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A COMPARATIVE STUDY OF BIM CONTRACT CONDITIONS AMONG THE UNITED STATES, UNITED KINGDOM AND HONG KONG

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Extended Abstract

Purpose: The Hong Kong SAR Government has actively promoted the use of Building Information Modelling ("BIM") in major capital projects in its Policy Address 2017. Effective from 1 January 2018, capital work projects with project estimates more than $30 million are mandatorily required to use BIM technology. This policy would lead a wide use of BIM. However, local employers, consultants, contractors and subcontractors are concerned with their risks and liabilities when using BIM. Therefore, proper contract conditions setting out the obligations and liabilities of each party are essential for successful implementation of BIM. In responding to this industrial need, the Hong Kong Institute of Surveyors (the "HKIS") has drafted the standard conditions of contract for BIM (the "HKIS BIM Contract Conditions"). The main purposes of this study not only outline the proposed HKIS BIM Contract Conditions, but also compare with the UK's CIC BIM Protocol and US's AIA BIM and Digital Data Exhibit so as to assess the suitability of the proposed BIM contract conditions.

Design/Methodology/Approach: Comparative law can be used as an instrument of learning and better understanding and also contributing to one's own legal system or concept. While this study is concerned with micro contractual obligations instead of macro legal systems, many methodologies developed in the comparative law could be used as guiding principles. Six different methods for comparative study are well established; the functional, structural, analytical, law-in-context, historical and common-core methods. This study is based on the functional approach as it can serve different purposes including understanding the relevant law, identifying similarities and differences, comparing and appraisal of law, determining a better law and building a new law or legal practice. The fundamental principle behind functionalism is to look at and compare the way how practical problems are resolved in different countries. It looks for such 'functional equivalents' at the level of solutions. The basic research question is what solution is given in countries X, Y and Z to the problem A?

In this study, comparison is made to three specific standard conditions of BIM contract: namely, (1) the proposed HK's HKIS Conditions of Contract for Building Modelling (the "HKIS BIM Contract Conditions"), (2) the US's AIA Documents comprising (a) BIM and Digital Data Exhibit, (b) Project Digital Data Protocol Form and (c) Project BIM Protocol Form (the "AIA BIM Exhibit"), and (3) the UK's CIC Building Information Modelling Protocol (the "CIC BIM Protocol").

For the detailed comparison, a number of legal issues is identified including (1) incorporation of BIM contract conditions, (2) linking with sub-contracts, (3) effects on original agreements, (4) conflict between BIM contract conditions and original agreement, (5) conflict between different BIM models and with drawings and specifications, (6) scopes and standards of BIM modelling, (7)standard of care, (8) obligation to find discrepancies, (9) centralised electronic document management system, (10) risks and liabilities in digital data exchange, (11) BIM execution plan, (12) intellectual property rights, (13) indemnity, and (14) insurance. When comparing these contractual provisions, it is not limited to identify their similarities and differences, but also their socio-economic contexts which are helpful to explain why there are differences in practice.

Findings/Results: Overseas BIM exhibit and protocol provide good references for Hong Kong. However, the US, UK and Hong Kong's construction industries have different stages of maturity in the use of BIM. Although they face the same or similar contractual issues, each has adopted different approaches to resolve the issues. Given the current stage of BIM development, one specific feature of the HKIS BIM Contract Conditions is that it contains various options to provide flexibility to cater for the needs of different employers. Another feature is that it matches with the existing standard forms of professional services appointments and construction contracts in Hong Kong. In other words, the HKIS BIM Contract Conditions do not impose a higher or lower standard and requirement. This is important to avoid conflicts and disputes.

Implications/Originality/Value: While BIM has become popular in many countries, most countries do not have their contract conditions governing the obligations and liabilities when using BIM. In addition, there is no previous comparative study on the BIM contract conditions. Therefore, this study would contribute to the body of knowledge in comparative study in BIM contract conditions. The proposed HKIS BIM contract conditions also provide a good reference for those countries without their own BIM contract conditions.

Keywords: BIM, Contract Conditions, Hong Kong.

Note: Full paper is available from the author upon request.

A COMPARISON OF FINANCIAL PERFORMANCE AND SUSTAINABLE STRATEGY OF FAMILY CONTROLLED AND NON-FAMILY CONTROLLED LISTED PROPERTY DEVELOPERS IN MALAYSIA

Boon Tik Leong, Lam Tatt Soon, Dr Kenn Jhun Kam, Fuey Lin Ang & Voon Fun Liew
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It is believed that the ownership type of a company will affect the culture, governance and the management of the company, hence impacts the financial performance and strategy of the company. Some researchers found that family controlled company that inheriting directorship might not be able to perform as good as company managed by professional manager. Some other researchers conclude that family controlled property developers have fewer agency disputes that leads family controlled property developers outperforms non-family controlled companies. This study aim to investigate the financial performance and sustainable strategy of two different types of property developers in Malaysia namely, family controlled and non-family controlled listed property developers. The population of this study is 97 property developers that are listed in the main market of BURSA Malaysia. Data were abstracted from firm's annual report and financial database – Bloomberg Terminal. Quantitative analyses focus on the financial statement, financial ratios and profitability of two different types of listed property firms. The results shown that family controlled property developers have higher Compound Annual Growth Rate (CAGR) on revenue, profit margin, assets growth and liabilities growth. Family controlled property developers also more preferable in term of debt ratio, net profit margin, return on assets (ROA) and return on equity (ROE). As for sustainable strategy, there is not evident that there are correlation between sustainable strategy and type of ownership. The results act as an important reference for investors, especially institutional investor that emphasis company performance and sustainable strategy.

Keywords: family controlled company, financial performance, sustainable strategy, Malaysia

Introduction

Family controlled property developers are popular and play important role in Asian countries (Chang, 2003). It is believed that the ownership type of a company will affect the culture, governance and the management of the company, hence impacts the performance of the company.

Some researchers found that family controlled property developers that inheriting directorship might not be able to perform as good as company managed by professional manager.

Gonzalez (2006) found that the upcoming CEOs in family based, if blood related to departing CEO, would undergo large declines in operating returns on assets and price-to-book ratios, in contrast with non-blood related CEO.

As for Taiwan, Filatotchev et al. (2005) do not find that family control associated with performance measured in terms of accounting ratios, sales per capital, earnings per share and market to book value.

Some other researchers including Anderson (2003) found that family companies have fewer agency disputes that leads family controlled companies outperforms non-family controlled companies.

Jim Lee (2006) studied the S&P 500 companies found that data gathered over the 1992–2002 period that family companies tend to experience higher employment and revenue growth over time and are

more profitable.

By looking at ROA, ROE and Tobin's Q, Lee (2007) concludes that family controlled form in Chile performed significantly better than non-family controlled companies over a 10-year study (1995-2004).

Allouche et al. (2008) did a study in Japan for year 1998 to 2003, by comparing at the financial indicators including ROA, ROE, liabilities and financial ratios, the team found better performance among family business in Japan.

In 2015, Naldi et al. did a research and concluded that that the family member advisors have a positive relationship with performance in 128 Swedish family companies.

As for sustainable strategy in Malaysia listed property developers, Newell and Manaf in their research in 2008 found that there are some of Malaysian property companies are seen to be leading the sustainable property agenda although the overall property company in Malaysia has room for improvement to align more fully with international best practice in sustainability.

In 2015, Razali et al. look into the sustainable property development by Malaysian Property Companies concludes that sustainable property development concept among listed property companies can be categorized as low level, although this is increasing.

This study aim to investigate the financial performance and sustainable strategy of two different types of public listed property developers in Malaysia namely, family controlled and non-family controlled companies.

METHODOLOGY

The population of this study is the property developers listed in BURSA Malaysia. As in December 2015, there are total of 97 companies list on main board – property. Out of 97 companies, there are 51 family controlled companies and 46 non-family controlled companies. According to Vilalonga (2010), in US, more than 50% of real estate companies are family controlled companies. Malaysia shows similar statistic at 53% of public listed family controlled property developers.

The study period for this research is from 2005 to 2014, The companies which changed the financial year end during the study period will be eliminate from the population, as the annual reports will consist of finanical information which is not at 12 months basis. The companies which are not listed throughout the study period are eliminated. There are a total of 72 companies listed as sample in this study.

For financial performance, the two sources of financial data are i) company's annual report, ii) online database - Bloomberg Terminal. Complete financial details following BURSA Malaysia reporting system including income statement, cash flow statement, balance sheet, and shareholders information were tabulated and further analyze. Compound Annual Growth Rate (CAGR) is calculated to rationalize the growth throughout the 10 years study period.

For sustainable strategy, the companies were further categorized into four rank according to their compliance to standard, achievement and initiative toward sustainable development.

RESULTS AND DISCUSSION

Revenue

Diagram 1 Revenue

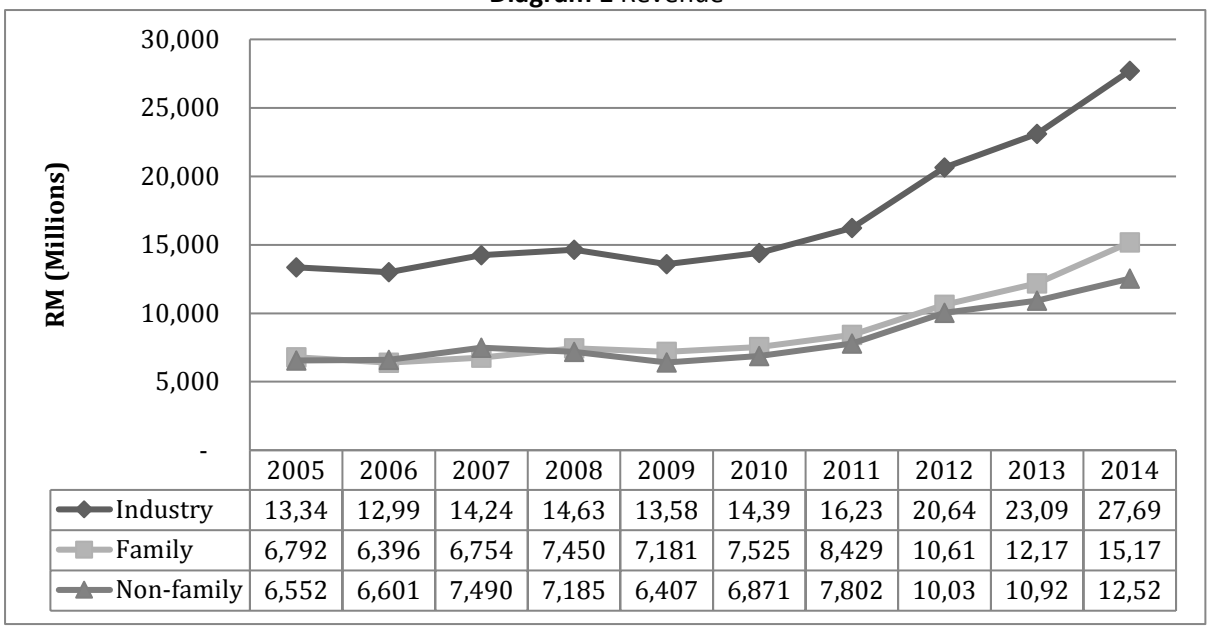


Table 1 Revenue growth

	2006	2007	2008	2009	2010	2011	2012	2013	2014	CAGR
Industry	-2.6%	9.6%	2.7%	-7.2%	5.9%	12.8%	27.2%	11.9%	19.9%	8.5%
Family	-5.8%	5.6%	10.3%	-3.6%	4.8%	12.0%	25.9%	14.7%	24.6%	9.3%
Non-famil	0.8%	13.5%	-4.1%	-10.8%	7.2%	13.6%	28.6%	8.9%	14.7%	7.5%

The revenue for industry growth more than double from RM 13,334 millions to RM 27,699 millions throughout the 10 years study period. This recorded 8.5% CAGR for the industry. Family controlled companies have higher than industry benchmark at 9.3% CAGR and non-family controlled companies has 7.5% CAGR.

It is observed that highest growth was recorded at 28.6% by non-family controlled companies at year 2012 and the lowest (negative) growth also recorded by non-family controlled companies at -10.8% at year 2009. The non-family controlled companies having denser fluctuation than family controlled companies.

Total Assets

Diagram 2 Total assets

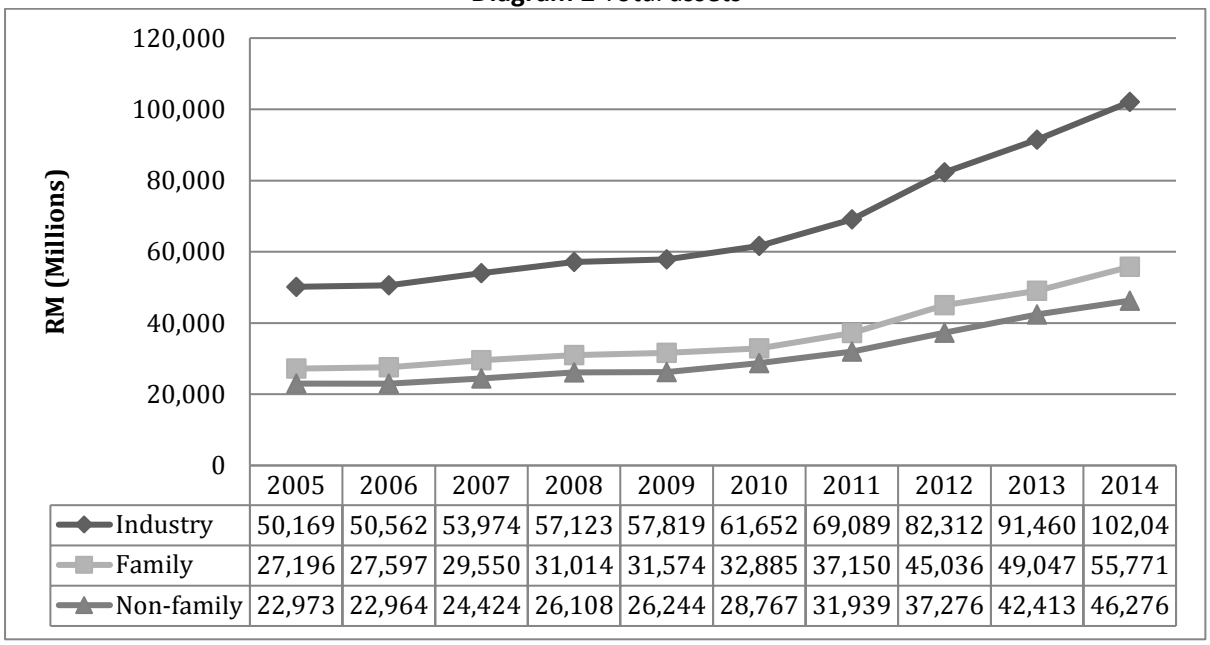


Table 2 Assets growth

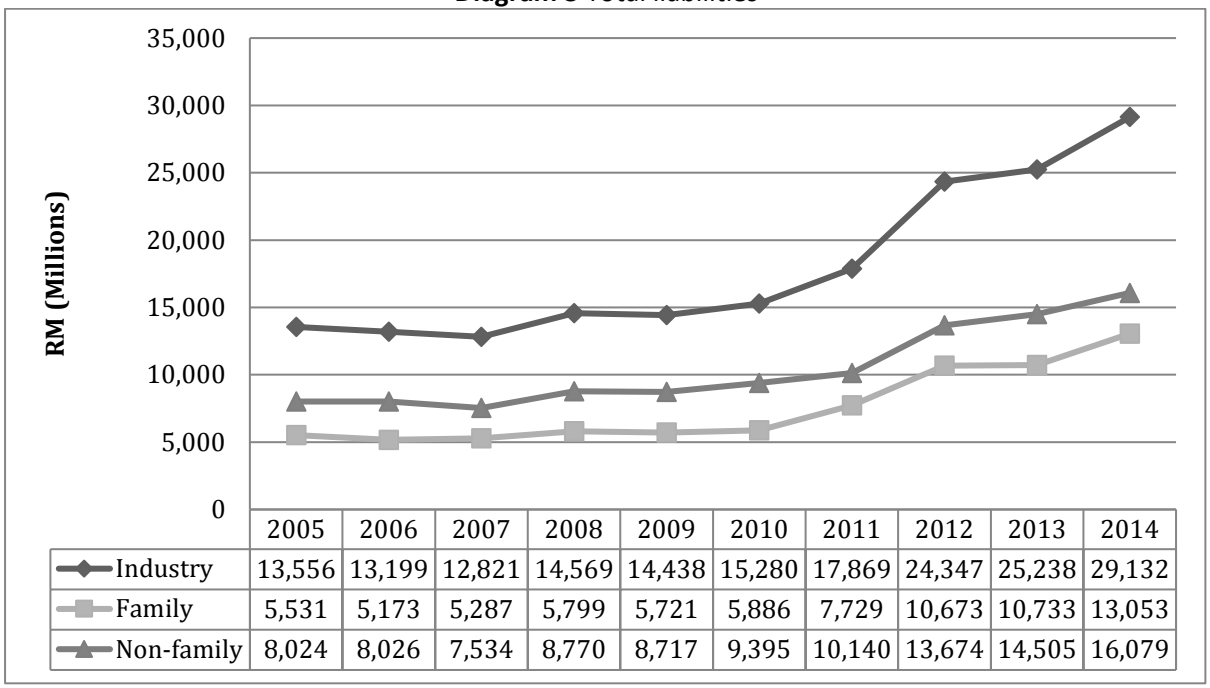
	2006	2007	2008	2009	2010	2011	2012	2013	2014	CAGR
Industry	0.8%	6.7%	5.8%	1.2%	6.6%	12.1%	19.1%	11.1%	11.6%	8.2%
Family	1.5%	7.1%	5.0%	1.8%	4.2%	13.0%	21.2%	8.9%	13.7%	8.3%
Non-family	0.0%	6.4%	6.9%	0.5%	9.6%	11.0%	16.7%	13.8%	9.1%	8.1%

Total assets value is another measure to deduce the health of companies. There is no negative growth for assets throughout the study period. Despite irregular growth pattern, the industry doubled up total assets within 10 year and recorded 8.2% CAGR. For assets, there is no significant difference between family controlled companies (8.3%) and non-family controlled companies (8.1%).

From the sample, it is observed that the family controlled companies hold more total assets than non-family controlled property developers. To further analyze the financial health, we shall check on the total liabilities of the companies too.

Total Liabilities

Diagram 3 Total liabilities



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	13,556	13,199	12,821	14,569	14,438	15,280	17,869	24,347	25,238	29,132
Family	5,531	5,173	5,287	5,799	5,721	5,886	7,729	10,673	10,733	13,053
Non-family	8,024	8,026	7,534	8,770	8,717	9,395	10,140	13,674	14,505	16,079

Table 3 Growth of total liabilities

	2006	2007	2008	2009	2010	2011	2012	2013	2014	CAGR
Industry	-2.6%	-2.9%	13.6%	-0.9%	5.8%	16.9%	36.3%	3.7%	15.4%	8.9%
Family	-6.5%	2.2%	9.7%	-1.4%	2.9%	31.3%	38.1%	0.6%	21.6%	10.0%
Non-family	0.0%	-6.1%	16.4%	-0.6%	7.8%	7.9%	34.9%	6.1%	10.9%	8.0%

Diagram 2 shows family controlled companies hold more assets than non-family controlled companies. Anyway Diagram 3 shows non-family controlled companies have more liabilities than family controlled companies.

