA) has set mandatory energy efficiency requirements and labelling systems for certain water and electrical fixtures. Dubai also has a Smart City Plan that includes a target of installing 250,000 smart meters and smart-grid power to all buildings by 2018.

The Dubai government has provided extensive financial incentives through collaboration with the private sector to provide US\$ 545 million to retrofit 100,000 buildings to meet specified green building standards. They have also allocated nearly US\$ 14 billion for renewable energy projects. The overall aim is to reduce energy consumption by 30% by 2030.

## **Beijing**

Beijing released their 'Green Building Action Plan' in 2013 that requires all new buildings to achieve at least a 1 star rating (out of 3) under the Chinese Green Building Label-3 rating system. For developments over 20,000m<sup>2</sup> a rating of at least 2 stars is encouraged. The plan also encourages the development of green eco-demonstration zones such as the Future Science and Technology City. These zones must have buildings that all meet a minimum 1 star rating and have at least 40% of the buildings achieving a 2 star rating or higher. Financial incentives are being developed with one Beijing District providing financial rewards based on areas of LEED certified building spaces.

## **Shanghai**

Shanghai was the first city in China to introduce a green standard in construction. This was introduced in 2011 and was followed by the Shanghai Municipality 3 year Green Building Action Plan for the period 2014-16. This requires all new civil buildings to meet the 1 star rating under the Chinese rating system and government office buildings over 20,000m<sup>2</sup> are required to meet a minimum 2 star rating. Other policies, plans and regulations have been developed through the Special Planning Shanghai Green Building and Eco-City plans. This includes the monitoring of these standards and energy auditing. Financial incentives include subsidies awarded by the Shanghai government for buildings with exceptional green features.

## **IMPLEMENTATION ISSUES**

### **Generally**

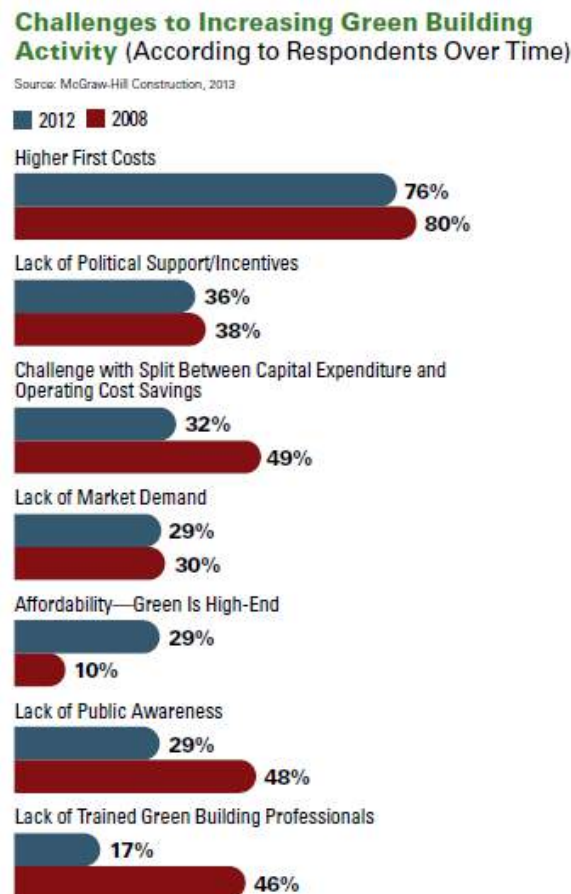
McGraw Hill (2013) have undertaken a series of global surveys on the main 'green building and retrofit' implementation barriers and issues since 2008 and found that these barriers/issues were relatively consistent around the world. Their surveys covered construction consultancy and contracting organisations in 9 countries – the United States, Australia, Germany, Norway, United Kingdom, Singapore, South Africa, the United Arab Emirates and Brazil.