Although the total liabilities of family controlled companies grow at faster rate, that is CAGR at 10%, the total liabilities of family controlled companies still lesser than non-family controlled companies at the end of the study period.

Further analysis on leverage can be found in following discussion at Diagram 4 – debt ratio.

Debt Ratio

Diagram 4 Debt ratio

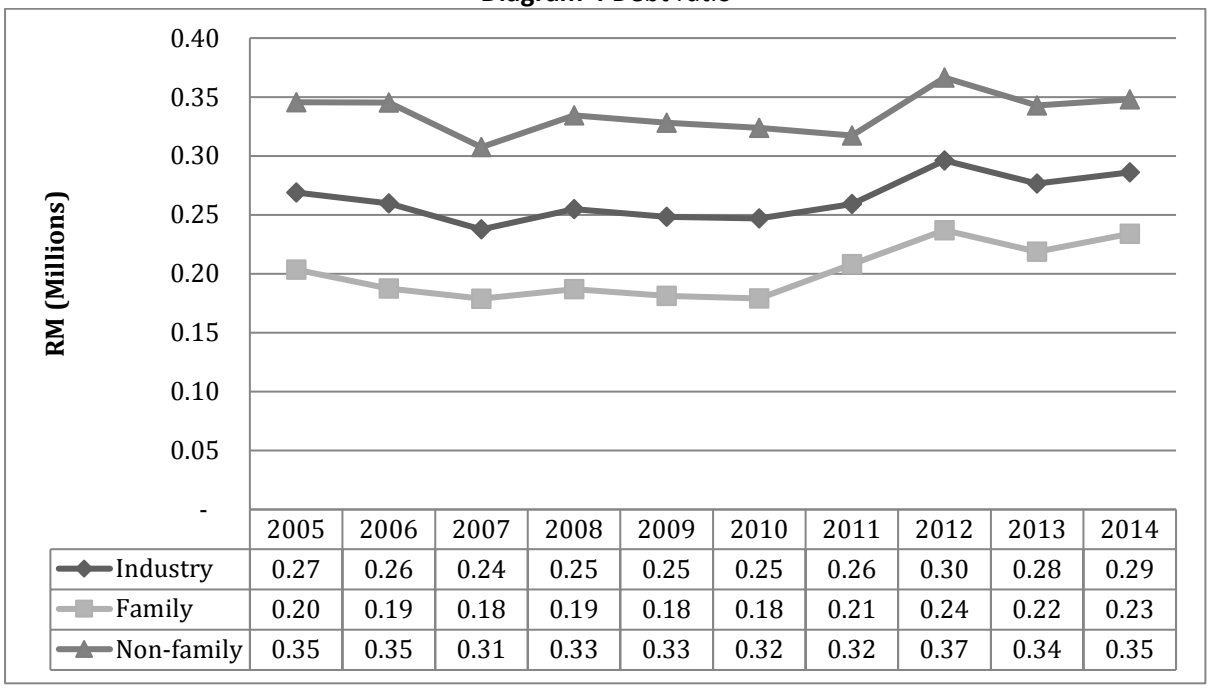


Table 4 Debt Ratio

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	0.27	0.26	0.24	0.25	0.25	0.25	0.26	0.30	0.28	0.29
Family	0.20	0.19	0.18	0.19	0.18	0.18	0.21	0.24	0.22	0.23
Non-family	0.35	0.35	0.31	0.33	0.33	0.32	0.32	0.37	0.34	0.35

Debt ratio takes both total liabilities and total assets into consideration. Higher the debt ratio means the companies rely more on liabilities to operate. The industry records relatively low debt ratio at 25% to 30%.

Family controlled companies have lower debt ratio at 18% to 24%, whereas non-family controlled companies having more than 30% of debt ratio at 31% to 37%. This may indicate the family controlled property developers are generally more conservative on liabilities.

Profit Margin

Diagram 5 Profit margin

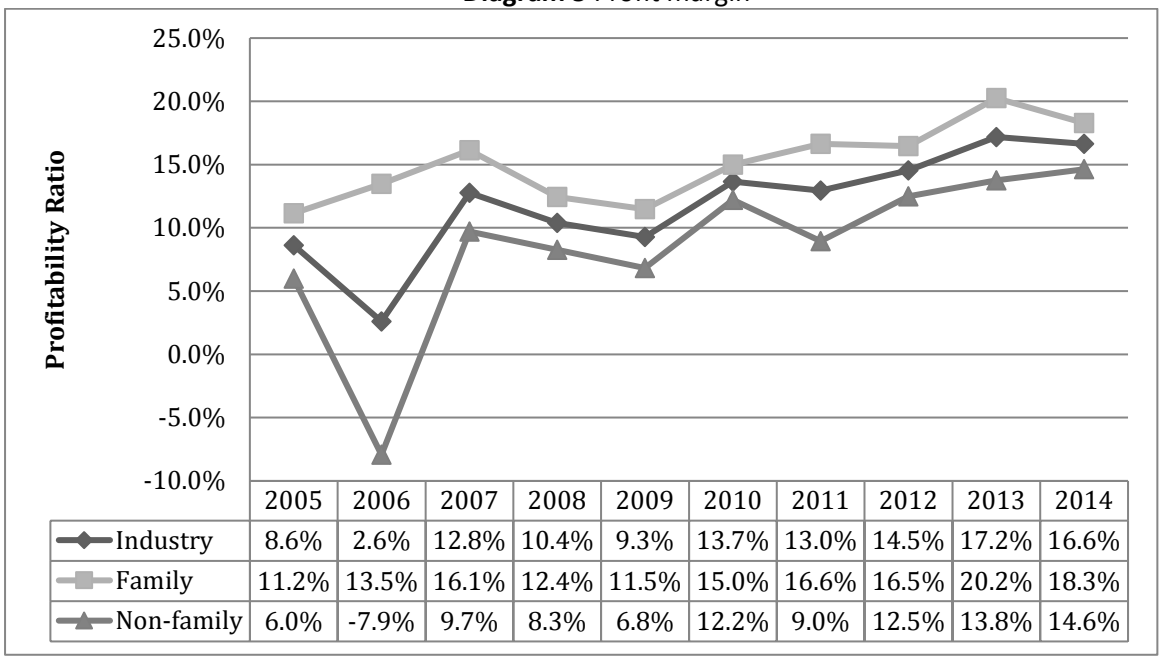


Table 5 Profit margin

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	8.6%	2.6%	12.8%	10.4%	9.3%	13.7%	13.0%	14.5%	17.2%	16.6%
Family	11.2%	13.5%	16.1%	12.4%	11.5%	15.0%	16.6%	16.5%	20.2%	18.3%
Non-family	6.0%	-7.9%	9.7%	8.3%	6.8%	12.2%	9.0%	12.5%	13.8%	14.6%

Profit is reported in the annual report and profit margin can be derived from the data. From Diagram 5, the profit margin of family controlled property developers range from 11.2% to 20.2%, which always superior than non-family controlled companies.

Profit margin cannot translate directly to the earning for investors, anyway profit margin is an important profitability measure.

ROE

Diagram 6 ROE

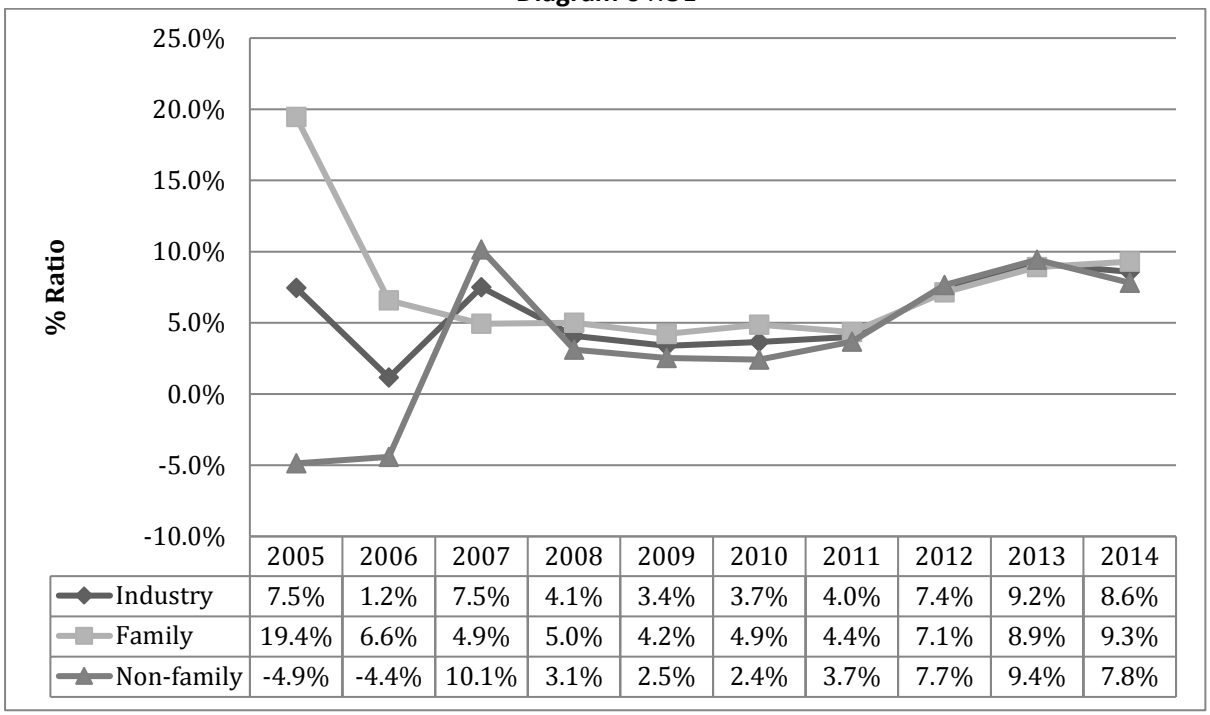


Table 6 ROE

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Industry	7.5%	1.2%	7.5%	4.1%	3.4%	3.7%	4.0%	7.4%	9.2%	8.6%	5.6%
Family	19.4%	6.6%	4.9%	5.0%	4.2%	4.9%	4.4%	7.1%	8.9%	9.3%	7.5%
Non-family	-4.9%	-4.4%	10.1%	3.1%	2.5%	2.4%	3.7%	7.7%	9.4%	7.8%	3.8%

Return on equity (ROE) for family controlled companies also superior than non-family companies for most of the year. For family controlled companies, average ROE for 10 year for is 7.5% compare to 3.8% for non-family controlled companies.

ROA

Diagram 7 ROA

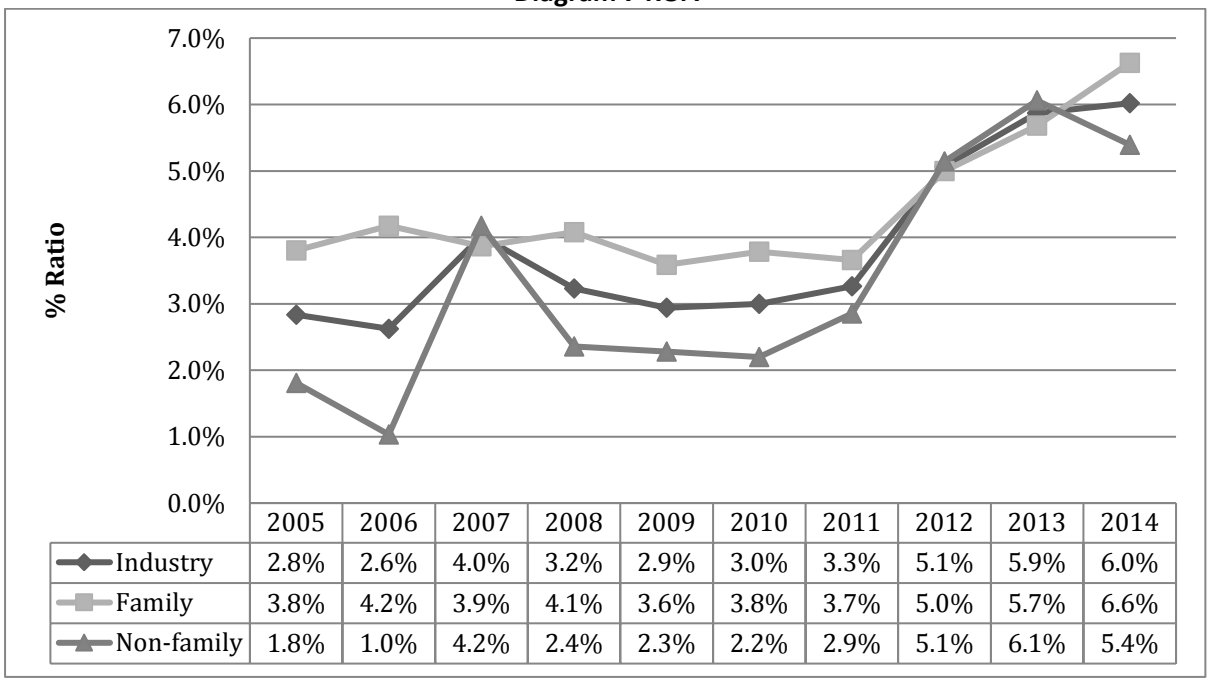


Table 7 ROA

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Industry	2.8%	2.6%	4.0%	3.2%	2.9%	3.0%	3.3%	5.1%	5.9%	6.0%	3.9%
Family	3.8%	4.2%	3.9%	4.1%	3.6%	3.8%	3.7%	5.0%	5.7%	6.6%	4.4%
Non-family	1.8%	1.0%	4.2%	2.4%	2.3%	2.2%	2.9%	5.1%	6.1%	5.4%	3.3%

Return on Assets (ROA) for family controlled companies have an average at 4.4%, non-family controlled companies recorded 3.3%. 7 out of 10 years family controlled companies have better ROA than non-family controlled companies. Overall family controlled companies have preferable ROA and ROE over non-family controlled companies.

For financial performance, family controlled property developers are superior in revenue growth, assets growth and but not growth of liabilities. Despite higher growth of liabilities, total liabilities and the debt ratio of family controlled property developers still lower than the non-family controlled property developers. It means there are rooms for family controlled companies to expand their liabilities.

In this study, profitability is measured by profit margin, ROE and ROA. All three measures of family controlled property developers show preferable performance over non-family controlled property developers.

On the other hand, this study also intended to find out if there is any correlation between sustainable strategy and type of ownership of property developers in Malaysia.

Leong (2016) developed 4 ranking to catogorize Malaysia property developers according to the sustainable strategy.

Table 8 The sustainable strategy ranking criterion

Rank	Description
1	Project won green/sustainable award OR Project certified GBI, LEED, Green Mark OR Green/sustainable certification AND Published the above achievement
2	Organised green/sustainable conference OR Sponsored green/sustainable conference OR Introduced green/sustainable features at project level OR Adopted green technologies/materials at project level AND Published the above achievement
3	Adopted green/sustainable practises at company level
4	Complied to government regulation

Companies with rank 1 and rank 2 qualified as Sustainable Developers with sustainable strategies.

Companies with rank 3 and rank 4 are considered as companies without sustainable strategies.

In this study, 17 out of 72, which is around 24% of property developers qualified as sustainable developers. Out of the 17 sustainable developers, 10 of them are family controlled property developers, 7 of them are non-family controlled property developers. There is no proof that there is correlation between sustainable strategy and type of ownership of property developers.

As conclusion, in Malaysia, for the 10 years study period, family controlled property developers have superior performance in term of financial performance. Anyway, there is no evident that the implementation of sustainable strategy is correlated to the ownership type.

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A REVIEW OF DEFECTS IN LOW-RISE RESIDENTIAL BUILDINGS IN THE AUSTRALIAN STATE OF VICTORIA

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ABSTRACT

Over the last few decades, quality and life-cycle costs of low-rise residential buildings has been a key issue in the construction industry as a result of construction and/or latent defects which undermines the functional requirements of various building elements. Most defects in these buildings are often latent in nature and appear during the occupancy stages of the building. Thus making these defects difficult and expensive to fix as getting access to the source of defective elements in a completed building could be difficult. Findings from previous studies showed that the number of defects associated with newly constructed low-rise residential buildings in the Australian State of Victoria increased between the year 1996 and 2004. As part of an ongoing research project, this paper presents an overview of the various associated latent defects in Victoria, commencing from 2010 when the current structure for issuing domestic building insurance was initiated. The Victorian Civil and Administrative Tribunal (VCAT) database was used and reported cases related to residential building defects were analysed and evaluated. Cracks on plasterworks and walls were found to be some of the common defects in the selected case study buildings. Research of this nature can assist regulatory bodies to evaluate the efficiency of existing building policies and further help them institute measures to prevent defects and subsequently improve construction quality in low-rise residential buildings.

Keywords: defects, latent, low-rise, residential building, Victoria.

INTRODUCTION

In Australia, low-rise residential building works constitute a significant percentage of the total value of the building works undertaken nationally. According to the Australian Bureau of Statistics (ABS), in the year 2016, the proportion of the total value of building works done in the residential and non-residential sector is 67% and 34% respectively (ABS, 2017). The residential building sector of the construction industry is one of the major contributors to the Australian economy. According to the report by Housing Industry Association (HIA), the aggregate residential industry's direct contribution to the Australian economy is over $150 billion per annum, with over one million employees in building and construction, tens of thousands of small businesses, and over 200,000 sub-contractors reliant on the industry for their livelihood (HIA, 2017). In 2016, the residential investment which includes gross construction of new dwellings (both detached houses and units), residential alterations and additions, manufactured dwellings and brokers' fees accounted for 5.8 per cent of GDP (HIA, 2017). Given the substantial contribution of the residential building sector to Australia's economy, it is essential to investigate the causes of defects in these domestic houses as extensive reworking of defects could influence productivity.

Previous studies conducted in Australia indicated that the number of defects per building in the State of Victoria increased. Georgiou et al. (1999) found, on average, a minimum of two defects per house in Victorian residential buildings constructed between 1988 and 1996. Successively, Georgiou (2010) concluded that the average number of defects per house for residential buildings constructed from 1997 to 2004 was five. The study concluded that changes in legislation after 1996 has no effect in improving the quality of housing. In an attempt to reduce the defects, the Victorian Managed Insurance Authority (VMIA) was established in 2010 to provide builders with domestic building

insurance that cover homeowners during construction. However, the percentage of claims associated with defective building works could not be reduced. Essential Services Commission (2017), compared the percentage of insurance claims from 2001 to 2010 and found that there was the highest percentage of claims in 2010. The objective of this paper is to analyse the Victorian Civil and Administrative Tribunal (VCAT) cases which are associated with defects in low-rise residential buildings between 2010 and 2017.

LITERATURE REVIEW

Defect is defined as the shortcoming in the performance of a building element (Georgiou et al., 1999). Previous researchers identified and classified defects with respect to elements of buildings and building materials. Lo et al. (2005) studied the roofs of medium-rise buildings in tropical climates and concluded that tearing of the waterproofing membrane was the most prominent defect. Forcada et al. (2012) found that most common defects in Spanish residential buildings were related to construction errors and omissions. The authors identified that incorrect installation, appearance defects and missing items or tasks, mainly related to finishing was recurrent. Del Solar et al. (2015) investigated defects in ceramic claddings and found errors in piece layout, excessive visibility of joints, uneven surfacing and hollow zones were some of the major defects. Carretero-Ayuso et al. (2015) concluded that fissures in walls and flooring, cracks in structural elements, and infiltration of humidity were some of the common defects in residential buildings.

According to Padgett Jr (1992), the most critical structural defect which caused the failure of balcony deck in the US was the vertical web buckling of pre-manufactured I-shaped wood joists with solid plywood webs. De Silva and Ranasinghe (2010) collected about 721 defects from flat roofs of 50 buildings in Sri Lanka and found that cracks, blockages in downpipes and splitting were the three major defects. Sassu and Falco (2013) found leakage from flat and pitched roofs as the most common source for damage caused by water. The study opined that non-load-bearing walls most often undergo more cracking. According to Plowman (1991), lack of long-term durability and the use of the wrong mix are some of the defects associated with concrete materials. The author also found that cracking, spalling and inconsistency in colour as some of the defects in bricks and tiles.

Previous researchers suggested the causes of the defects could be related to human errors or workmanship, faulty design, impacts and vandalism. Atkinson (1999) concluded that human errors are the main sources of defects in buildings. Olubodun and Mole (1999) explained that causes of defects can be attributed to design issues, the age of the building, change in the standard and vandalism. Similarly, Assaf et al. (1996) suggested faulty design and construction as the two main causes of defects in buildings. Chew (2005) further concluded that the sources of defects are related to deficiency in construction, design, material and maintenance practices.

According to Mohd-Noor et al. (2016), impact damage or vandalism, change of use or service of the property, artificial movement or vibration, natural movement, ageing, deficiency in material selection and poor workmanship were some of the major causes of defects in buildings. Atkinson (1998) suggested that defects can be caused by poor performance of workers such as ignorance, negligence and fraud. The author mentioned that management related shortcomings which include failure to carry out appropriate supervision and control; errors caused by changes; errors caused by concurrency; confusions of responsibility; and failures in communications. Chong and Low (2006) found that the effects of weather, the impacts from occupants, and loads and moisture from the wet areas were the three most important design-related causes of defects. López-Patiño et al. (2017) concluded that the defects can occur due to changes in quality materials used during construction, prevailing winds, temperature variations, strong winds, lightning strikes, and actions of living organisms such as insects, animals, vegetation, fungi, lichens, and human beings.

Some studies compared defects in buildings by considering the regulations enacted to improve the quality of low-rise residential buildings, construction methods, construction and occupancy periods and the type of builders. Georgiou et al. (1999) analysed defects in houses constructed by homeowners and registered builders and found no significant quality difference between the houses delivered by the two categories of builders. Chong and Low (2005) compared defects during construction and between two to six years after initial occupancy and found that the defects during both periods were different. The authors mentioned that some construction defects become latent defects, while some latent defects began to emerge. The study opined that construction materials related defects could take time to develop and will usually appear during occupancy rather than during construction. Furthermore, the authors stated that any faults committed by the designers might not usually appear during the construction phase. Similarly, Forcada et al. (2016) analysed defects during construction and post-handover in residential buildings in Spain and concluded that many defects during construction are similar to those detected at the handover stage. The study showed that structural defects and inappropriate installation of roofs and facades can be fixed during construction whereas other aesthetic and functional defects arise at the handover stage. Johnsson and Meiling (2009) analysed defects in 'industrialized housing' and 'ordinary construction' and found that industrialised buildings had lower defects. Georgiou (2010) studied building defects under two different Acts of the Parliament of the Victorian state of Australia and concluded that changes in legislation might not reduce the defects.

Many researchers developed the classification system for defects in various countries. In Italy, Sassu and Falco (2013) classified the most common building defects into seven categories: Water Damage (leaks, seepage, infiltration); Cracking; Systems Failure or noncompliance (electrical, heating, plumbing); Defective Finishing (windows, metalwork, facings); Dampness from Condensation; Noncompliance with Acoustic Requirements; and Partial or Total Collapse. In Spain, Macarulla et al. (2012) developed a comprehensive classification system of housing defects. These include Affected Functionality, Inappropriate Installation, Biological Action and Change, Broken/Deteriorated, Chemical Action and Change, Detachment, Soiled, Flatness and Levelness, Misaligned, Missing, Stability/Movement, Surface Appearance, Water Problems and Tolerance Errors. In Australia, Georgiou et al. (1999) proposed a defect classification system for residential buildings. The categories included in the classification system include Cracking, Damp, Drainage, External Leaks, Incomplete, Internal Leaks, Structural Adequacy, Water Hammer and Workmanship.

The cost of defects has been estimated by previous researchers. In the Australian construction industry, Mills et al. (2009) concluded that the cost of rectification of residential building defects in Victoria could reach up to 4% of the construction contract value. In Sweden, Josephson and Hammarlund (1999) predicted the cost of defects in construction using case studies of seven building projects. Accordingly, the cost of defects was found to be 4.86% of production cost.

RESEARCH METHODOLOGY

To investigate the trends of the number of court cases related to defects in low-rise residential buildings, the Victorian Civil and Administrative Tribunal (VCAT) database has been used as a data source. The court collects various evidence including independent expert witnesses and decides whether a particular complaint by the homeowner is considered as a defect or not. The court cases from 2010 to 2017 were analysed. Overall, 662 cases were reviewed and analysed. The analysis was conducted with respect to the year of construction of the buildings, the suburbs in the Victorian state of Australia, and the year in which the case got a decision.

To identify some of the defects, the case study approach was adopted. Two cases were chosen from the VCAT database, and the type of defects as well as the decisions made by the court were qualitatively analysed. The two cases are selected as they were widely reported by different media outlets in Australia such as The Age newspaper. For the sake of anonymity, the name and the exact location of the two low-rise residential buildings are not mentioned in this research. The houses were termed as "Melton West Home" and "Tarneit Home."

ANALYSES OF DEFECTS

Figure 1 shows the trend of the cases related to domestic building defects between the year 2010 and 2017. All the cases presented in the figure were heard in court and decisions were made by the Victorian Civil and Administrative Tribunal (VCAT). The year 2017 has the highest index of 1.85 and the year 2011 has the lowest index value of 0.84. While computing the indexes for the years, 2010 was used as a base year.

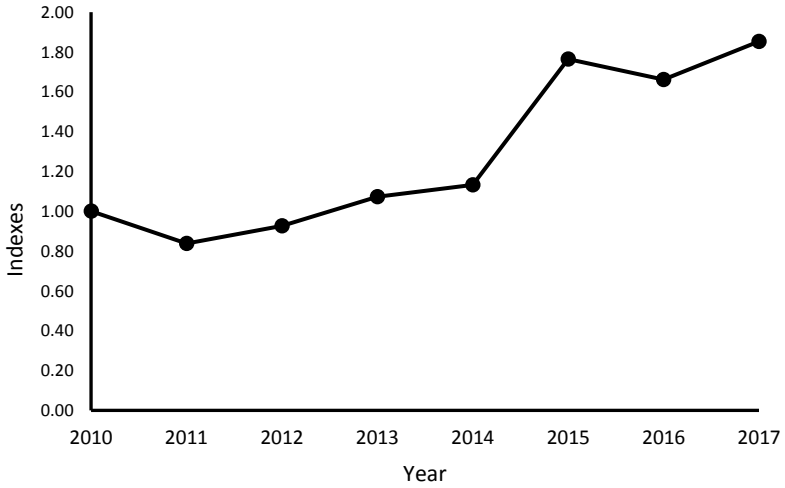

Figure 1 Trends of the defects in low-rise residential buildings in Victoria

As indicated in Figure 1, there is an increase in the number of cases despite the establishment of the Victorian Managed Insurance Authority (VMIA) in 2010. The finding suggests that the introduction of new domestic building insurance management system might not reduce the number of disputes associated with defects in low-rise residential buildings.

Figure 2 shows the percentage distribution of reported building defects in low-rise residential buildings based on the year of construction of the buildings. Accordingly, the highest percentage of 17% was reported for buildings that were completed in 2009. This significant spike in complaints could be as a result of the turmoil that the building insurance industry faced at the time which almost led to the collapse of the insurance market that eventuated the government taking over of the builders' warranty insurance scheme and the birth of the Victoria Managed Insurance Authority (VMIA) (Victoria State Government, 2010). The finding also suggests that latent building defects may not be observed in buildings which are recently completed (in 2016 in this research context). The defects appear as the age of the buildings increase.

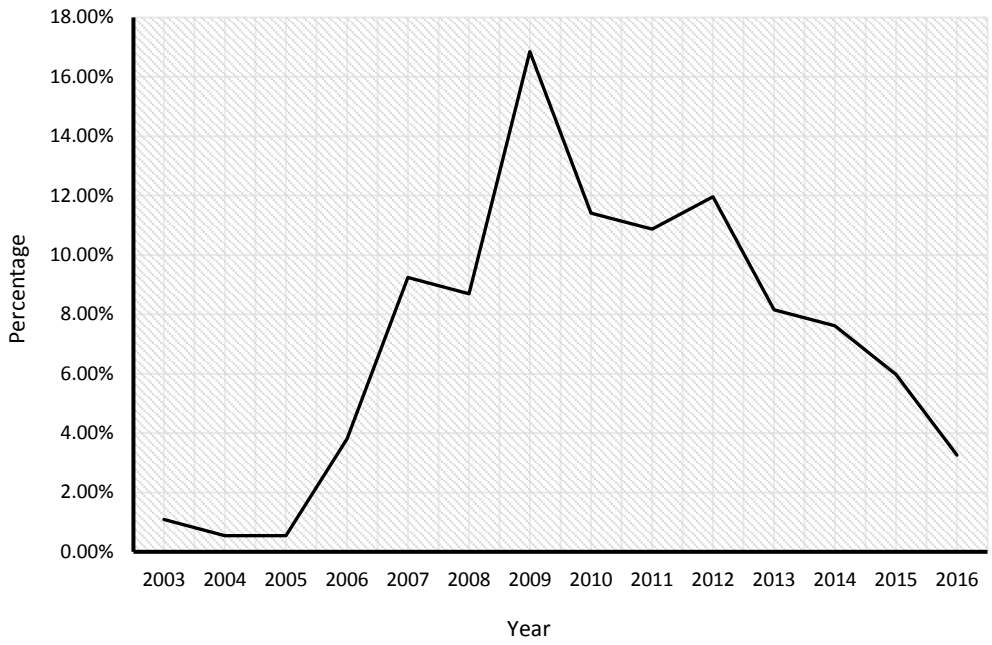

Figure 2 Distribution of court cases based on the years of completion of construction

The distribution of the VCAT cases with respect to the suburbs in the Australian state of Victoria is presented in Figure 3. Although the cases of 155 suburbs were resolved by VCAT between 2010 and 2017, for the sake of brevity, only 25 suburbs with higher frequencies of court cases related to building defects were presented in Figure 3. Accordingly, Pakenham, St. Kilda, Doncaster Easter and Brighton are the four suburbs in Victoria in which the majority of the complaints regarding the defects in low-rise residential buildings were submitted to the court.

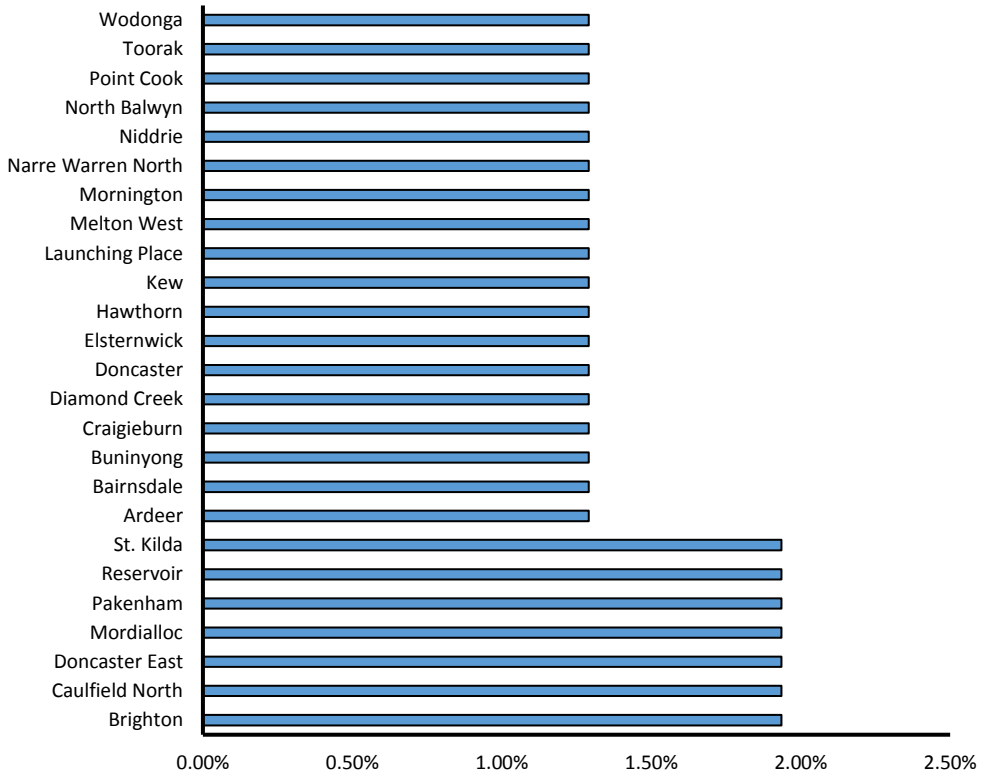

Figure 3 Distribution of court cases according to the suburbs in Victoria

CASE STUDIES

Based on the VCAT databases, two cases, "Melton West Home" and "Tarneit Home" have been selected and their details are provided below. The exact location of the houses and names of builders and owners are not mentioned herein in compliance with research ethics. However, the houses are in the Western suburbs of the city of Melbourne, Australia.

Melton West Home

The domestic building contract between the owner and the builder was signed on 25th February 2009. The total contract price of the project inclusive of GST was $200,140.00. The building comprises of a family room, sitting room, a dining room, a rumpus room together with three bedrooms, a double garage and alfresco area at the rear. A building permit was issued on 10th September 2009, and construction began on 10th October 2009. The Occupancy Certificate was issued on 16th February 2010. The owners of the house have moved into their new three-bedroom home on 10th March 2010. However, in early July 2010, the owners noticed some various severe defects in a house they have occupied in only 3 months. The defects reported in VCAT database were shown in Table 1. Some of these defects include cracking of block work, heaving of the slab, separation of wall plaster and cracking of plaster.

Following consultations and series of court hearings, the VCAT decided that the builder should rectify the defective works and the cost of rectification work was $134,703.50.

Table 1 Reported Defects in the Melton West Home

No.	Defects
1	Diagonal and horizontal plaster cracking over rear door and RUMPUS window
2	Separation of ceiling cornice and plaster sheet at multiple locations around the dwelling.
3	Cracking of cornice mitred joints at multiple locations
4	Lifting of FAMILY/RUMPUS wall (10mm) off the slab.
5	Separation of wall plaster sheet and skirting
6	Horizontal movement of the ceiling in RUMPUS relative to plaster sheet of OUTDOOR ROOM
7	Separation of cornice from DINING rear wall plaster sheet
8	Diagonal cracking and horizontal movement of brickwork at location of outdoor room timber
9	Diagonal cracking to brickwork of rear wall of house at bottom of rumpus room window.
10	Cracks between tiles at floor edge in laundry.
11	Wrinkling of plaster taping on an external wall in corner of BED 2

Tarneit Home

On 1 November 2006, the owner signed a building contract with the builder for the construction of a dwelling house. A building permit for the construction was issued on 14 November 2006. The construction of the house was completed and an occupancy permit for the house was issued on 10 July 2007. The Owner moved in on 10 October 2007. According to the owner, within two months of moving in, severe cracks at various locations were noticed. Subsequent inspection undertaken by an

expert revealed the major defects presented in Table 2. Cracks on plasterwork, fracture of the service pipes, jamming of doors and windows and leaning of walls were some of the defects of the Tarneit Home.

Table 2 Reported Defects in the Tarneit Home

No.	Defects
1	Ceilings are out of level
2	Shower door cannot be closed
3	Windows, doors and cabinetry are out of level
4	Windows and door frames distorting
5	Walls leaning and bulging noticeably
6	Weather tightness being impaired
7	Service pipes fracturing
8	Large cracks opening up in the plasterwork
9	Front bedroom window would not be opened

Upon series of court hearings, the tribunal ordered the builder to pay $289,589.65 to the owner of the house. The sum includes the cost of demolition and reconstruction of $264,784.00, loss of rental during demolition and reconstruction of $ 15,600.00 and loss of rental of $ 9,205.65.

CONCLUSION

The trends of the cases related to defects in low-rise residential buildings in the Victorian state of Australia were investigated from the year 2010 to 2017. The analysis was carried out based on the data obtained from the Victorian Civil and Administrative Tribunal (VCAT). The finding shows that there is an increase in the proportion of defects despite the establishment of the Victorian Managed Insurance Authority (VMIA) since 2010. The court cases were also analyzed with respect to the year in which the occupancy permit had been issued. Accordingly, most of the disputes related to the defects were reported from buildings which were completed in 2009.

The cases of two houses in the western suburb of the city of Melbourne, Australia have been selected for further analysis. Accordingly, cracking of cornice, diagonal cracking and horizontal movement of brickwork, cracks on floor tiles, large cracks in the plasterwork, jamming of doors and windows, service pipes fracturing and leaning of walls are some of the defects observed in the two case studies evaluated. This study can help regulatory bodies to assess the efficiency of the current policies of low-rise residential buildings. It can also guide them to propose mechanisms to reduce the recurrent defects and improve the quality of low-rise residential buildings. Further research is being undertaken to analyse all the available VCAT cases from 2010 to 2017 regarding the defects in low-rise buildings. The output of the study can help to understand the most frequent types of defects in residential buildings in the Victorian state of Australia.

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Adopting technology for better cost advice

By Silas Loh and Grace Lam

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Introduction

The landscape of the construction industry is undergoing a period of change. We as quantity surveyors (QS) are feeling the pressure to meet demands to provide value-added services in times of increased competition and rapid change. Toor and Ofori (2012) said the changing landscape of the industry demands that current practitioners as well as future professionals should be proactive to drive change instead of merely coping with developments.

Smart Information Deliverance – BIM and more

Much is asked these days how advanced QSs are in adopting the technology of Building Information Modeling (BIM) in their practice as other professionals in the construction industry are already demonstrating their BIM capability and reaping its benefits. But, what is BIM? Perhaps an effective definition is provided by Schewegler et. al. (2001) as the process of creating an information database for a project in which lifecycle information is expressed in an interoperable manner to create, engineer, estimate, illustrate and construct a construction project.

BIM is now regarded as a part of a larger paradigm shift towards the adoption of digital technology as automated quantities technologies and BIM systems are revolutionizing current practices and automating the measurement of quantities from drawings. These technologies facilitate the preparation of accurate estimates (Aouad, Wu and Lee, 2007). Mitsutaka (1989) thinks that new technologies have the potential to provide competitive advantages by increasing opportunities and lowering costs. BIM measurement (a.k.a. 5D BIM) presents an approach that has already proven to have a marked impact on preconstruction processes. It is also considered to be a challenge to the conventional QS services and other construction disciplines. There is growing demand for experts like us in cost engineering and financial management; this is a chance for us to broaden our involvement in projects, while improving upon our skill sets and traditional knowledge bases, with our responsibilities evolving from bill producers to cost advisors.