*They found that the main challenge/issue was clearly cost. "Essentially, it comes down to cost. Whether real or perceived, higher first costs for green building efforts is viewed as the most significant obstacle between current levels of green building and future growth. In fact nearly all other challenges became significantly less important between 2008-12. Therefore it is incumbent upon the industry invested in growing green to help more effectively make the business case for the market. This will require better measures and performance tracking, and building operators will need to become involved and educated on green so that they maximise the performance of green buildings, since even the greenest building can only yield results if it is operated and maintained efficiently" (McGraw Hill 2013, p. 20).*

The lack of consistent measurable environmental has been identified by the Global Alliance for Construction (GABC 2015). The GABC (2015, p. 8) stress that *"transparency and comparability rely on consistent data. Yet the way buildings are currently measured varies dramatically, this significant variability introduces high uncertainty in valuation and project-cost estimation"*. They highlight the need for the development of *"international standardized and vertically integrated (inter-governmental) measurement and reporting to enhance the understanding and international comparison of energy efficiency data and relevant resource flows for reduced GHG emissions"* and the *"development of international data, measurement, and standards"* in the built environment sector.

The following table shows the difference in global responses between the surveys undertaken by McGraw Hill (2013) in 2008 and 2012 for the main challenges identified for increasing green building activity.

**Table 1 – Challenges to Increasing Green Building Activity (Difference in Survey Responses from 2008-12)**



**Source - McGraw Hill 2013, p.20**

The McGraw Hill study showed that the next greatest issue after cost was a lack of government support and incentives followed by difficulties in articulating the business case to justify capital expenditure on green building. In countries where the green movement is less developed, a lack of public awareness was cited as a major inhibitor which highlights the importance of the education of not only the industry but also general society.

Sourani, A, & Sohail, M. (2011, p. 232) identified the following major barriers to green retrofits and green construction generally in the following categories:

- lack of funding, restrictions on expenditure and reluctance to incur higher capital cost when needed
- lack of awareness, understanding, information, commitment and demand
- insufficient/inconsistent policies, regulations, incentives and leadership commitment
- insufficient/confusing guidance, tools, demonstrations and best practice
- vagueness of definitions and diversity of interpretations
- separation between capital budget and operational budget
- lack of sufficient time to address sustainability issues
- lack of long-term perspective
- general perception that addressing sustainability always leads to incurring greater capital cost

- resistance to change
- insufficient integration and link-up in the industry
- insufficient research and development.

The World Bank (2014, P.5) contend that “*some barriers to greater energy efficiency (in existing buiars specific to certain stakeholder groups. For example, high transaction costs relative to returns and the perceived unreliability of repayment often deter commercial banks from financing building EE projects. Other barriers are sector-wide, such as energy subsidies and/or a widespread lack of data and information on EE opportunities, costs, and benefits. Addressing systemic problems such as these typically requires policy interventions and support at the national and regional level, although municipal governments can be influential in policy design and implementation*”.

## RECOMMENDED RETROFIT POLICIES & INCENTIVES

The World Bank (2014, pp. 6-7) have recommended the following policy and regulation instruments and tools to improve the energy performance of both new and existing buildings. They emphasise that to be most effective these measures need to be accompanied by a portfolio of support programs and actions. This type of holistic approach will generally be more effective than standalone strategies.

- **Energy regulatory policies**  
Usually formulated at the national or regional level, energy regulatory policies address general inefficiencies in energy markets.
- **Mandatory standards and codes.**  
Generally developed at the national and regional level and updated periodically, mandatory standards and codes address key market failures or inefficiencies, in this case, defined as situations in which rational decisions taken by market participants have led to negative or suboptimal economic outcomes for society as a whole.
- **Labels and certificates.**  
These are means of recognizing and encouraging efforts that go above and beyond the mandatory requirements outlined above.
- **Financial facilitation schemes.**  
These include fiscal and monetary incentives to encourage investments in energy efficiency. Examples include tax credits, cash rebates, and capital subsidies, as well as special funding vehicles and risk-sharing schemes to increase funding and lending for investments
- **Requirements for energy management.**  
Mandatory energy performance benchmarking and disclosure programs that require large public and commercial buildings to monitor and Improving Energy Efficiency in Buildings (continues on next page)
- **Public sector financial management and procurement policies.**  
These can have a significant impact on municipal efforts to retrofit public buildings and upgrade inefficient energy-consuming equipment.
- **Awareness-raising and capacity-building initiatives**  
Outreach and public information initiatives can help increase the knowledge and know-how of stakeholders and enable the design and implementation of effective EE programs and investment projects.

The details of the World Bank (2014) recommendations are provided in Figure 1:

**Figure 1 – Key Policy Interventions & Support - Matching Barriers With Policy Tools**

Policy Tools	Issues Addressed	Examples of Intervention	What City Government Can Do
Energy Regulatory Policies	Weak financial incentive to invest in EE by consumers Disincentive for energy utilities to invest in DSM activities due to lost sales	Remove general price subsidies for public, residential, and commercial users Decouple energy utility revenue from sales*	Support and participate in national or regional policy reform programs
Mandatory Standards and Codes	Split incentives, fragmented building trades, fragmented building ownerships, etc. Underinvestment in EE by equipment makers	Building energy efficiency codes Minimum energy performance standards for equipment	Set and/or enforce standards Encourage or mandate (public sector) purchase of EE equipment
Labels and Certificates	Lack of credible and consistent energy performance information and/or recognition of excellence	Energy Star label for equipment or buildings Green building rating systems	Promote the adoption of nationally/internationally recognized labels and certificates
Financing Facilitation	Insufficient financial incentive Lack of commercial lending to EE Risk concerns of commercial lenders	Subsidies for EE investments Dedicated EE fund and credit line Partial risk/credit guarantee	Use public funds to leverage private and commercial investments
Energy Management	Lack of transparent and consistent monitoring and control of energy use	Energy performance benchmarking and disclosure	Require energy performance benchmarking and disclosure for large public and commercial buildings
Public Sector Financial Management and Procurement Policies	Disincentive for EE efforts in budget-supported public entities Difficulty for public entities to contract energy service providers, or make EE equipment preferred purchase choices	Revise budgetary rules to allow retention of energy cost savings for other justified public spending Revise public procurement rules to allow for contracting of energy service providers and adopt EE purchase requirements	Make adjustments based on a city's own policy-making authority
Capacity Building and Awareness Raising	Inadequate knowledge and skills for BEEC compliance Lack of general awareness and sensitivity to energy waste Lack of specific knowledge and skills to perform energy management duties	Train building trades on BEEC requirements and proper approaches Public campaign to promote efficient use of energy Train building managers of large public and commercial buildings	Organize trainings and sponsor awareness campaigns

**Source: World Bank (2014, pp. 7)**

However, Matisoff, D. et al. (2016, p. 343) warn against an over-reliance on government mandates and focusing on new construction rather than existing buildings. *“Numerous policies have emerged that promote green building as a means to overcome market failures related to buildings. However, to date, these policies have been incomplete at best, and most rely on mandates. Pigovian taxes and subsidies for building construction and operation have the potential to be far more cost effective than the command-and-control approaches that are typical of the construction market. For example, policies that could align these incentives to improve market efficiency include construction permitting fees, impact fees, and targeting subsidies to buildings that provide positive externalities. Designing a tax and subsidy system that accurately characterizes and quantifies context-specific costs and benefits associated with building construction and operation is far from simple. Several jurisdictions have taken small steps to provide these types of incentives, often relying on the point structure provided by USGBC’s LEED program. Nevertheless, policymakers should be mindful of the unintended consequences of encouraging too much new (green) building on undeveloped sites rather than retrofitting existing (brown) building stock”*.

Sourani, A, & Sohail, M. (2011, p. 233) identified four key parties that are most capable of reducing green retrofit barriers. These were government (including regulatory bodies), professional/educational bodies, the supply chain and the end-users.

The IEA (2013, p. 217) argue that ‘whole-building’ performance policies are required that incorporate affordable widely available products that can be integrated into advanced retrofit building systems. This should also include new and innovative technology development strategies supported by a wide range of policies that will *“drive technical solutions from concept to full market saturation”*. The IEA (2013) also advocate new cross-sectoral policies across the industrial, power and building sectors to facilitate the diffusion of co-generation, waste heat utilisation and renewable technologies.

Policies also need to embrace ‘smart city’ strategies that cover ‘whole-of-city/precincts’ approaches rather than policies that solely target specific market sectors or building types.