Demanding expectations from QS services

Poon (2003) wrote that QSs are ubiquitous in the construction industry. Conventionally, we know the scope of QS services is wide and knowledge intensive. Generally, the QS profession is necessary to estimate the cost of the whole endeavour, as well as the quantity of the building materials, on top of cost and contract management. It typically involves preparing a cost estimate of the concept design to assist the developers to set a feasible budget, monitoring cost implication as the design develops, and preparing tender documents. Primarily, we are the project's cost consultant; we act as an advisor to the client and other project team members on matters relating to procurement and the contract (Fellows et. al., 2003). Considering the prevailing and future challenges and opportunities, our profession is at an important road junction from which it can go beyond its

traditional cost engineering and financial management roles and use its core competencies to assume a value-added and leadership role in the industry.

To deliver more sophisticated cost management services, it is very important for us to embrace and become a key player in the BIM environment. Ultimately, what clients want from all their consultants is to complete their construction projects within three important parameters – Time, Cost and Quality. We ought to note that quantity take-offs from BIM software and automated quantities technologies is only part of the process to meet the value add.

Implementing 5D BIM practice

There are perceived barriers to implementing 5D BIM for Cost Management. According to Olatunji (2014), it is frequently the prerogative of the firms to explore how best to manage their BIM-specific solutions. With so many vendors in the market touting different types of software, industry professionals in the construction industry may find themselves lacking the knowledge/skills to work with each other's different software due to software incompatibility, even though currently there are the Industry Foundation Classes (IFC) standards to improve the exchange of data between CAD software tools, estimation software tools and other construction application software tools. Other barriers include prohibitive initial cost outlay, the lack of protocols for coding objects within building information models, or the lack of an electronic standard for coding BIM software, which are an essential pre-requisite for full interoperability. Consequently, the potential of 5D BIM is yet to be realised.

Muzvimwe's (2011) studies found that the value of QS services is raised by being able to simulate and explore various design and construction scenarios for the client in real time through having their cost data and quantities integrally linked in the live BIM model. Smith (2015) thinks it is equally dependent on the QS having BIM capabilities/expertise and having the intuition to analyse and critique the information that is being generated by the model.

Being on track with this paradigm shift, our local authority, the Building and Construction Authority (BCA) is inspiring action and stimulating innovative ideas for the whole construction industry with its most recent theme of "Embracing Innovation, Building Our Future". BCA is leading industry players in transforming the construction industry into a culture of Integrated Digital Delivery (IDD). IDD encapsulates various collaborative practices such as Integrated Project Delivery (IPD), Integrated Concurrent Engineering (ICE) and Virtual Design & Construct (VDC) to form a more complete picture of how technology adoption is shaping the evolving process of design, design review and construction execution in this 4.0 industry revolution.

Computational BIM for QS

It is empirical that maturity and progress toward BIM adoption is uneven among the QS professional practice. Despite the current challenges and constraints, for our profession to move away from being traditional bill producers to value-add cost advisors, we need to quickly adapt and learn computational skills instead of relying on commercial software/ programmers to do 5D BIM. Once we attain the right level of computational BIM skill, we would be able to achieve parametric documentation of a project's financial data, including embedding project models with valuations or actual project information, as well as reconciliation of a project's financial data.

Adopting technology for better cost advice

So, in RLB Singapore, we explored on how to work outside commercial 5D BIM software - literally out-of-the box - and embarked on coding and scripting to mine data of any BIM Model. This is done through a series of processes as illustrated in the flowchart (*Figure 1*) below.

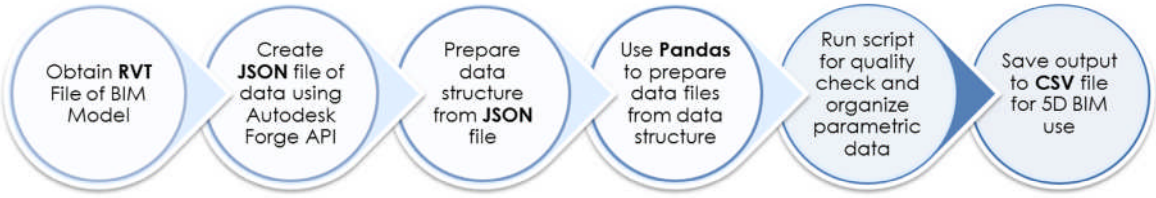

Figure 1. Mining of BIM data outside commercial software

With this approach, our QSs can validate the quality of the BIM Model, organise and manage the design data according to various elemental categories before applying standard method of measurement and other code compliance as required. It also improves processing speed as data are handled without having to wait for 3D rendering refresh on screen. Once the data of the BIM Model is organised in CSV (Common Standard Value) format, the data can be worked upon in any common spreadsheet software. Bills and reports can be generated as usual, and with relevant spreadsheet skill such as pivot table and macro scripts, bespoke dashboard reports can be creatively produced for presentation to client and assist with improved making on design options based on cost viewpoint.

Applying BIM and Blockchain for post-contract management

Another possible application of BIM for QS is on progress payment and valuation at the post-contract stage. We know the traditional procedure for progress claim and payments is tedious and the lengthy cycle time is unproductive for all stakeholders involved as different stakeholders' reports and claims are mostly kept separate. Traditional QS duties require us to produce numerous documentation and verification. Locally, disputes with contractors over the quantum of work done are common and projects often see accumulated unresolved disputes which pose potential risk of formal dispute resolution such as adjudication under Singapore's Security of Payment (SOP) Act. BIM technology, applied together with blockchain technology, can circumvent these issues by integrating fragmented information.

The process involved is fairly simple:

1. Create a Valuation BIM Model by mapping the contract value of bills of quantities items to the Contract BIM Model.
2. Share Valuation BIM Model with all stakeholders involved in payment process. This may include resident site staff if their site report on progress of work is conventionally used as supporting documents to verify work done. Parameters in the shared model may be restricted to hide contract value from technical staff if it is deemed not appropriate.
3. Apply blockchain technology to track every task in the payment process. Blockchain technology is typically known as "technology of trust" by using smart ledgers to record transactions and activities of various stakeholders. Bitcoin is one common example of how blockchain technology works.

4. Contractor updates the Valuation BIM Model and submits together with his payment claim to indicate the work done on site for the QS to review their payment claim in 3D visual form.
5. The centralised Valuation BIM Model should contain records (smart ledgers) of digital approvals of resident site staff on inspections carried out and quantum of work done on site.
6. QS relies on the records in the Valuation BIM Model to verify the claimed amount against the Contract Sum to recommend payment-on-account.

By sharing and working on a singular model and digital platform, the process would be more integrated and perhaps gaps and disputes between the contractor's claim and the QS's valuation can be reduced substantially. This would provide detailed documentation and clarity for all parties and would also certainly improve productivity in the payment process.

Conclusion

In today's construction projects, where vast design information are collaborated digitally, there is a sense of urgency for the QS profession to develop and build their own computational skills set and adopt technology for their work to avoid being left behind from other professionals in the construction industry. Being able to grasp the inherent opportunities in BIM will help deliver the profession from being traditional bill producers to become value-add cost advisors.

Computational BIM and blockchain technology application will probably be a common practice soon and newer technology and collaborative method may soon be developed to harness on augmented reality technology which many other industries are already exploring. Some say it is better late than never. We say "you snooze, you lose" in this demanding industry.

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ALLIANCE PROCUREMENT: PROMISES, TRUTHS, AND BEHAVIOURS

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Abstract

Alliancing is a contractual structure created to overcome some of the adversarial postures caused by traditional contracts, requiring all parties to subscribe to a 'no-blame' culture. This type of relationship contract often promises benefits that are uncommon in traditional forms of contracting. The purpose of this paper is to discuss the culture, behaviour, benefits, promises, and lesser known truths about alliance contracts, drawing on a combination of hands-on professional experience and over a decade of research in both Australia and the United States. The paper offers practical help to those considering alliancing as a framework for the procurement of major projects.

Keywords: Alliance contracts, trust, culture, guanxi

Introduction

Alliance contracting is a type of procurement that integrates relationship components into the contractual documents. A project alliance can be considered both a project delivery method and a contractual device. The project alliance concept was developed and introduced on North Sea offshore oil and gas projects in the early 1990's. It improves upon the earlier concept of project partnering, in that it offers protection to signatories via a legally enforceable contract (Chen et al., 2012). Alliances "are characterized by joint member sharing of all project risks in a no-disputes and no-blame environment where unanimous decision-making takes place" (Lloyd-Walker, B., Mills, A., & Walker, D., 2014), thus endeavouring to improve upon the perceived norm of adversarial relationships in construction (Mills, Devery, and Nalewaik, 2016).

Alliancing requires an integrated and collaborative approach, intended to achieve goals, innovation, and efficiencies through a long-term relationship in which risk and reward are shared. A pool of contractors is often pre-qualified as part of preparation for future projects, meaning a long-term alliance can greatly reduce procurement time and facilitate early contractor involvement. Terms of the agreement typically include an open-book relationship in which all information is shared, and a non-adversarial, best-for-project stance.

Preconditions to Successful Alliances

A literature review was conducted to understand the balance between culture and control mechanisms in alliance contracts. One of the precondidtions to success is what is known as a "Best-for-Project" approach, where all participants in the alliance agree to make decisions and adopt behaviours that is to the benefit of the project and not the individual participant.

Contractual governance is used to reduce the risk of opportunism and ethical vulnerability, incentivizing best-for-project behaviour in contractual partners. Governance in alliance contracts exists in two forms: formal, and informal control. Formal control appears as prescribed, written rules that shape processes and reward desirable performance (Das and Teng, 2001). These rules define what behaviours and costs are allowed and not allowed, codify decision-making mechanisms, and establish the calculations for sharing risk and reward (Faems et al., 2008). Informal control appears in the "establishment of organizational norms, values, culture, and the internalization of goals to encourage desirable behaviour and outcome" (Das and Teng, 2001). Other terminology used to describe informal control include clan control, psychological contracts, and normative control.

There is some evidence that informal control may have a greater influence on alliance partner behaviour in a long-term commitment than formal control (Lee and Cavusgil, 2006). Because alliance contracts are a relational type of agreement, there is "greater interdependence both between the parties and between the parties and others interested in the transaction" (Zhang and Ahtonen, 2015) than with traditional contracts. Relational agreements are characterized by elements of trust, familiarity, mutual respect, and an "implicit psychological contract [of] … loyalty and obligation beyond the bounds of a written contract" (Kwok, James, and Tsui, 2013).

Success of alliances may be positively related to the geographical, cultural, and environmental similarity of the project alliance participants" (Zhao, Y., Feng, Y., Li, C., 2018). This is a challenge in alliance contracts in construction, as the industry has long been characterized as fragmented, with "a plurality of different organizations with different goals, cultures, and professional skills" (Guo, S., Lu, P., Song, Y., 2013). Dissimilarities between social actors can negatively affect the quality of interactions in a partnership and thus hinder the complex integration and transformation of disparate pools of tacit know-how into value creation (Sarkar et al., 2001).

Information asymmetry and agent opportunism are not uncommon in construction projects (Guo, S., Lu, P., Song, Y., 2013), which has typically led to over-reliance on explicit contractual control to reduce partner risk. This is particularly true when new project partners arrive with ingrained combative habits and behaviours, which can be difficult to overcome and may lead to culture shock (Reed and Loosemore, 2012). When contractors are unaccustomed to an alliance contracting arrangement, they "…may import behaviours from traditional and design-build types of arrangement with which they are more familiar" (Laan, Voordijk, & Dewulf, 2011). Participants such as these "don't devote sufficient time, energy, and resources to cultivate trust" (Guo, S., Lu, P., Song, Y., 2013), all of which are needed to build and maintain the necessary relationships for successful alliances.

Allianced partners need to adopt new values, attitudes, and behaviours, and have a flexible approach to the situation (Reed and Loosemore, 2012), in order to improve the chances of alliance success. However, there are specific elements of the alliance contracts mentioned above are worth discussing further, in the context of normative behaviour, in particular the concepts of trust and the power of relationships

<u>Trust</u>

Trust, in the context of alliances, has been defined as "one's expectations, assumptions, or beliefs about the likelihood that another's future actions will be beneficial, favourable, or at least not detrimental to one's interest" (Robinson, S., 1996). It is very much a definition based in reality, in a world where opportunism and competition are pervasive. Das & Rahman (2010) define partner opportunism as "… behavior by a partner firm that is motivated to pursue its self-interest with deceit to achieve gains at the expense of the other alliance members." Trust is an important element in the success of alliances, an emotional bond that manifests as a willingness to share information (Kwok, James, and Tsui, 2013), and avoid behaving in an opportunistic manner that takes advantage of partner weaknesses. The ultimate objective is to work together to maintain the partnership, and reap the benefits thereof as a team, and not as an individual.

Such a high level of trust is not easily created, however, a history of personal interactions is very important to relational bonding (Tai, S., Sun, C., and Zhang, S., 2016), and the level of trust between contractual parties increases over time (Guo, S., Lu, P., Song, Y., 2013). Some of this bonding may be achieved by investing time and money in adopting the relationship contract, including group activities such as coaching, team bonding exercises and workshops (Ling et al, 2014), but it must also be maintained and nourished. Through the process of socializing, ongoing interaction, and co-location, "members [of the alliance] become more committed to the organization, and shared views serve to influence strongly the behaviour of the members" (Das and Teng, 2001).

A no-blame culture is one in which members of the alliance project team do not fear consequences when contributing to discussions and identifying issues. In such a culture, open communication, honesty, process improvements, and shared knowledge lead to innovation and efficiencies. Diversity of perspectives and the challenging of assumptions are key to a no-blame culture, "a safe haven for robust respectful debate" (Lloyd-Walker, B., Mills, A., & Walker, D., 2014). Such things are less achievable in an environment that discourages speaking up and taking risks, where failure is unacceptable. A no-blame culture contributes significantly to increased partner trust.

In an alliance contract, there are many opportunities for the sharing of research, knowledge, and skills between alliance partners, once trust has been established. This is known as partner learning. There is evidence that "partner learning reduces scepticism and paranoia" (Schilke, O., and Lumineau, F., 2016), thus helping to build and maintain a strong relationship. Other outcomes include effective communication, goal alignment, cooperation, and the "development of routinized interactions and shared language" (Schilke, O., and Lumineau, F., 2016); in other words, trust and shared information contribute to a strong team culture and behavioural norms.

Once trust is established in a relationship, the parties become motivated to maintain it. Alliance partners are incentivized to address risks cooperatively, instead of shifting risk to each other, as "the potential costs of putting their relationship in danger really outweigh any short-term advantages of opportunistic behaviour" (Laan, Voordijk, & Dewulf, 2011).

<u>The Power of Relationships</u>

Strong long-term contractual and interpersonal relationships have many benefits to the parties involved, beyond just profit and competitive advantage through continuous improvement. Not the least of these additional benefits is a shared culture of understandings and values (Zhang and Ahtonen, 2015). Other characteristics are mutual respect, a "willingness to help each other in difficult times" (Kwok, James, and Tsui, 2013), and a "high level of mutual goodwill" (Zhao, Y., Feng, Y., Li, C., 2018).

This element of goodwill is especially important during the project, as conflict is inevitable. "Conflict is a key characteristic of interorganizational alliances, since these alliances tend to contain the seeds of behavioral contradictions (cooperation vs. competition), temporal contradictions (short term vs. long term), and structural contradictions (rigidity vs. flexibility)" (Schilke, O., and Lumineau, F., 2016). In alliances, both formal and informal control mechanisms enable the contracting parties to find satisfactory private solutions to resolve contractual disputes (Zhang and Ahtonen, 2015) without damage to reputation (Kwok, James, and Tsui, 2013), while enhancing efficiency and accountability (Chan et al, 2008). This both reduces transaction costs by avoiding litigation, and increases trust, credibility, and commitment (Zhang and Ahtonen, 2015). Most importantly, conflict resolution mechanisms maintain harmony and dignity and help to further build the relationship between parties. A recent study in Hong Kong indicated 43.8% of alliance projects studied achieved a dispute-free record, and another 40% of projects achieved a lower than average incidence of disputes and claims (Chan et al, 2008).

Maintaining long term relationships also helps to contribute to a positive reputation for both organizations. Reputation is another type of informal control in alliance contracts. "Because reputation signals trustworthiness, companies have an intrinsic desire to maintain their good reputation" (Zhang and Ahtonen, 2015). Formal contractual enforcement may result in loss of trust and reputation, thus good behaviour is incentivized in cultures that place a high value on reputation.

Case Studies: Illustrations from Practice

The case study approach allows real-world inspection of theory. Over the past decade, the authors have studied both large and small construction programs structured as alliances. The capital programs discussed below include infrastructure, water treatment, and grade level rail crossing projects in Victoria (Australia), and gas utilities projects in California (United States of America). Content analysis of project records and semi-structured interviews were used to capture alliance members' perspectives and experiences.

Trust

It is worth noting that trust did not just spontaneously occur on the alliance projects in the study. Victoria water treatment project leaders took care to emphasize that trust was built over time, and made easier by selecting team members whose personality was a good fit with others on the alliance (Mills, Devery, and Nalewaik, 2016). This suggests, in part, that some

behavior can be learned, but that much of the team member behavior was culturally innate and thus highly sought after. Once the right staff members were selected, project leadership organized relationship coaching, team building, and other efforts at forming a connection and learning to listen, team members came together to align expectations, form a cohesive unit, and create a framework of trust. As the project director commented, the efforts expended to establish trust ultimately resulted in an environment where "it was very clear we're all pulling in the same direction" (Mills, Devery, and Nalewaik, 2016).

Similar to the Hong Kong study by Chan et al mentioned above, interviewees in the Victorian infrastructure alliance stated alliance contracting minimized the number of claims and disputes (Mills, Devery, and Nalewaik, 2016), and instead engaged alliance partners to resolve issues amicably. Even where there were cost implications for the individual firms, the alliance partners worked together to make best-for-project decisions (Mills, Devery, and Nalewaik, 2016).

Interviewees indicated that trust resulted in a number of new behaviors, which greatly enhanced the relationship between both parties. These new behaviors included (Mills, Devery, and Nalewaik, 2016):

- A reduction in the inclination to monitor each others' actions
- Less need for formal contractual and procedural controls
- A more congenial atmosphere, without inequality
- Higher levels of accountability

This was also true on the California gas pipeline upgrade projects, where it was seen that the alliance project team was more likely to rely on the spirit of the alliance and the strength of relationships than the strict wording of the contract (Nalewaik et al, 2015). Although the Owner's top management tended to rely heavily on contracts and audit to monitor contractor performance, that was accepted as a natural tendency for an organization that was implementing an alliance for the first time. The true nature of the alliance was seen in the field and in project management, where managing for reasonability and collaboration with others became normalized behavior (Nalewaik et al, 2015).

<u>The Power of Relationships</u>

On both the Victoria infrastructure projects and the rail crossing projects, interviewees stated the relationships extended not just at the organizational level but also to personal friendships (Mills, Devery, and Nalewaik, 2016). Indeed, the organizational relationship was strengthened by relationships between top-level stakeholders. Although arguments did occur between individuals, which could have put the inter-organizational relationships at risk, the arguments were most often resolved without damage.