## CONCLUSION

The full potential of the retrofit market is not yet being achieved. Globalisation and government leadership provide the key to more effective global implementation of environmental retrofit solutions for the built environment.

Globalisation provides the ability to share information and knowledge about best practices, technologies, materials and long term strategic plans that are being developed around the world. This paper has demonstrated that government leadership has been at the core of successful implementation but it is acknowledged that government intervention can be complicated and varies from country to country. For example, McGraw Hill (2013) point out that in more developed markets such as in the USA, the UK and Canada governments provided the initial catalysts for green development in their countries. This helped demonstrate the value of green building and retrofitting and the green markets in these countries has reached relatively advanced and sophisticated levels. In contrast, in countries such as Brazil and Chile, the private sector has been important leaders in encouraging green development but have now reached points where they require government intervention to increase the depth of green building to more meaningful levels. The right combination of market and government forces in individual countries will vary with a key challenge being developing the right mix to suit.

However, ultimately, cost and the business case will be the key determinants. Effective sustainable retrofitting and design relies on solutions that not only reduce environmental impact but can do so as economically as possible. Quantity surveyors should therefore be well placed to take advantage of this opportunity via their economic input.



## REFERENCES

ESMAP (2014), Improving Energy Efficiency in Buildings – Energy Efficient Cities, Energy Sector Management Assistance Program (ESMAP) Report, New York, USA

GABC (2015), Global Alliance for Buildings and Construction Report, London, UK

IEA (2013), Transition to Sustainable Buildings - Strategies and Opportunities to 2050, International Energy Agency, Paris, France

Matisoff, D., Noonany, D. & Flowers, M. (2016), Policy Monitor Green Buildings: Economics and Policies, Environmental Economics and Policy, volume 10, issue 2, Summer 2016, pp. 329–346

McGraw Hill (2011), Business Case for Energy Efficient Building Retrofit and Renovation, Smart Market Report, McGraw Hill Construction, Bedford MA, USA

McGraw Hill (2013), World Green Building Trends – Business Benefits Driving New and Retrofit Market Opportunities in Over 60 Countries, Smart Market Report, McGraw Hill Construction, Bedford MA, USA

Solidiance (2016), The Top 10 Global Cities for Green Buildings, Solidiance, Singapore

Sourani, A. & Sohail, M. (2011), Barriers to Addressing Sustainable Construction in Public Procurement Strategies, Engineering Sustainability, Volume 164 Issue ES4, pp. 229-237

UNEP (2016), Sustainable Buildings are the Most Cost Effective Solution to Climate Change, United Nations Environment Program (UNEP) Report, Division of Technology, Industry and Economics Sustainable Buildings and Climate Initiative (SCP/SUN)

United Nations (2016), Global Sustainable Development Report, Department of Economic & Social Affairs, New York, USA

World Bank (2014), Improving Energy Efficiency in Buildings, Energy Sector Management Assistance Program (ESMAP) Report, The World Bank, Washington, DC USA

World Economic Forum (2011), A Profitable and Resource Efficient Future: Catalysing Retrofit Finance and Investing in Commercial Real Estate, World Economic Forum Report, Geneva, Switzerland

World Economic Forum (2016), Shaping the Future of Construction - A Breakthrough in Mindset and Technology, World Economic Forum, Zurich, Switzerland

# The Infinite Evolution of Green Building and Sustainability

Dr. Alexia Nalewaik

## ABSTRACT

This technical paper is a sequel to the oft-cited 2008 paper<sup>1</sup> by the same author, “Costs and Benefits of Building Green” (Nalewaik & Venters, 2010). That paper diverged from typical ‘sustainable construction’ papers of its time, in that it tackled not just the cost of construction, but addressed the prestige of certification, business case justification, and emphasized less tangible benefits (such as health and productivity) resulting from green design. Subsequently, that paper has been cited in journals as diverse as sport management, environment and behavior, industrial engineering, and newborn and infant nursing.

The author acknowledges the surprising appeal of the original paper, and wants to expand upon the elements of that paper that were (unexpectedly) attractive to such a wide range of researchers. This second paper discusses the evolution of and advancements in the sustainability industry, and devises compelling arguments for continuing to broaden the sustainability mandate.

## INTRODUCTION

Green building has evolved considerably since its boom in the 1990’s and early 2000’s. The cost-benefit and return on investment (ROI) of green construction remains a very popular research topic. Lifecycle cost savings and savings by design are well documented. The prestige of certification is widely accepted, and is reflected in property values, as is the business case for those who place high worth on concepts of corporate responsibility, social value, and public image.

The sustainability industry, likewise, has evolved. There are additional compelling justifications for sustainable construction and building green, which have broadened considerably beyond the original cost savings and satisfaction arguments. This paper discusses these concepts, which include Ubudehe, biophilia, resilience, smart cities, ethical obligations, and active design.

### Sustainable Development and Green Building

The first recognized definition of sustainable development was offered by the ‘Brundtland’ report in 1987 as “development that meets the needs of the present without compromising the needs of future generations to meet their own needs” (World Commission on Environment and Development, 1987). The American Society of Civil Engineers (ASCE), similarly, defines sustainable development as “a set of economic, environmental and social conditions in which all

---

<sup>1</sup> Originally presented in 2008, reprinted in 2010 in IEEE Journal.

of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality or the availability of economic, environmental and social resources” (American Society of Civil Engineers, 2016). Since then, sustainable development has emerged as a guiding principle for long-term urban and capital planning by both public and private organizations, that seeks to achieve a balance between economic development, social development, and environmental protection. It is worth noting that definitions of sustainability continue to evolve; ASCE has refined and expanded its definition over time<sup>2</sup>. Some of the proposed steps to achieve sustainable balance included growth management (smart growth), new urbanism, renewable energy, and ‘green’ development (Freilich & Popowitz, 2010).

Whereas growth management and new urbanism became the nearly-invisible darling and extreme long-term purview of city planners, renewable energy and green buildings were seized upon with infectious enthusiasm by cities, architects, developers, and owners alike. Public funding was made readily available for renewable energy installations and public transportation, resulting in very visible and tangible additions to the urban landscape across all public, industrial, commercial, and residential sectors.

“The philosophy of green building is derived from Arcology, a combination of architecture and ecology put forward by Paolo Soleri in the 1960’s” (Zhao, He, Johnson, & Mou, 2015). The United States Environmental Protection Agency defines green building as “the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction” (United States Environmental Protection Agency, 2017). The design, construction, and remainder of the building lifecycle are often guided by green building certification programs such as Leadership in Energy and Environmental Design (LEED, U.S. Green Building Council), Green Star (Green Building Council Australia), and BREEAM (BRE Global).

Tax incentives, rebates, grants, preferred zoning considerations, expedited permit reviews, reduced insurance premiums, and esteem value (Nalewaik & Venters, 2010) “helped real estate developers and investors realize higher profits and upfront cost savings” (Freilich & Popowitz, 2010), including savings by design (value engineering) and lifecycle cost savings. Unfortunately, “at present, most of the green labeled buildings exist in the form of [discrete] individual buildings, not large-scale communities” (Zhao, He, Johnson, & Mou, 2015). As such, opportunities for synergy and broader impact on the urban ecosystem and community have been lost. Guided in part by technical specifications and achievable certification points, the engineering and design of green buildings (specifically, high performance and smart buildings) ushered in a visually unique category of architectural style.

---

<sup>2</sup> ASCE’s first definition of sustainable development was written in 1993. The 2007 version stated, “...the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and waste management while conserving and protecting environmental quality and the natural resource base essential for future development” (American Society of Civil Engineers, 2016).