The Victoria water treatment projects also had similar benefits, and interviewees commented that communication and availability of data were markedly easier than on non-alliance projects, due to the duration of the relationship (Mills, Devery, and Nalewaik, 2016). Organizational growth was a very tangible benefit; contractors in the alliance were able to

use the tools, experience, and knowledge to build their businesses, obtain necessary certifications, and attract new clients (Mills, Devery, and Nalewaik, 2016).

On the California gas projects, the contractors were keen to be assigned to future projects, and thus were especially motivated to foster and nurture the alliance relationship (Nalewaik et al, 2015). In this particular capital program, there were multiple contractors signed to alliance contracts, all with the same owner. Unilaterally, the contractors and owner experienced a number of benefits from the long-term relationship, including (Nalewaik et al, 2015):

- The ability to collect historical cost data in a consistent format
- Open communication
- Streamlined processes
- Reduction in safety incidents, due to long-term field personnel
- Better quality of field-installed construction work, due to long-term field personnel
- A collegial, co-located project office
- More consistent leadership, due to long-term construction and project management staff
- Better project outcomes due to early contractor involvement

Conclusion

All the case studies indicated that high levels of trust helped to reduce conflict in the alliance, and enabled team members to create an environment where alliance partners were willing and even eager to explore future projects and a more long-term relationship.

Despite the diversity of projects studied, the advantages of a long-term relationship were clear on all the case studies. The companies and team member individuals alike benefited from a more stress-free environment, with lower turnover of staff, and the ability to openly share tools, knowledge, and data. These benefits extended to the quality of the construction project itself, resulting in a win for all parties involved.

Although a formal contract is necessary on construction projects, the case studies and literature review both indicate that informal control is a strong requirement for alliance success. Whether it is called clan control, cohesive culture, or a psychological contract, trust and the high levels of familiarity and respect created by long-term relationships help to create strong inter-organizational and interpersonal bonds that engender loyalty and a sense of obligation to each other. Building trust and the relationship, however, requires commitment and a significant level of effort and investment in team-building, along with the careful selection of staff members who will be a good fit for the blended alliance team.

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ANALYSIS OF INTERNATIONAL VERSUS RUSSIAN ESTIMATING STANDARDS

Dr Sean Regan, ICEC

Abstract

The internationalization of estimating practices has been consistent in most International Markets generally in accordance to AACE Recommended Practices, except for in Russia and Customs Union mandates by the Russian Normative. The Russian System of Estimating is based on the Normative and Standards, which continue to reflect that the approach from estimating based on a functionally outdated model. While Russian firms have adopted current technology, the estimating practices are not consistent with International projects. The Normative guides are basically a set program of books with prices from 2001 to 2004 and then factored accordingly.

Due to the market changes, Russian firms working in international markets conflict with the standards of international estimate development such as Construction Standards Institute (CSI) and this is having a negative impact on their ability to work on the projects due to the significant difficulties experienced by overhead, labor studies, regional payments, and structure.

The presentation will discuss the differences in the systems and then review actual projects in Russia and by Russian firms in Europe, Africa, and Middle East, and review the positives, negatives, and lessons learned, as Russian Companies are embracing AACE TCM and Recommended Practices.

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Introduction

Estimating is in many cases a challenge for programs. But to work in the International Projects and review methodologies, as well as languages and processes can be a complicated issue. The Author has worked for over 20 years on the development and implementation of project estimates and programs in Russia, and the Former Soviet Union countries. Projects in Oil and Gas, Nuclear, Infrastructure for programmatic Total Installed Cost more than $15 Billion successfully executed and $ 4 Billion in current construction.

During the time-period in review for this program, many of the original estimates were required to be executed in both Russian and International formats. This required the programs to be reviewed in accordance to the local structure and regulation called the SNiPs (Normative and Standard), which are developed and reviewed by the Ministry of Construction of Russia.

The implementation of the International Estimating standards reflected in many cases were Western Estimates being executed in Russia, so a form of dual estimating was done. Due to the international expansion of firms from Russia into EU, Africa, Middle East and China there are now requirements for Russian firms to be able to implement International standards, instead of the existing Normative and Standards format.

This presentation reviews the basic information and the processes that have been required in supporting the programs and projects of Russian firms as required to meet the requirements of these areas. Critical to these companies is that to work in the International areas, they are being required to meet the requirements, as well as the impacts that have been realized by the Russian firms in losses on the programs.

International versus Russian Estimating Methodologies

The review of the program has come from the development of International Estimates and Russian Estimates from 1998 to 2018.

Russian Estimating Standards

Russian Estimating Standards rates are aligned from 2000 to 2004, depending on the estimating scope of work. The standards were validated in that period and then are factored based on the annual inflation. This type of estimating is mandated by the laws of the country on any type of project starting from engineering works for simple construction works as well as complex projects and are predicated by having a series of documents for the estimate process.

Key to this process, would be like the utilization in the International Programs of RS Means, where the book is aligned to a region and factored accordingly. The difference is that everyone competing on the project uses the exact same rates and works to adjust their differences through the ODC rates and their experience levels.

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The other items that become an issue is that it impacts the program, as the rates applied in the normative are set, so if the craft or equipment has changed or adjusted, these are comparable to a unit rate. Moreover, the rates are considering only the local market with no factors for procurement abroad, which parenthetically are covered by other existing factors, that makes estimation not reliable and worthy.

The Quantities are assigned and then the rate is applied and adjusted with factorization. Usually factorization is used to come up to the value that a company would like to see at the total, because at different estimations, there are not only annual inflation factors are used, but also factors such as winter works, complexity of work, etc. are added on top using different reasons and it varies from program to program to raise up the unit rates dictated by norms and standards. A critical issue to this is that there are required documentation that are applied in the Russian System. The estimate in Russian is called a SMETA. These are then aligned to government regulations SNiP. The SNiP (translated construction norms & regulations) is basically a government regulation on the requirements of the execution of the scope. If the work executed does not match, then the Act of Acceptance of which are required to process the documents called the KC-1, KC-2, and KC-3 will not be accepted and project start up is failed. Another items companies need to be experienced with is that if being paid in currencies different then the Russian Ruble (RR), they must complete a currency passport for the transfer.

International Estimating Standards

AACE International Practices

An example as identified is that the recommended practices such as the 17R-97 and 18R-97, estimate classifications, these changes present multiple definitions that expand, but, the terminology in translation gave appearance they were different processes.

	Primary Characteristic	***Secondary Characteristic***			
Estimate Class	**Maturity Level of Project Definition Deliverables Expressed as % of complete definition**	**End Usage Typical purpose of estimate**	**Methodology Typical Estimating Method**	**Expected Accuracy Range Typical +/- range relative to index of 1 (i.e. Class 1 Estimate)**	**Preparation Effort (Typical degree of relative to least cost index of 1)**

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Class 5	0% to 2%	Screening or feasibility	Stochastic (factors and/or models) or judgment	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization or Control	Mixed but primarily stochastic	2 to 6%	3 to 10
Class 2	30% to 75%	Control or Bid / Tender	Primarily deterministic	1 to 3	5 to 20
Class 1	65% to 100%	Check Estimate or Bid / Tender	Deterministic	1	10 to 100

Figure 1, RP 17R-97, AACE, Morgantown WV, Mar 2016

	Primary Characteristic		*Secondary Characteristic*	
Estimate Class	Maturity Level of Project Definition Deliverables Expressed as % of complete definition	End Usage Typical purpose of estimate	Methodology Typical Estimating Method	Expected Accuracy Range Typical +/- range relative to index of 1 (i.e. Class 1 Estimate)
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or Feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%

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Class 3	**10% to 40%**	**Budget, Authorization or Control**	**Semi-detailed unit costs with assembly level line items**	**L: -10% to -20% H: +10% to +30%**
Class 2	**30% to 75%**	**Control or Bid / Tender**	**Detailed unit cost with forced detailed take-off**	**L: -5% to -15% H: +5% to +20%**
Class 1	**65% to 100%**	**Check Estimate or Bid / Tender**	**Detailed unit cost with detailed take-off**	**L: -3% to -10% H: +3% to +15%**

Figure 2, RP 18R-97, AACE, Morgantown WV, Mar 2016

International and Russian Estimate Classes are now working to become aligned, based upon recent efforts of programs in AACE. The Russians had traditionally applied a Three (3) Class system. The Class 4 and 5 are considered one estimate and the Class 2 and 1 were considered the final definitive. Due to the fact of the alliance to the Normative and Standards, there is not a requirement for the Russians to reconcile the Estimate to the Class 3 Budgetary estimate. This is requiring a philosophical change to the programs for the Internationals, where management or donating governments requiring the reconciliation. The other issue this has posed to them, that by employing historical reviews, when they do, and the Normative Estimates there have been significant overruns on projects for the items that were not inclusive into their programs. This is resulted in losses on programs by 200 to 300%. Which had to be financed by Russian guarantees on the program.

Another identification process within the Estimating System for the Russian Estimating programs, is that the estimates where in international programs we establish bench marking in estimates, such as utilization of previous executable cost to a program. Benchmarking in the Russian System is deemed the criterion like a GATE acceptance of the program.

Framework Estimating International Practices

International estimates may utilize a traditional basis such as the CSI standards, as identified in figure 3. This process is widely accepted, as well as similar materials such as RS Means or Richardson's.

The coding utilized as discussed above, as well as, many of the leading Engineering, Procurement, and Construction (EPC) firms with historical structures, are generally based on consisting coding based upon the premise of the five estimate classifications, as identified in figures 1 and 2. These

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lead to another issue that the classifications and the contingency levels as established are utilized within the estimating process.

The International may run a contingency level for example in a Class 4 of 15 to 25%. The Russian System utilization of Contingency was surprised to many that a Class 4, Class 3 in their determination, is contingency of 5% with the consideration that detailed design is final, this would normally be the level set at a Class 2 estimate within an international program.

48 12 00 Nuclear Fuel Plant Electrical Power Generation

	Equipment
48 12 13	Nuclear Fuel Reactors
48 12 13.13	Nuclear Fuel Fission Reactors
48 12 13.16	Nuclear Fuel Fusion Reactors
48 12 23	Nuclear Fuel Electrical Power Plant Steam Generators
48 12 26	Nuclear Fuel Electrical Power Plant Condensers
48 12 29	Nuclear Fuel Electrical Power Plant Turbines
48 12 33	Nuclear Fuel Electrical Power Generators

Figure 3, Extract Master Standard, CSI, Alexandria VA, 2016

The following, figure 4, is an example of the Russian Normative. This estimate from the Ministry based on the work of Rosatom Nuclear, for the equipment can be highlighted by reviewing the pricing. As such you can see that the estimate costing level is based on 01.01.2000, this is 1st of January 2000. This numbers for the price of the equipment would be based upon 2000 actual cost and then must be factored by escalation prices from 2000 to 2018.

An issue that can be reviewed on these is that in 2008 to 2010 there was the Credit Crisis and similarly the issue that can cause further issues is that there was a currency float in 2015 of the RR, which lead the currency to devalue between 2015 and 2017 to as high as 80 RR to the USD, where most equipment is US Purchased. The current rate in 2018 has dropped back to 60 RR to USD, but with 5 of the past 10 years in an economic ping pong effect this can skew the ability to accurately factor.

As such the additional issue is that on the International Estimate for the Russian equipment on the construction has led to significant changes as well as potential licensing issues. Other impacts on the Russian estimating and budgeting process is that Sanctions as applied are not applied for the programs on a consistent factor. This consistent factor is that firms are not willing to provide the equipment, despite non-sanctioned, out of a predicated risk. So, to named Normative and Standards cannot cover such exceptional cases and estimation is not adapted to a program, but program is adapted to estimation in Russian norms and standards.

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This means that while a Risk Contingency should be applied to the estimate, based on the contingency levels as applied in AACE and other international standards, are not being applied. This is continually having an unrecognized impact in the systems, leading to a diametric issue for the programs.

By the non-utilization of historical cost against the normative estimate this is resulting in additional risk and contingency cost not being utilized. As such, the normative is not in alignment to the program. This is further compounded by the training and education on the programs. You have Senior estimators that have historically run the Normative program, thus a 30 Year estimator is of course reluctant to change, and this support and faith causes issues on the ability of the programs to viably change, without incorporation of new strategies, as identified in Western programs.

КОНСТРУКЦИИ, ПРИМЕНЯЕМЫЕ В СТРОИТЕЛЬСТВЕ

Часть I. Материалы для общестроительных работ

Шифр ресурса	Строительные материалы, изделия и конструкции	Ед. изм.	Цена руб. на 01.01.2000	
			отпускная	сметная
1	2	3	4	5
Раздел 1.01. Материалы для общестроительных работ				
Подраздел: Материалы и изделия асбестосодержащие				
Группа: Асбест				
101-3201	Асбест антофилитовый	кг	35,06	37,86
101-0001	Асбест хризотиловый	т	3 144,41	3 395,33
101-1967	Асбест хризотиловый	кг	3,15	3,40
	Асбест хризотиловый волокнистый, марка:			
101-3202	А-7-370 (С7 М7-370)	т	2 127,51	2 297,30
101-3203	А-7-450 (С7 М7-450)	т	2 256,62	2 436,70
	Асбест хризотиловый марки:			
101-0005	М-3-60	т	12 706,91	13 720,92
101-0006	М-6-40	т	3 331,28	3 597,12
101-0007	М-5-50	т	3 490,44	3 768,98
101-0008	М-5-65	т	4 119,44	4 448,17
101-0009	К-6-30	т	1 365,18	1 474,12
101-0010	К-6-45	т	1 201,50	1 265,29
101-0002	Асбест хризотиловый тонкоизмельченный	т	2 972,78	3 072,00

Figure 4, Extract Russian Normative, Materials, Nuclear, Rosatom, Ministry of Construction, Moscow Russia, 2013

International Differences

The differences in International and Domestic utilization are often more of the lack of cultural diversity and lack of flexibility in the programs. As such, the standard excuse utilized is that the complication of the international programs is the difference.

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The key aspect that is generally seen is that the International Processes are based on a competitive model, while the estimators in Russia are used to a similar process and the programs are based not on the competitive model, but the relationship and dictated processes. As is often the case, many processes are in many cases over complicated than the actual processes. Procedures often do not have to be re-written but augmented for the work processes that will be utilized.

One of the key differences is in most cases the lack of development of Execution Plans in the Russian System, which reflect the full aspect of the program on International programs but are not fully diagnosed and determined by set program numbers.

What may present a major difference in the processes is also the language and the terminology have not been presented correctly. During the translation some words or phrase were not translated correctly and as such the meaning would be lost. These aspects present difficulty in the alignment.

- Transportation Cost too low, specifically there seems to be no storage and potential demurrage, also VAT rate will be 15% and while stated in Overhead, VAT would be under Construction cost. Overall would reflect a 15% VAT + 17% Freight and Storage Allowance, until verification this is standard custom and transportation allowance. Should not be in Overhead, but a direct capitalized cost.

- Payroll Labor Rate – Summary Cost Used is 19.85 Euro/Hour, the experience of the current EU team is Finnish Labor Statistics are not viable to estimate, need to review regional actuals.

- Labor Pay to Production – EU Law says all employees overnight traveling overnight will be paid 40 hours for each 35 worked, this has not been considered. 8% Increase

- Premium / Overtime – EPCM will not work a 40-hour Work 35 pay 5 Fringe) they will work 50 or 60 hours no identification Made 20% Increase

- Labor Uplifts for Travel – EU Law says all employees traveling overnight, such as 1 month on site and one month off – will receive Travel and Food Allowance for being away this can cost from 1500 to 2000 Euro a month. 20% Increase

<u>Overhead and Indirects</u>

Another interesting aspect encountered in Program was a review the ability to support the estimates in recognition of Overheads and indirects. As such, a critical need in most programs was to map scope to the mandatory regulations called Norms & Standards that are utilized in Eastern Europe, Russia, Former Soviet Union States (FSU), and China. These norms and

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standards dictate specific processes, rates and production that are aligned to regional codes that align up to their programs with the consideration of local market only.

These Estimating Norms & Standards have a set code dictionary and are in some instances dictated into the numbers and processes. Additional codes or lines are not allowed to be added.

Based upon this they have difficulty in categories such as Other Direct Charges (ODC) and the overhead amounts, which are percentage differently due to the Norms and Standards and are directly related to the work of execution.

While in an International Estimating program most estimators would have a checklist of potential Construction Indirects, Home Office Indirects, Overhead and G&A. In the Russian Normative process, the direction is to have a dictated percentage from the Ministry or from the corporate program. Yet the International Programs work on check list specifically from program to program:

Examples of traditional items which are in an International Estimate but excluded in the Russian Normative Estimates which impacted the ODC and Overhead:

- On Site Design Supervision Cost 5%.
- Considerations on International Employment Laws. For example, on one project Russian estimate excluded the estimated cost required in European Union (EU) Law that all people traveling over 100Km and spending night at compound are entitled to 50 to 60 Euro a Day.
- There is traditionally the cost of the Housing, but the Dining, Recreation facilities for the program are excluded into a very bare program. Russian estimates include as aa percentage in overhead which is not broken down by details and established in 2001.
- Labor cost limitation of amount of people allowed to be imported, with the cost of Visa, Support excluded as they rely on Government Agreements. The agreements though, do not represent the EU Labor requirements.
- Survey Cost for Survey is set at 5% as a percentage, but low based on current development items such only covered the ISBL, but failed to recognize the OSBL, Infrastructure (Port, Rail, Road).
- Reactor Engineering was not based on the EU requirements, but were review only, yet there are mandated changes which would be required in EU safety, as such the lack of final review impact the program. This also was impacting the estimate class as the Owner was declaring the drawings were Class 3 for issuing EPCM Contracts, but as they all had to be re-worked would have aligned it to a Class 4. Also, in clarification the estimate had no cost for the re-adjustment, but the Engineering Director estimated one year to clear the drawings, which was required to meet Class 3, but the cost was excluded.

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- All the indirect cost has been duplicated from last similar project that had different location, different logistics, etc.

Conclusion

As identified the author has worked on estimates within the region of Russia, Eastern Europe, and China. The system as identified in the paper reflects the differences between the programs of a Russian Normative and Standard estimate and an International estimate program. These programs have been working based on a standard of taking a historical reference book and a mandated regulation of processes that have an impact on the ability of the programs to function in the international market.

Many international companies try to force the international process, but due to the legal issues that are imposed on the Russian programs this requires a dual formed program.

As such now that we are seeing Russian backed programs having to work in international programs, this forces the alignment to the programs that the Russian systems must compensate for the International programs.

When aligned and the differences are clearly explained the ability of the programs to adjust for the contingency and risk are allocable to the correct application of the estimates.

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BIM AND ARCHITECTS' JOBS IN JAPANESE BUILDING PROJECTS

Dr Takashi Kaneta, Kyoto University

Keywords: architects' jobs, building construction, building information modelling, project management, supply chain.

The implementation of BIM in building projects has been a big topic in Japan. However, as with previous CAD, system development of BIM has been led by vendors and suppliers. Stakeholders involved in building projects are positioned to be just users. Originally, the supply chain of a building project is divided both in the process and among the organizations. They are mutually connected by contract and fee to relay design and product information until the completion of a building. For that reason, much research, development and case studies on current BIM has been limited to consideration within the divided range. So, there is a lack of discussion through the whole supply chain. On the other hand, the architects' jobs are now reviewed by Japanese government considering the environment of contracts where the variety comes to be allowed even in public building projects. BIM influences architects' jobs. But most of Japanese architect firms are not aware of the direction of the business. In this paper, while overviewing the supply chain of building projects, the author aims to describe the relationship between organization, contract and BIM at each stage to present future strategy of architects' jobs. Regardless of the use of BIM, analysis is being conducted from the standpoint that the current building production system includes fragility.