## DISCUSSION

To the casual observer, then, sustainable development is all about green-certified buildings, solar panels, and bike paths. “Green buildings [remain] the darling of the media and trendy, politically-correct owners and tenants” (Nalewaik & Venters, 2010). However, sustainability originated from ancient concepts, and continues to evolve as society explores the true meaning of concurrently meeting present and future ‘needs’, including what constitutes a fundamental ‘need’ or ‘right’. These concepts considerably broaden the perceived scope of sustainable development beyond just energy savings and reduced waste, to include social and humanistic needs, such as security, safety, comfort, and health (Zhao, He, Johnson, & Mou, 2015). “Not just a building style, sustainable development is a design, construction, and lifestyle philosophy with both tangible and intangible benefits” (Nalewaik & Venters, 2010). Indeed, these ideas can be seen to radiate ever outward over time, like waves from a pebble in a pond, to the point where they now already include the health, well-being, and livelihood of past, present, and future generations, and the earth (and all its living creatures). It is even conceivable that, as human knowledge and achievement evolve, through space exploration the ‘indefinite’ sustainability concept could well expand to reach beyond planet earth itself.

Perhaps certification scoresheets need to be thrown away, in order to refocus investment in the broader explicit and implicit intents of sustainability. The following concepts are just a part of the broadened scope of sustainability, as applied to the built environment.

### Ethics

Broadening the sustainability concept has even raised the question if it is ever ethical to not design for sustainability, which could potentially impact the design, engineering, construction, and facilities management professions. Most professional institutions include an ethics clause or code of conduct by which members must abide. These are now expanding to include such notions as awareness of potential consequences of professional work [International Project Management Association, (IPMA)], avoiding harm to local communities [IPMA], promoting environmental responsibility [IPMA, Project Management Institute (PMI)], thinking long-term [IPMA], and acting in the best interests of both society and the environment [PMI] (Young, 2017).

### Smart Cities

Rapid advancements in disruptive technology are powerful, and already impacting the way cities’ problems are solved. The ability to capture data on all activities within a city has led to a substantial increase in the analysis and use of data to inform decision-making and design. A city is considered ‘smart’ when “investments in (i) human and social capital, (ii) traditional infrastructure, and (iii) disruptive technologies fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance” (Deloitte, November 2015). Smart cities can both adapt to human behavior and change human behavior through adoption of new tools.

Disruptive technologies and social innovations contributing to the rise of smart cities include (Deloitte, November 2015):

- Internet of everything
- Sensors and surveillance
- Social robotics
- Gamification
- Sharing economy / peer-to-peer
- Social media / digital platforms
- Big data
- Artificial intelligence
- Cloud computing
- Drones
- Renewable energy
- 3-D printing
- Crowdsourcing
- Dynamic pricing
- Blockchain
- Real-time information
- Mobile technologies

In smart cities, the opportunities presented by the adoption of new technology are seemingly limitless. From assisting housebound elderly, to parking and traffic improvements, crime reduction, simplicity of payment for public services, predictive policing, digital identity, and more, technology is already and will substantially change the way people live and work. The infrastructure cost for a smart city, however, is considerable and return on investment becomes a significant factor; this will undoubtedly influence choices and innovation in financing and delivery methods. It is expected that smart elements will be prioritized and introduced as funds are available and public acceptance is demonstrated. Health, safety, and security will likely top that list, as will multiple system redundancies to reduce the effects of natural disasters, accidents, and sabotage.

If the definition of resources is expanded beyond energy and money to include health, systems, people (workers), time, and more, the optimization of all resource use is implicit in the very definition of sustainability. Smart cities mean smart use and conservation of resources, reduction of stress and burden for inhabitants, and the preservation of those resources for future generations.

### Design for Resilience

While much of the ‘design for resilience’ discussion focuses on protection from climate change (such as higher temperatures, and flooding), urban resilience is considerably broader, addressing “the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience” (The Rockefeller Foundation, 2017). Such challenges may be physical, social, or economic; they may be foreseen, or sudden. Examples of such stresses and shocks include natural disasters, adverse events, violence, unemployment, infrastructure decay, climate change, and more. The objective is to foster economic prosperity, ensure social stability, meet basic human needs, ensure food security, provide continuity of public and critical services, and ensure cities and communities can continue to function even as all the above are scaled up or down.

The philosophy of resilience evolves from ecology, and is fundamentally about adaptability and elasticity (Minnery, 2015). Key to resilient design in cities are diverse and redundant systems, with a focus on passivity, flexibility, and durability (Resilient Design Institute, 2017), that anticipate interruptions and dynamic conditions, including fluctuating supply and demand, and changing conditions. Some cities are already designing versatility into key elements of infrastructure, such as water treatment plants that can handle input from different water sources (Armistead, 2017). Resilient design in architectural engineering becomes very practical and focused on basics such as: air quality, water quality, prevention of flooding, and other known vulnerabilities in buildings and communities. Design is a process. Resilient design, especially, requires continuous learning, crowdsourced input, and the embodiment of ‘messy vitality’ (Minnery, 2015), in order to address risk and uncertainty. This will likely extend to changes in building code requirements, as buildings already well exceed their expected lifespan and must be expected to continue to function; it may even trickle through to tax codes, as replacement of buildings at the end of their ‘expected life’ becomes an outdated concept.

Dynamic risk management, ensuring continuity of current services and shelter for present generations, and flexibility to adapt to demand for future generations are all key tenets of sustainability.

### Active Design

One sustainability question is how far planners should go in trying to safeguard citizens and the environment. Should planning include protecting people from themselves? Community health and wellness is one of those battlegrounds (Spula, 2017), as cities begin to adopt and implement active design guidelines.

The overarching goal of active design is to improve “all aspects of design for health – physical, mental, and social – at home, work, and throughout a neighborhood” (Spula, 2017). This includes planning to include community gardens, interactive civic spaces, infrastructure to support active lifestyles and mobility (walking, running, and bicycling, in addition to many other solo and group activities and sports), and green space such as parks. Other innovations include improved access to fresh produce, traffic calming features, ‘programmed’ spaces that include art and events, pedestrian-oriented programs, and public water fountains (City of New York, 2010). Interior features of active design include the placement and design of staircases, motivational signage, and exercise facilities.

How is active design sustainable? It could be argued that a healthy community reduces the need for reliance on medical and other civic services, and improves the quality of life for both current and future generations.

## Biophilic Design

Tied to the 'active design' concept of physical and mental health is the philosophy that humans require daily physical, visual, and emotional contact with nature because they, themselves, are part of nature (Kellert & Wilson, 1993). Biophilia, as a concept, was introduced in 1984. Biophilic design focuses on including nature in building and landscape design, both directly and indirectly, such as light, air, water, plants, natural materials, and images thereof. Where green design encourages all these, biophilic design elevates it, prioritizing nature and wildlife first in their planning objectives (Downton, Jones, Zeunert, & Roös, 2016), and celebrating biodiversity.

Such activities may include establishing nature reserves, adopting an urban forestry plan, reclaiming abandoned sites for the purposes of parks, designing buildings to include indoor gardens, or improving accessibility to existing green space in urban areas. Key to the concept is imagining the city as a garden, instead of a city with gardens.

Provisions for a healthy community, as stated for active design, certainly applies to the concept of sustainability. Above and beyond that, however, is the idea that nature and wildlife should be preserved for and provided to future generations.

## Ubudehe

One approach that embraces the broader sustainability goal is the Rwandan practice and culture of 'Ubudehe', which translates as "community working for the community". Originating from community participating during farming season, the idea has expanded to include solving problems that affect everyone, and was reintroduced in 2001 as a government initiative (Shah, 2011).

For the built environment, this introduces a locally fabricated ('lo-fab') approach to building, with four pillars (Murphy, 2016):

- Hire locally
- Source regionally
- Train where you can
- Think about every design decision as an opportunity to invest in the dignity of the places where you serve

When fully embraced, Ubudehe has the potential to better both the community and individuals. On a recent project in Butaro, hundreds of community members were trained and hired to perform construction labor. Instead of purchasing and importing furnishings, a guild was formed, and master carpenters hired to train others to fabricate furniture. A purpose was even found for discarded local waste (volcanic stone), material which was incorporated into the building design.