INTRODUCTION

The implementation of Building Information Modelling (BIM) in building projects has been one of the biggest topics in Japanese construction industry. However, just like as with previous CAD, system development of BIM has been led by vendors and suppliers. Stakeholders involved in building projects are positioned to be just users. Originally, the supply chain of a building project is divided both in the process and among the organizations. They are mutually connected by contract and fee to relay design and product information until the completion of a building. For that reason, much research, development and case studies on current BIM has been limited to consideration within the divided range, e.g. BIM for design, BIM for construction, BIM for Facility Management, and so on. So, there is a lack of discussion through the whole supply chain.

On the other hand, the architects' jobs are now reviewed by Japanese government considering the environment of contracts where the variety comes to be allowed even in public building projects. BIM influences architects' jobs. But most of Japanese architect firms are not aware of the direction of the business. In this paper, while overviewing the supply chain of building projects, the author aims to describe the relationship between organization, contract and BIM at each stage to present future strategy of architects' jobs. Regardless of the use of BIM, analysis is being conducted from the standpoint that the current building production system includes fragility.

BUILDING PROJECT PROCESS

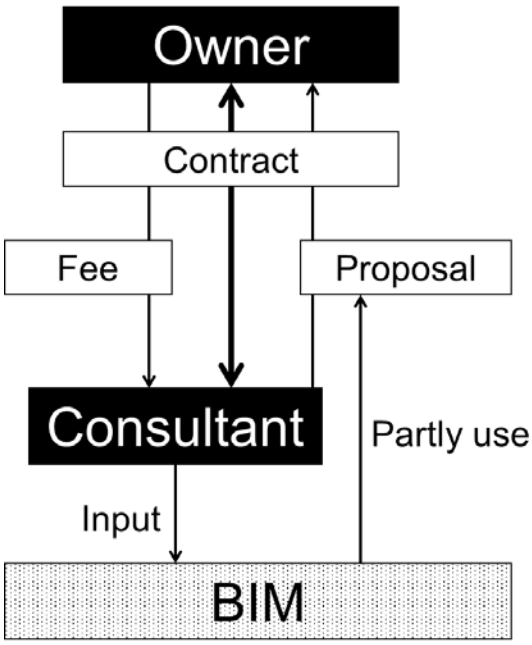
Building project process can be divided into several phases: preparation and brief, design phase, tender and procurement, construction phase, and operation and facility management. At each phase, stakeholders or organizations that are considered to be involved in the standard project will be listed. Their contractual and operational relationships along with BIM will be also illustrated in the figures. For information flow, BIM is assumed to be used consistently at each phase, but the position of BIM will vary with each phase.

Preparation and brief

The concept and business plan of the building project should be originally produced by the building owner, but it will be sometimes contracted out in many projects in Japan as shown in Figure 1. As an alternative to the building owner, a selected consultant may estimate the business balance, the selection of the site, and the setting of the scale and the specifications of the building. Fee will be paid to the consultant by the building owner as the consideration to the proposal in accord to the business contract. There are range of the contents of the proposal by conditions of projects.

Though most of the output of this phase is related to a business plan and a financial plan, information on the site condition and various building regulations will be saved in BIM. Any matters requiring development permission or authorization must be confirmed and reviewed in BIM.

Figure 1 Stakeholders and BIM in preparation and brief



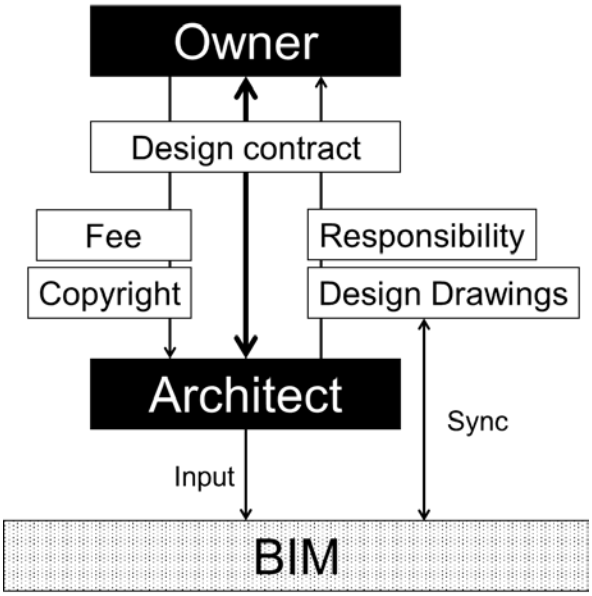
Design phase

After the design conditions have been settled and the selection of the architect has ended, the owner concludes the design and supervision contract with the architect as shown in Figure 2. In this paper, design and supervision are treated integrally. The owner pays the design fee as a consideration for production of the design drawings and project basis specifications. As for supervision, the architect's job is confirming that the construction work is done as shown in the design drawings.

As the design drawings is a work, it is thought that the copyright belongs to the architect. But there is an opinion that the building owner buys the copyright by paying the design fee, and the conclusion is not decided. Design drawings can be regarded as the paper-based information taken out from BIM. Therefore, the copyright of BIM should be discussed.

If a building defect is caused by negligence of the architect, a certain responsibility arises with the architect, though there is a room for discussion in the scope of responsibility. From the view of the architect, it is unclear what scope should be subject to the architect's responsibility, because the changes are repeated over time with BIM. This is one of the project risk.

Figure 2 Stakeholders and BIM in design phase



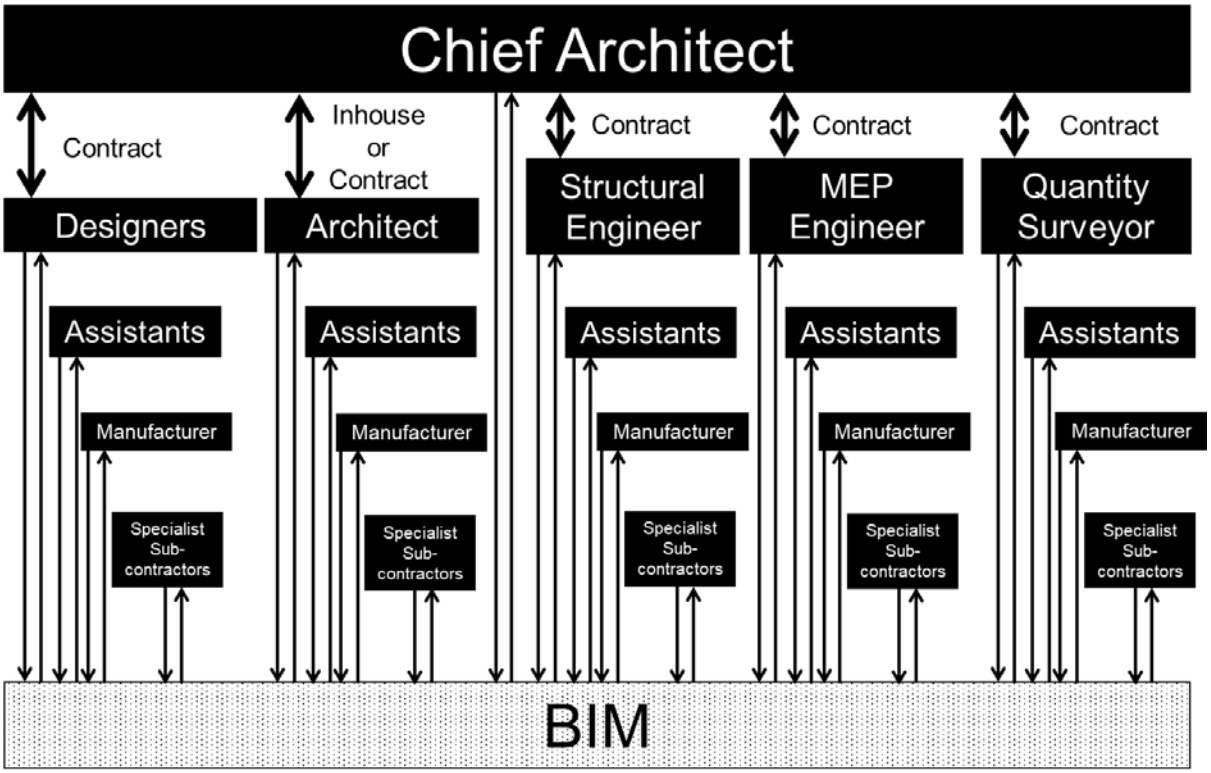
Design team and BIM

In addition, further detail of the design team is shown in Figure 3. It is a well-known fact that architectural design is produced in teamwork by several firms, even if only one name of the architect is found in the fact sheet of the project. We assume that the final responsibility of the design drawings is owed by the chief architect. The one (organization/individual) in charge of general architectural design is an architect who is positioned under the supervision of the chief architect. The structural engineering and mechanical, electrical and plumbing (MEP) engineering are specified as advanced technical design in Japanese architects' law. A variety of professional designers may participate in the façade design, interior design, gardening design, landscape design, and so on. Some consultants may be requested in discussion about city planning or area management.

In order to calculate the quantity accumulation and to estimate construction cost at the design phase, the involvement of the quantity surveyor is necessary. The building owner does not always have enough ability to estimate construction cost by himself/herself. Besides quantity surveyors in Japan, construction managers support building owners to get accurate cost information in preparation for tender and procurement.

There are many co-workers (partners) subcontracted with each stakeholder. They are assistants. For special materials and equipment, the stakeholder may ask the manufacturer to provide reference drawings or quotations regardless of a fee or charge. As for the installation of the equipment, the knowledge of the specialist subcontractor will be obtained. These entities are also directly or indirectly involved in the input/output to BIM.

Figure 3 Design team and BIM



Tender and procurement

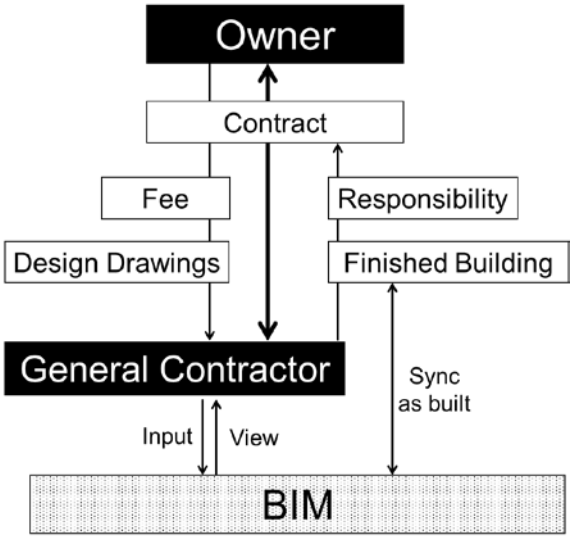
When the contractor is selected by the competitive bidding, it may be a possible operation that the candidates can access BIM to view the building information and obtain the quantity data in addition to providing the design drawings to the candidate. It is basic features of BIM that the structure and the construction method can be confirmed in 3-dimensions, which helps workers to understand the design drawings. If the quantity information is provided from BIM, the estimate work of the candidates can be greatly improved. As a result, if the uncertainty and the risk for general contractors, which causes more contingency cost, can be reduced, the cost of construction work can also be expected to be reduced.

Construction phase

After the selection of the contractor is finished, the building owner contracts with the general contractor assuming the completed design drawings. The general contractor obtains the construction fee as a consideration for the delivery of the completed building. In Japan, payment of the fee becomes the instalment according to the construction progress. The design drawings are attached to the construction contract agreement in usual. The information in the design drawings could be communicated by enabling the general contractor to input and output to BIM.

In the case of a building defect caused by the negligence of the contractor, as in the case of the architect, the general contractor's responsibility arises. In addition, in the case where a defect is constructed without notifying the architect and the building owner while knowing that it causes the defect if the construction is proceeded as shown in the wrong design drawing, the general contractor's responsibility might be accused. There is tendency to recognize more responsibility on general contractors comparing with architects in Japan. There exists legal obligation in effect for the general contractor to make technical checks on the contents of updated BIM and the design drawings. Therefore, Japanese general contractors have inhouse architects and engineers to add and modify an insufficient part on the design drawings.

Figure 4 Stakeholders and BIM in construction phase



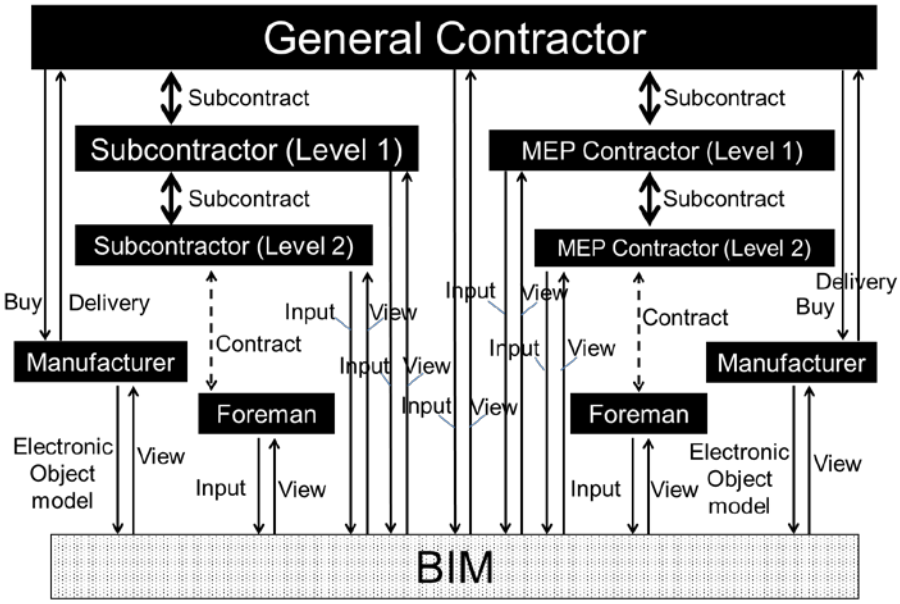
Construction team and BIM

It is also well known that the organization of the construction team forms a heavy-layer subcontract structure. In construction phase, it is not enough for BIM to be accessed by the general contractor. Foreman of specialist subcontractors or an individual worker should access to BIM to view the design drawings from a mobile device at the construction site. The system to read CAD information has been developed in past research and development, e.g. laptop personal computer (PC), personal digital assistant (PDA), and tablet PC at construction site. But the communication speed and operability have always been a challenge.

It is necessary to cooperate with BIM, if we intend to manage the construction utilizing equipment such as robots and drones. Whether the manufacturer provides information about materials and equipment by the format that is compatible with BIM influences the efficiency of the project. For example, electronic object model provided by the manufacturer is quite useful. Now it is for free of charge. But is it possible to depend on only an investment on the manufacturer side for that? We should pay attention to a movement of future discussion.

Regarding MEP, it is highly independent from construction work. There are many projects where the general contractor and the MEP contractor separate the construction contract with the building owner. In such cases, the agreement with BIM should be clear as the construction team has been divided.

Figure 5 Construction team and BIM

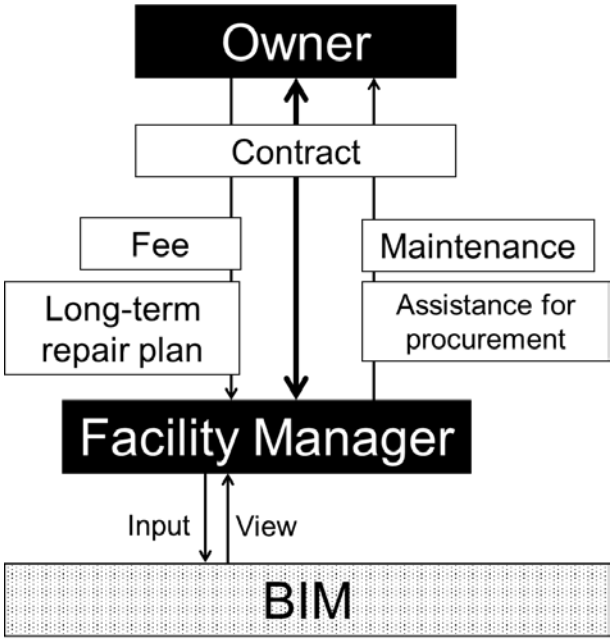


Operation and facility management

The principal involved in operation phase after completion of the construction is a variety of facility managers, property managers, asset managers, and condominium management companies. But if simplified, it is summarized to the building owner and facility manager. Both parties conclude a business consignment agreement, and the building owner shows a long-term repair plan as a condition and pays the fee. The facility manager conducts maintenance operations, including routine inspections, periodic inspections, statutory inspections, and provides procurement support services for renovation work and large-scale repair work. For these works, the jobs including the design, the tender, and the construction will be repeated.

The operation phase extends over a long period of time. The direct person in charge of the original design team and the former construction team become scattered. And so, the building owner is forced to rely on the information such as the design drawings “as built”. The results of part exchange, repair, and reform must be reflected by BIM ceaselessly to use BIM instead of the design drawings and specifications. It's important not to make the present state of the building become estranged with BIM. Then, it is expected that the due diligence (proper evaluation procedure) for the transfer of building owners and the liquidation of building assets will be significantly more efficient.

Figure 6 Stakeholders and BIM in operation and facility management



PROBLEMS FOR BIM IMPLEMENTATION

The position of BIM is mentioned at each stage of the building project process. it is understood that there is a lack of organizations that are consistently involved in the process other than the building owner. The principal beneficiary of BIM will be the building owner. It is a major influence on the spreads of BIM whether the building owner is interested in the implementation of BIM and acknowledge the value of BIM. The building owner does not provide input and output to BIM. A new business such as BIM manager or BIM consultant can be responsible for the building project, but it is also governed by the needs of the building owner and the market.

Ownership of the electronic record data and the attribution of intellectual property rights are not allowed to be operated in an ambiguous state. BIM of large number of projects could be used as big data to streamline the design approach, but the security and the confidentiality of the building and information remain unsolved.

In addition, there is a gap between the contract and the realities of the right and the responsibility. It is not shown in the process model, but the level of development (LOD) of the design drawings is sometimes low and poor in Japan. As for the complement when there is discrepancy in the design drawings each other, what should be done based on the contract, and what the compensation should be settled? Many years of discussion have been continued in Japanese construction industry, but the consensus has not been formed.

BIM becomes possible to input and output as corresponding to the design drawings and specifications at the construction stage. The agreement of the parties concerned must be achieved about LOD of BIM at the construction contract. Storing the 3-dimensional information of real (1:1) scale, it should be easy to find inconsistencies between the design drawings through the view of BIM. It is expected to significantly reduce the lack of input by warning displays. However, it may be a considerable load or technically impossible to complement it in the design phase if it is not a simple mistake but a lack of completion due to the postponement of the decision. There are remaining issues that must be resolved before BIM, such as the systematic support system that enables it, the allocation of resources to design review, the design period and ensuring the architects' business reward.

CONCLUSIONS

In this paper, the position of BIM in each phase of the building project process is analysed. The common presence of the entire supply chain is BIM and the building owner. This is an obstacle to the broad-based strategy of utilization. A comparison with the country, United Kingdom, etc., where building owners have high expectations on BIM will be a challenge for the future.

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BIM AND GLOBALIZATION OF LABOR FORCE

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Abstract:

Keywords: BIM, Modelling, Quantity Surveying, Artificial intelligent

1. Technical

Findings had shown that most BIM model received from the design team had not been fulfilling the standard for quantity surveyors to deliver their service. Amendment on these models are required and it would be very time consuming for the quantity surveyor to adjust the model to suit the tendering purpose.

As a result, this paper aims to find the best solution to standardize the modelling practice and transfer the information to localize professional for the use of tendering. BIM can act as a platform to extract most of the information from the modelers using artificial intelligent and pass and filter the most useful information to local professionals. The best business model for implementation of BIM is to select the right modeler at the cheapest labor cost and pass on to unique individuals using the best artificial intelligent technology and model format. It is a matter to control the workflow and standardize the procedure.

However, establishing the standard procedure is not an easy task. It would require majorly three steps to achieve this. The first step is to find a common format for BIM model. This may not be possible at this stage as to arrive with either a common software or format as it involves commercial and technical issues. As a result, it is proposed to mitigate this problem by having a checklist to the model received, for instance: the information in concrete grade, the marking for column and beam, the materials for finishes must be shown on the model. The second step is to modify the model so that it can suit our requirement, e.g. quantity surveying. This should be done by an artificial intelligent software so that simple rules can be set by the users and doing it automatically every time. For instance, the software can automatically identify and fix the defects in model to a certain extension and allow the users to choose the method and types of error to be fixed, e.g. closing all the required wall gaps in the model in a click of button, changing one type of elements to another by bulk selections. At the end, the last steps should be sorting the useful data by the professionals. The whole process would require a traditional and I.T. approach.

The methodology is by using real life case studies to define the limitation of each method currently using in real life practice and propose the best solution to solve the problems we are facing. The findings are that there are no BIM model standards in Hong Kong and places around the world, so that the model received in often in a bad quality. Fixing the model to our requirement may take a long time which perhaps would take longer than traditional practice. As a result, a better practice would be established a simple checklist at this stage before the standards to be proposed in the industry. A simple checklist would point out the major defects in the model and would require the original modeler to fix this major error before presenting to us. This may be pre-agreed with the client and different parties so that the whole progress for the project can speed up.

Several projects were put into the test ass case studies and professionals in the modeling view had

been interview and provided valuable comments on the way to standard practice in BIM for quantity surveying. There are basically two main approach in the industry. One is to suggest drawing everything out as to cater for all the parties within the model so that the level of detail would be very high and the knowledge required from the modeler would be very high. The second approach would be having a raw simple model for all the parties to share and each party would have their own amendment for their internal use. For instance, a quantity surveyor may use a raw data from the modeler, the raw data should consist of the most basic information of the building. The quantity surveyor should then use some specific Quantity surveyor software to adjust the model. For instance, the software is able to change the distribution of elements based on the definition of quantity surveyor instead of other parties, given that the engineer beam is different form the understanding of quantity surveyor in terms of measurement. The second approach would be a better one as it can reduce the model quality from the industry making the implementation of BIM more realistic. In addition, the amendment by individual parties to the BIM to suit their own requirement by some AI software can make the procedure more standard and systematic.

The value of this paper is to investigate the labor force available, workflow and model format for a more realistic implementation of BIM so as to reach its highest productivity at the lowest cost.

BLOCKCHAIN FOR CONSTRUCTION SUPPLY CHAINS: A LITERATURE SYNTHESIS

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Abstract
Blockchain technology, founded a decade ago, has created a technological and innovative boost among industry and academia. Blockchain is a type of a decentralized distributed ledger where encrypted transactions of digital assets are recorded in an incorruptible manner. Numerous benefits and applications of Blockchains have resulted in it becoming increasingly popular among a broad spectrum of businesses.

This research paper is based on the literature synthesis carried out on blockchain technology and its applications. Blockchain consists of several unique features such as decentralization, anonymity, security, immutability, trust among others. These features emphasise and fascinate users to adopt blockchain in various other industries. A public blockchain is open to any user who wishes to transact while a private blockchain is more controlled by its users. In a public blockchain miners validate the transactions and until most nodes reach consensus, the transactions will not be recorded in the block. In a private blockchain, a permissioned member of the blockchain would validate the transaction.

Blockchain has revolutionized many industries by identifying various markets and opportunities and introducing various blockchain applications. Whereas Blockchain 1.0 was initially used for cryptocurrencies, Blockchain 2.0 is recognized for economic, market and financial applications and Blockchain 3.0 for applications beyond currency, finance and markets. This research intends to use Blockchain 3.0 applications where decentralized accounting process used in blockchains, will be applied to the purpose of accounting embodied carbon in construction supply chains.

Keywords: blockchain, consensus mechanism, features, public vs private blockchains.

INTRODUCTION
Blockchains have increased the interests within various industries such as finance, insurance, logistics, energy and transportation in experimenting its applications (Hamida et al., 2017). Blockchain is a decentralized distributed ledger technology, which allows creation, validation and encrypted transactions of digital assets to occur and be recorded at the same time in an incorruptible manner (WU Global Tax Policy Center, 2017). In a blockchain, the consensus mechanism within the peer-to-peer network is used to ensure that the transaction is valid before it is recorded to the ledger (Weernink et al., 2017). Blockchain consists of a salient unique set of features such as decentralization; anonymity; security; immutability; auditability (Dorri et al., 2016); veracity; transparency; disintermediation (Zheng et al., 2016); trust (Weernink et al., 2017) among others.

Risius and Spohrer (2017) are of the opinion that research on blockchain will assist in understanding the effects of unique blockchain properties and to identify suitable societal fields of application. Initially, blockchain was used for cryptocurrencies as a mode of securely validating and storing information of transactions which was identified as Blockchain 1.0 (Dimitri, 2017). Subsequently, Blockchain 2.0 was introduced for economic, market and financial applications while Blockchain 3.0 was recognized for applications beyond currency, finance and markets (Swan, 2015). This research project uses blockchain 3.0 application for the accounting of embodied carbon in construction supply chains of projects.

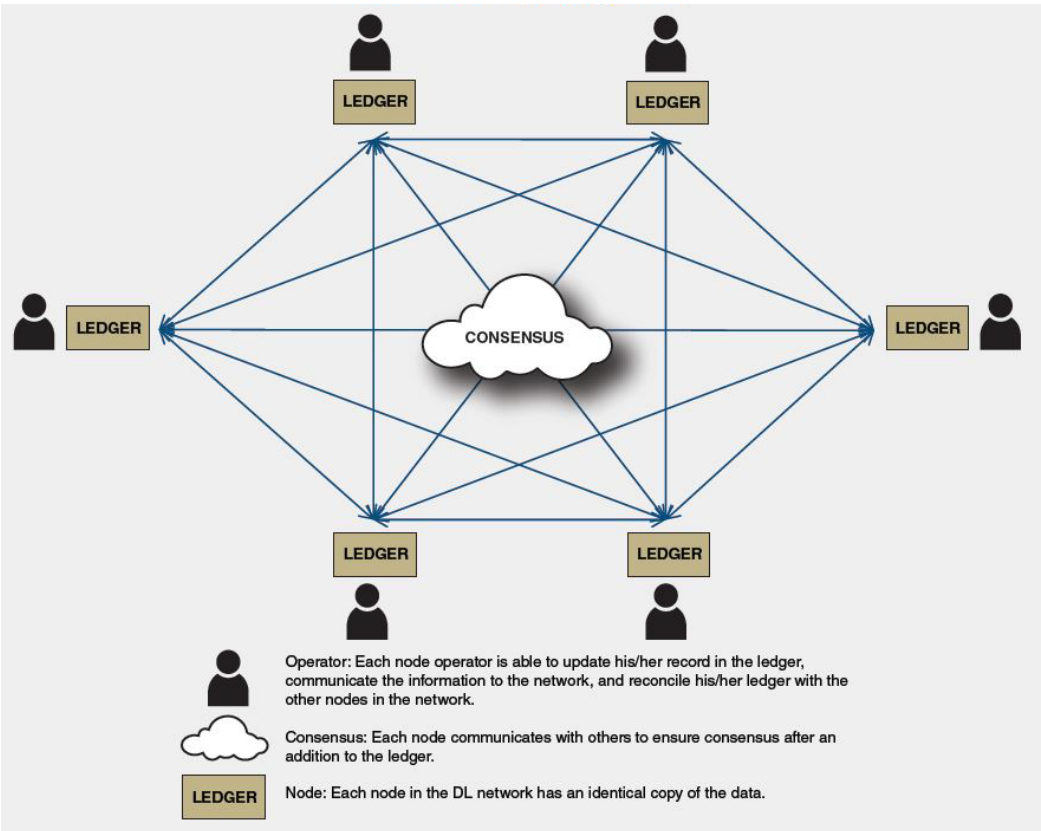
Serpell and Heredia (2014) identified that construction supply chains face many problems such as lack of coordination between suppliers and clients within the supply chain, design problems, poor quality of materials and components among others. Blockchain would be an ideal solution to overcome such issues in construction supply chains. Kinnaird and Geipel (2017) in ARUP's Report on 'Blockchain Technology' opined that an immutable blockchain would improve coordination, integration and logistics and thereby improve construction supply chain management. Similarly, carbon implications of suppliers could be monitored through blockchains. Hence the research aims at estimating embodied carbon in construction supply chains using the blockchain technology.

The paper discusses the background of blockchain and elaborates the concept of blockchain in detail. Consequently, the salient features of blockchain have been explored followed by detailed discussion on private/permissioned blockchain and public/permissionless blockchain along with its consensus mechanism used in validating transactions and creating blocks. Finally, various applications of blockchain have been conversed.

BLOCKCHAIN TECHNOLOGY

Blockchain is a decentralised distributed ledger technology which creates, validates and records encrypted transaction of digital assets in an incorruptible way (WU Global Tax Policy Center, 2017). 'Blockchain technology refers to a fully distributed system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors' (Risius and Spohrer, 2017). Blockchain technology is the algorithms and computational infrastructure of creating, inserting and using the blocks of stored information (Zhao et al., 2016).

In a blockchain, all transactions are stored in a single database where each user stores a copy of the database resulting no single point failure as exists with traditional relational databases (Lewis et al., 2017). Blockchain provides security, anonymity and data integrity without the control of the transactions by any third party organization (Yli-Huumo et al., 2016). A distributed ledger technology



comprises the basic elements; a digital ledger, consensus mechanism to confirm transactions and a network of node operators as shown in Figure 1.

Figure 1 Distributed Ledger Network

Source: Lewis et al. (2017)

Santori et al. (2016) opined that blockchain technology involves a ledger of transactions that are maintained on a network of servers called 'nodes'. Nodes act as the entry points for new data, as well as the entity for validation and propagation of new data that have been submitted to the blockchain (Lewis and Larson, 2016). The ledger is considered as distributed as it is maintained simultaneously on all the nodes in the network. Any node can request any transaction to be added, however, the transaction is only accepted if majority of the nodes agree that it is legitimate (Boucher, 2017). When all nodes reach to a consensus that the submitted transaction is valid (Lewis et al., 2017), the transaction is recorded on a new block and added to the existing chain (Singh and Singh, 2014). This work is known as 'mining'.

Each block does not only contain transactions, but also the hash of the previously accepted block in the blockchain (Vranken, 2017). The blocks in the blockchain are linked to each other forming a chain of blocks, signifying the term 'blockchain'. Every blockchain has a different kind of a consensus mechanism to add blocks to the database (Lewis et al., 2017). Consensus mechanism has been descriptively discussed under permissioned and permissionless blockchains.

A blockchain comprises of a peer-to-peer network where a peer is generally referred to as a node. The peer-to-peer network uses a consensus mechanism in order to ensure that the transaction is valid before it is recorded to the ledger (Weernink et al., 2017). In a peer-to-peer network all nodes have access to data and create an autonomous network wherein data are requested and provided among these nodes (Nomura Research Institute, 2016).

Blockchain uses public-key cryptography to maintain its anonymity and provide security. Public-key cryptography is a cryptographic method using different keys for encryption and decryption (Nomura Research Institute, 2016). Each user has a private key for private use and a separate public key available for anyone. A transaction will occur only if the sender receives the receiver's public key in advance. The public-key mechanism used in transactions related to blockchain has been illustrated in Figure 2.

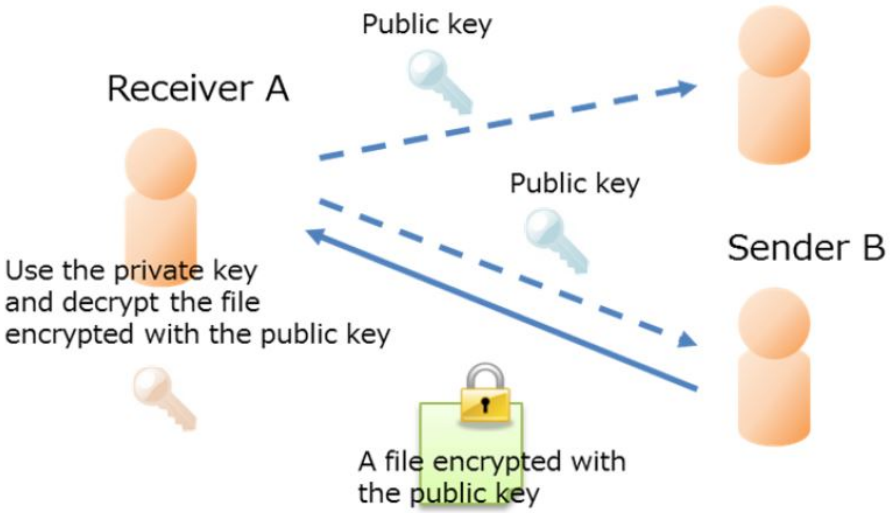


Figure 2 Mechanism of public-key cryptography
Source: Nomura Research Institute (2016)

SALIENT FEATURES OF BLOCKCHAIN

Blockchain consists of unique features which enhances the uses and applications of blockchain within various industries. The salient feature of blockchain, identified by various researchers have been summarised in Table 1.

Table 1 Salient Features of Blockchain

Feature	Identified Research Study											
	Dorri et al. (2016)	Zheng et al. (2017)	Chartered Accountants of Australia and New Zealand (2017)	Weernink et al. (2017)	Zhao et al. (2016)	Lewis and Larson (2016)	Tapscott and Tapscott (2017)	Yli-Huumo et al. (2016)	Risius and Spohrer (2017)	Sun et al. (2016)	Underwood (2016)	Atlam et al. (2018)
Decentralization	✓	✓			✓	✓	✓	✓	✓	✓		✓
Anonymity	✓	✓						✓		✓		✓
Security	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Immutability	✓	✓			✓		✓		✓		✓	✓
Auditability		✓							✓		✓	✓
Veracity			✓									
Transparency			✓			✓			✓	✓	✓	✓
Disintermediation			✓				✓	✓		✓	✓	
Trust				✓		✓				✓	✓	

Decentralization - Lack of central control creates robustness and eliminates many-to-one traffic flows avoiding delays and single point of failure (Dorri et al., 2016). According to Yli-Huumo et al. (2016) 'the goal of Blockchain technology is to create a decentralized environment where no third party is in control of the transactions and data'.

Anonymity - Blockchain transactions are recorded using public and private keys; thus, people can choose to remain anonymous to protect their privacy while enabling third parties to verify their identity (Sun et al., 2016). In a blockchain network, each user will interact using a generated address to avoid identity exposure (Zheng et al., 2016). This indicates a certain amount of privacy on transactions being preserved.

Security - The encryption mechanism used in a blockchain ensures the validity of the information stored and prevents fraud (Weernink et al., 2017). Blockchain uses heavy-duty encryption involving public and private keys to maintain virtual security (Tapscott and Tapscott, 2017). Encryption keeps private data private while digital signatures ensure authenticity, data integrity and non-repudiation (Lewis and Larson, 2016).
Immutability - Blockchain stores immutable records of data which are secured by a network of peer-to-peer participants (Dorri et al., 2016). Once the records are added to a blockchain, transactions cannot be undone resulting the ledger to be an immutable record of all previous transactions (Lewis et al., 2017).

Auditability - Each of the transactions on the blockchain being validated and recorded with a timestamp, any user could easily trace the previous records by accessing any node in the distributed network (Zheng et al., 2016).

Veracity - Multiple copies of the historical records of the ledger is stored in the network of nodes and each record is verified by consensus improving veracity at a higher level where bogus entries are identified and eliminated by failure to reach consensus (Chartered Accountants Australia and New Zealand, 2017).

Transparency - In a public blockchain network, all the transactions are transparent and announced to the public (Yli-Huumo et al., 2016). The records of activity can be made public to be visible to all market participants (Chartered Accountants Australia and New Zealand, 2017) or else the level of transparency can be controlled as required. As a use case, creating land registry in a blockchain provides greater transparency which is immensely beneficial to the general public (Boucher, 2017).

Disintermediation - The blockchain avoids centralised control and operates within a peer-to-peer network where intermediaries are eliminated (Chartered Accountants Australia and New Zealand, 2017) thereby operational costs are lowered and the efficiency of the sharing service is increased (Sun et al., 2016). Blockchain technologies can negate the need for third parties to be involved in data management while resolving the problem of needing to trust the intermediaries (Lewis and Larson, 2016).

Trust - Majority of the participants in a blockchain need to agree on data being added before it becomes part of the definitive blockchain (Lewis and Larson, 2016). As blockchain is based on shared consensus among different parties, the information stored on blockchain is reliable (Weernink et al., 2017). Due to the trust built up, intermediation can be avoided.

PUBLIC VS PRIVATE BLOCKCHAIN

Public Blockchain

Public blockchain is also known as permissionless or unpermissioned blockchain. A public blockchain is open to any user who wishes to transact and all transactions on the blockchain can be seen by all users (Lewis et al., 2017). Anyone can join the public network and write to the blockchain (Martinovic et al., 2017) as a result no authority is required to grant permissions on reading and writing to the blockchain. For users who do not trust one another or any other single central authority it is quite beneficial as the consensus mechanism ensures the accuracy of the ledger (Lewis et al., 2017).

Blockchain technology adopts the decentralized consensus mechanism in order to guarantee the reliability and consistency of the data and transactions (Li et al., 2017). Consensus refers to a series of

procedures related to approving and confirming a transaction as an official one by using the consensus algorithms such as proof of work, proof of state among others (Nomura Research Institute, 2016).

In a permissionless blockchain, the miners use a variety of algorithms to validate the transactions and finally confirm the transactions (Lewis et al., 2017). Only when most of the nodes confirm by reaching a consensus, the transaction is recorded in the block and added to the blockchain. In a bitcoin blockchain a Proof of Work consensus mechanism is carried out. Proof of Work, developed in 1999, is used by the system's users to repeatedly run the algorithms to validate the transactions of the system's other participants (Seibold and Samman, 2016). Public blockchains use proof-of-work as it ensures that transactions cannot be tampered as long as no single miner controls more than 50% of the network's hash power (Vranken, 2017). A Proof of Work mechanism needs a lot of calculation, resulting in a waste of computing power (Li et al., 2017).