*“When you go outside today and you look at your built world, ask not only: ‘What is the environmental footprint?’ — an important question — but what if we also asked, ‘What is the human handprint of those who made it?’ What more can architecture do? And by asking that question, we were forced to consider how we could create jobs, how we could source regionally and how we could invest in the dignity of the communities in which we serve. ... Architecture can be a transformative engine for change.”*  
(Murphy, 2016)

How is Ubudehe sustainable? By providing training and jobs, Ubudehe better the lives of the current generation and community, reduces urban poverty, and creates a healthy environment for entrepreneurship and trade, bolstering the local (formal and informal) economy. Utilizing local materials reduces waste, energy, and long-distance transportation, and celebrates local culture. There are many ways Ubudehe can be explored and applied worldwide

## CONCLUSION

In the built environment, the definitions and models of sustainability continue to evolve over time, refined by both practical experience and theory. While the most visible and tangible elements, such as green-certified buildings and renewable energy, are well known, some of the finer points of sustainability are often overlooked or even unknown by the general public.

Key to the global core concept of sustainability is a utopian balance between economic, environmental and social conditions. Some of these ideas are not new; Ubudehe is rooted in culture, and biophilia was first introduced 30 years ago. Others, such as resilience, smart cities, and active design, appear as conditions change, social issues are identified, and technology enables leaps forward in building, city, and community performance. This evolution of the sustainability definition, enabled by both global historic awareness and disruptive advancements in available tools, supports the compelling argument for continuing to broaden and proliferate the sustainability mandate.



## References

- American Society of Civil Engineers. (2016). *Policy Statement 418: The Role of the Civil Engineer in Sustainable Development*. Reston, VA: American Society of Civil Engineers.
- Armistead, T. F. (2017, June 14). How to Build a Versatile Water Treatment Plant. *Engineering News-Record*.
- City of New York. (2010). *Active Design Guidelines: Promoting Physical Activity and Health in Design*.
- Deloitte. (November 2015). *Smart Cities: How rapid advances in technology are reshaping our economy and society*. The Netherlands: Deloitte.
- Downton, P., Jones, D., Zeunert, J., & Roös, P. (2016). Biophilic-Inspired Railway Stations : The New Frontier for Future Cities. *9th International Urban Design Conference*. Canberra.
- Freilich, R. H., & Popowitz, N. M. (2010). The Umbrella of Sustainability: Smart Growth, New Urbanism, Renewable Energy, and Green Development in the 21st Century. *The Urban Lawyer*, 42(1).
- Kellert, S. R., & Wilson, E. O. (Eds.). (1993). *The Biophilia Hypothesis*. Washington DC: Shearwater Books.
- Minnery, R. (2015, August 4). Resilience to Adaptation. *Architect Journal*.
- Murphy, M. (2016, September). *Architecture That's Built to Heal*. TED Talk.
- Nalewaik, A., & Venters, V. (2010, June). Costs and Benefits of Building Green. *IEEE Engineering Management Review*, 38(2), 77-87.
- Resilient Design Institute. (2017). *The Resilient Design Principles*. Retrieved July 6, 2017, from Resilient Design Institute: <http://www.resilientdesign.org/the-resilient-design-principles/>
- Shah, A. (2011, July). The Paradox of 'Hidden' Democracy in Rwanda: The Citizens Experience of Ubudehe. United Kingdom: Oxford University, Wolfson College.
- Spula, I. (2017, June 20). Designing for Health and Wellness: The Next Great Challenge. *Architect Journal*.
- The Rockefeller Foundation. (2017). *Resilience*. Retrieved July 6, 2017, from 100 Resilient Cities: [http://www.100resilientcities.org/resilience#/\\_/](http://www.100resilientcities.org/resilience#/_/)
- United States Environmental Protection Agency. (2017). *Green Building*. Retrieved July 6, 2017, from U.S. Environmental Protection Agency: <https://archive.epa.gov/greenbuilding/web/html/about.html>
- World Commission on Environment and Development. (1987). *Report of the WCED: Our Common Future*. Oslo: General Assembly of the United Nations.
- Young, M. (2017, April 6). *Are you breaching the Code of Ethics by not being sustainable?* Retrieved July 6, 2017, from Green Project Management Blog: <http://www.blog.greenprojectmanagement.org/index.php/2017/04/06/are-you-breaching-the-code-of-ethics-by-not-making-your-project-sustainable/>
- Zhao, D.-X., He, B.-J., Johnson, C., & Mou, B. (2015). Social problems of green buildings: From the humanistic needs to social acceptance. *Renewable and Sustainable Energy Reviews*(51), 1594-1609.