An automated consensus mechanism allows for the near-instantaneous update of every copy of the ledger (Lewis et al., 2017). Once a transaction is added to the blockchain, as all nodes share a copy of the ledger, all ledgers reflect this change.

Private Blockchain

In a private/permissioned blockchain, only certain participants can join the peer-to-peer network (Martinovic et al., 2017). According to Boucher (2017) a limited group of actors retain the power to access, check and add transactions to the ledger. In a permissioned blockchain, participants can be limited to those who are pre-approved and further it is possible to limit the participants regarding the varying levels of access to the information in the ledger (Lewis et al., 2017). As an example, some users will be allowed to view all the transactions in the ledger but not allowed to add any transaction. Depending on the level of access of each user, the information and transactions in the ledger will be visible to them.

In a permissioned blockchain, the users' access levels and roles have been pre-decided. Once the transaction is submitted by the two parties involved, it would be validated by a permissioned member of the blockchain (Lewis et al., 2017). Building a consensus in a private blockchain is quite easy as the mechanism is only open to the relevant organization or group of people (Nomura Research Institute, 2016).

BLOCKCHAIN APPLICATIONS

Blockchain has commenced to revolutionize many fields whereas three generations of blockchain have been identified, namely Blockchain 1.0 for digital currency, Blockchain 2.0 for digital finance and Blockchain 3.0 for digital society (Zhao et al., 2016). Not only established businesses can be changed but also new business opportunities may arise through blockchain based applications (Risius and Spohrer, 2017).

Blockchain 1.0

Initially, blockchain was used for cryptocurrencies as a mode of securely validating and storing information of transactions which was identified as Blockchain Level 1 (Dimitri, 2017). Cryptocurrencies tend to rely on encryption techniques to generate, transact and validate their values (Lewis et al., 2017). Cryptocurrencies are represented by transactions which are recorded in a blockchain which leverages the resources of a large peer-to-peer network to verify and approve each transaction (Tapscott and Tapscott, 2017). The essential advantage of using blockchain for digital currency is that it provides a credible way to transfer an asset without the need of involvement of trusted intermediaries or counterparties (Brainard, 2016).

Satoshi Nakamoto introduced the first cryptocurrency, 'Bitcoin' in 2008 and the first block was created in 2009 (Nomura Research Institute, 2016). In addition to Bitcoin, there are many other cryptocurrencies, such as Litecoin, Dogecoin and so on and some of which are currently available in the financial market (Li et al., 2017). Presently there are over 1600 types of cryptocurrencies and their total market capitalizations are over 200 billion US$ (CoinMarketCap, 2018).

Though Blockchain was born with Bitcoin, its applications have gone far beyond Bitcoin and other digital currencies (Zhao et al., 2016). Identification of such novel perceptions generate new markets and opportunities. Whereas Blockchain 1.0 is used for decentralization of money and payments, Blockchain 2.0 is recognized for decentralization of markets (Swan, 2015).

Blockchain 2.0

Swan (2015) identified usage of Blockchain Level 2 for economic, market and financial applications such as stocks, bonds, smart property, smart contracts which have been further categorized into several classifications as illustrated in Table 2.

Table 2 Blockchain Applications beyond currency

Class	Examples
General	Escrow transactions, bonded contracts, third-party arbitration, multiparty signature transactions
Financial transactions	Stock, private equity, crowdfunding, bonds, mutual funds, derivatives, annuities, pensions
Public records	Land and property titles, vehicle registrations, business licenses, marriage certificates, death certificates
Identification	Driver's licenses, identity cards, passports, voter registrations
Private records	IOUs, loans, contracts, bets, signatures, wills, trusts, escrows
Attestation	Proof of insurance, proof of ownership, notarized documents
Physical asset keys	Home, hotel rooms, rental cars, automobile access
Intangible assets	Patents, trademarks, copyrights, reservations, domain names

Source: Swan (2015)

Blockchain 3.0

Blockchain Level 3 is used for applications beyond currency, finance and markets, particularly related to government, health, science, art, culture and others (Swan, 2015, Wang et al., 2017). According to Kuo et al. (2017) Blockchain 3.0 has been introduced for non-financial applications of the distributed ledger technology. In Blockchain 2.0 and Blockchain 3.0 applications, combination of other activities related to government, education and finance can make these non-financial activities express the property of currency (Chen et al., 2018). As a use case for Blockchain 3.0, supply chain management is one of the key sectors where blockchain applications have been experimented in the current scenario mainly related to logistics. However, blockchain technology has not yet been applied to the construction supply chain.

POTENTIAL USES IN CONSTRUCTION SUPPLY CHAINS

Recent adoption of blockchain technology promises better supply chain provenance (Kim and Laskowski, 2018). In a supply chain a shared, consensus based public ledger is used to track the origin and the processes related to a product/service (Zhao et al., 2016). The potential tracking of supply chains via blockchain provides greater traceability (Lu and Xu, 2017), transparency (Wang et al., 2017) and simpler processes for the businesses to deal with (Chartered Accountants Australia and New Zealand, 2017). Blockchain used in supply chain management will also provide certification and documentation including the lifecycle data of the product to be accessible to all parties but impossible

to falsify (Peck, 2017). The product could be tracked from the factory and continue during transit and to the distributor or store. Similarly, in a building project, each item could be tracked to the site and linked, on a blockchain, to the digital version of the same item in the Building Information Modeling (BIM) model. In this manner an immutable record of data will be stored and maintained throughout the entire life cycle of the project. It also provides greater security and induce trust among suppliers and clients and provides transparency for auditing purposes as well. A similar concept to explained above will be applied in this specific research project to monitor the carbon implications of suppliers in a construction supply chain.

SUMMARY AND WAY FORWARD

Blockchain has been revolutionizing number of industries such as finance, insurance, logistics, energy and transportation by its promising advantages and various applications. Blockchain being a decentralised distributed ledger provides several advantages creating immutability, transparency, trust, security, audibility among others. Blockchain comprises of a peer-to-peer network which assists in mining to validate the records prior to the creation of blocks. Public-key-cryptography used in a blockchain provides greater security and trust to its users. In a public blockchain anyone can join the network and involve in transactions, however, a transaction will be recorded on a block only when most of the nodes have reached consensus that the transaction is valid. In a private blockchain, only certain participants can join the peer-to-peer network and only a selected group of participants retain the power to access, check and add transactions to the ledger. Several blockchain applications have been introduced where Blockchain 1.0 is for cryptocurrencies, Blockchain 2.0 for economic, market and financial applications and Blockchain 3.0 for applications beyond currency, finance and markets. Blockchain 3.0 applications are used for this research project to identify and monitor the carbon implications in construction supply chains. Blockchain technology enables efficiency and transparency in monitoring construction supply chains, hence, there exists a potential application in estimating embodied carbon in a construction supply chain with the use of blockchain. The research project will consider the embodied carbon addition occurring at each supply chain node and subsequently the embodied carbon occurring throughout the construction supply chains will be added to estimate the total embodied carbon. Finally, a blockchain application will be developed and tested to estimate the embodied carbon in the construction supply chains. However, this research paper is based on the literature synthesis carried out on blockchain and its applications.

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COACHING THE TEAM TOWARDS HIGH-PERFORMANCE: FACILITATION FOR INFRASTRUCTURE DELIVERY

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Engendering teamwork, trust and cooperation is essential for high performance, innovation and problem-solving. This can be challenging in transactional traditional design-bid-build with fixed price contract environments where the commercial drivers of clients and contractors on a collision course. The upshot is adversarial relationships, variation-seeking behaviour, cost overruns and expensive change orders. Team coaching, using a Project Facilitation Model is presented here for client-contractor relationship management to enable optimum team performance based on the principles of relationship contracting. The model was applied on a water infrastructure project that involved four principal contractors working on different packages based on traditional lump-sum contracts. Using a case-study approach and evidence from 27 semi-structured interviews, the study explores the effectiveness of project facilitation, when it can be implemented and its limitations. The results indicate that facilitation may be able to support a less adversarial and more collaborative environment than that experienced on classic traditional lump-sum contract frameworks. Key outcomes of the model include a platform for transparent communications, joint problem-solving and engendering a level of psychological safety among the team. The innovation of this research is that relationship-based principles have been integrated into the delivery of a traditional lump-sum contract. However, further explication and testing of the model on different projects and teams is necessary to explore its efficacy and possible limitations.

Keywords: coaching, collaboration, project facilitation, project success, psychological safety, relationship management, trust.

INTRODUCTION

Creating a team culture that can support a productive social and project environment often leads to high performance, innovation and efficiency (Hanna 2016, Kim and Nguyen 2018). There has thus been an emphasis on the importance of inter-organisational relationships in an attempt to harness the value of social capital for effective project delivery (Pryke 2012). This is perhaps based on a recognition that there can be mutual benefit in a healthy and somewhat altruistic relationship between the differing contracting parties. However, there still exists a transactional and production-oriented mentality in project delivery. Inter-firm relationships in the construction industry are often governed by contracts to allocate risks between parties with provisions like performance bonds and guarantees, liquidated damages and retentions that attempt to enforce performance. What is often overlooked is that such contractual environments often lead to adversarial mentalities; an 'us versus them' environment

between clients and contractors that usually leads to disputes, variation-seeking behaviour, delays and limitations on value-adding project innovation.

This research examines the effectiveness of a Project Facilitation Model (PFM) as a coaching tool within the context of traditional design-bid-build contract for developing effective working relationships that might support high-performance of the team. Using a case study action research approach, the study investigates the strengths and limitations of team coaching and project facilitation for team integration and building a high-performance project team. The paper is structured as follows: a review of the extant literature on trust, cooperation and the role of contracts, before critically reviewing the context and application of coaching for team development and integration. The results of team coaching through project facilitation is then presented. The paper concludes with an appraisal of the effectiveness and limitations of facilitation in project based environments.

OF TRUST, COOPERATION AND CONTRACTS

A common mode for risk transfer for clients is the use of traditional lump-sum contracts based on design-bid-build frameworks (You *et al.* 2018). However, traditional lump-sum contract environments generally set the commercial drivers that define the strategic goals of clients and contractors on a collision course. Clients pursue value-for-money and a product with the requisite functionality. Ultimately, clients seek a product at lowest cost with the highest quality. Contractors, on the other hand, aim to increase their revenue and maximise profit. Ideally, they would prefer not to significantly exceed the agreed minimum specifications of compliance in the contract, especially if it reduces their profitability. Contractors would generally use post-contractual devices like variations, claims and extensions of time requests as 'highly appropriate and critical' for increased profitably, even if opportunistic (Lu *et al.* 2016). According to Hayford (2017), such a contractual environment only perpetuates an adversarial win-lose mentality that may cause the overall quality of the project delivery to suffer or relationships strained as a result of claims and disputes. A lot of resource is often thus dedicated to detailed documentation, even where parties are in relatively good terms, just in case there might be a dispute later (Hayford 2017).

There has been studies that have explored how effective relationships can add value to the project for client organisations and how this value may be derived and translated into profit for the contractors (Bresnen and Marshall 2000, Meng 2012). This has included the exploration of long-term strategic partnering agreements incorporating a move from *zero-gain mentality* ("my gain, your lose") to effective teamwork and collaboration ("we all win") (Lloyd-walker *et al.* 2014). In construction, contracting approaches such as alliancing and partnering (Bresnen and Marshall 2000, Lahdenperä

2012) have been used in an attempt to build better than the usual functional relationships and cooperation. They are based on the assumption that parties within the contract framework are able to meet their own strategic goals and business objectives more effectively by collaborating and working as a team. The aim within these frameworks is to allow for greater information flow between parties, reduce adversarial and opportunities behaviour by engendering trust (Manu et al. 2015). However, relationship contracts such as alliancing may only be truly beneficial to clients, contractors and suppliers that are able to manage a regular high-volume and highly standardised business with the same parties over a long period. As a result, traditional design-bid-build contracts with fixed-price are thus the most common construction business arrangements except for large value projects.

The establishment, development and maintenance of relationships is key to sustainable business and hinges on the ability to build trust and cooperation between stakeholders (Davis and Love 2011). While there is no universally accepted definition of trust, it may be conceived as a psychological state that enables people to accept a level of vulnerability based on positive expectations regarding the intentions and behaviours of other parties (Rousseau et al. 1998). Relational trust is heavily dependent on prior and repeated interactions between trustors and trustees. Its nature is also contingent on expectations and predictions of how the other party might behave i.e. their trustworthiness (Mayer et al. 1995). Maurer (2010) thus observed that team members in inter-firm projects who have had prior collaboration or worked together previously, had greater capacity to develop mutual trust and cooperation. However, as noted by Buvik and Rolfsen (2015), the transient nature of construction projects pose significant constraints on developing trust between cross-functional teams. The situation is exacerbated when teams are put together using transactional contracts with elements of deterrence, sanctions and damages. The expectation of trust for parties within a new relationship thus raises contradictions - "How much should I trust you?" and "In what areas and in what ways do I trust you?" Buvik and Rolfsen (2015) identified four features of relationships that may be crucial for early trust development in temporarily teams:

- early formation of integrative work practices,
- development of a common philosophy,
- open communication, and
- early and clear role expectations.

Trust is also dynamic and changes with time and circumstance. It may also vary depending on the relationship's history, its stage of development, in addition to other signals of change within the context of the relationship. The study of trust must thus be approached using paradigms that recognises the

different forms, levels and dynamics within the concept. According to Rousseau *et al.* (1998), therefore, trust can be studied at the following levels:

- multi-level trust (between individuals, groups, firms, and institutions);
- trust within and between different organizations;
- the multiple casual roles of trust (trust as a cause, outcome and/or and moderator); as well as
- the dynamics of trust as impacted by organizational change.

Further, Green (2006) also notes that proponents of trust-based relationships often fail to distinguish between *micro* (interpersonal) and *macro* (organisational) level analysis of trust and assume that individuals will exhibit the same behaviours as the organisations they are drawn from. Forming a construction team using a partnering or alliance agreement does not necessarily translate to cooperation, trust and teamworking during the day-to-day delivery of the project. Interpersonal relationships at the site level have a significant bearing on the successful delivery of the project and the ability to mitigate the adverse effects of conflicts and unnecessary disruption to the project (Hanna 2016).

It is imperative to explore approaches that might help develop strong and resilient relationships both at the organisational level (*macro*) as well as the interpersonal level on sites (*micro*). This should, at least in theory, support high team performance and develop relationship behaviours that reduce the adversarial nature of construction delivery. There is, however, no agreed approach to engendering and sustaining the four key features identified above by Buvik and Rolfsen (2015) in project teams. The next section of the paper discusses the possible role of team coaching using facilitation in an attempt to overcoming some of the barriers of integration, cooperation and trust building in project teams.

COACHING AND TEAM PERFORMANCE

While general project management generally implies the planning, coordinating, control of tasks and teams to achieve a particular objective, *team coaching* focusses on enhancing performance within a team by attempting to remove relational obstacles and empower the team to reach optimum potential. The performance of a project team during the construction stage significantly depends on how they work together to navigate these uncertainties and respond to risks and changes. Team coaching thus focusses on empowering *teams* with the resources and capabilities to circumvent challenges (Whitmore 2002); solve problems jointly (Styhre 2008); and reinforcing good performance (Berg and Karlsen 2016). Coaching has gained popularity in organizations as evidenced by the growth of the coaching industry and programs during the past few decades (Ely *et al.* 2010, Segers *et al.* 2011).

While not exhaustive, the coach's role would thus include the following: goal setting, critical analysis of situation, providing assessment and feedback, encouraging and motivating the team, building trust and rapport, and even confronting and challenging others, where necessary. Reflection on prior experiences have been identified as key for learning and performance improvement within teams (Edmondson 1999, Shikhar and Christopher 2003). The coach thus seeks opportunities to encourage the team to 'never waste a good opportunity' to learn from difficult situations as well as recognise the combination of factors that helps to achieve success. The approach adopted for coaching a team may be shaped by a number of conditions including the frequency and duration of the coaching relationship, the purpose of the coaching, the number of teams involved in the coaching framework, whether the outcome of the coaching exercise relates to short-term or long-term goals (Segers *et al.* 2011).

The coaching environment itself may be goal oriented one-on-one sessions, facilitated workshops for groups, or a mixture of both. Where facilitated workshops are adopted for inter-organisational teams within project-based environments, they are usually aimed at building trust and cooperation towards the achievement of strategic goals (Buljac-Samardzic and van Woerkom 2015, Dimas *et al.* 2016). worth mentioning that project project facilitation is uncommon on traditional design-bid-build contracts with lump-sum payment regimes. However, facilitators are usually integral to alliance frameworks due to the substantial change in the normal working relations expected from the parties within an alliance. Facilitators would typically be engaged to design and lead the culture management program within the alliance so as to support proactive joint-problem solving, effective conflict management and best-for-project ideals. Their role usually focusses on the following key areas:

- Developing an environment of trust, co-operation and open communication
- Help the team build best-for-project behaviours and a prioritization of agreed project objectives
- Encouraging innovative and proactive problem-solving through a culture of joint-problem ownership ("your problem is my problem")
- Helping the team develop and commit to interpersonal relationship behaviours that support a healthy working environment

The key departure of this research is that project facilitation was implemented within a traditional design-bid-build project environment with four principal contractors.

RESEARCH APPROACH:

A case-study action research approach was adopted for this study to allow for collaborative and participatory steps of problem identification, intervention planning, implementation, evaluation of

outcomes and reflection among the project team. At the core of action research is the belief that a complex social process can be studied best by introducing interventions into that process and observing the effects of those interventions. Denscombe (2014) thus posits that action research allows for problem-solving and to produce guidelines that may help to alleviate the problem. Attributed to Lewin (1948), the 'action research spiral' is composed of a cycle of planning, action and fact-finding about the result of the action with the aim of identifying strategies for improvement within the organisation or community of practice. Action research involves actively participating in a change situation, often within a social or organisational context, whilst simultaneously conducting research. The ethos of action research methodology was combined with the prescriptive mechanism of case study analysis. Case studies are appropriate where an in-depth knowledge of an individual example is more helpful than fleeting and superficial knowledge about a larger number of examples (Gerring 2006). It is preferred research strategy when the phenomenon and its context are not readily distinguishable and when a deeper understanding of practical issues on how things actually work is required (Denzin and Lincoln 2011).

Data collection

Carrillo *et al.* (2013) note that post-project reviews and face-to-face meetings are the most informative and useful practices in capturing lessons in projects. Focus group workshops were held on June 2, 2017, after project completion. The focus group comprised the client's project delivery team members, Directors of all four Principal Contractors (PCs) along with their site supervisors or project managers, as well as representative of the design consultant. There were 35 participants in the focus group workshops. Twelve hours of audio data (1.5hr x 8) was collected and transcribed verbatim for analysis using the qualitative data analysis software, NVivo 11.

In addition to the focus group workshops, a series of 27 one-on-one semi-structured interviews were conducted with project participants to further explore some of the issues identified in the group sessions. The interviewees included a variety of personnel including Project Managers, Site Supervisors, Design Engineers, Safety Quality and Environment (SQE) Manager, Project Delivery Managers and Construction Coordinators. With prior permission from the interviewees, all the interviews were digitally recorded. Notes were also taken by the researchers to supplement interview data that was obtained. The interviews were either conducted face-to-face or over the phone where it was impractical to meet the interviewee. The interviews lasted between 45mins to 90mins and were carried out between August and October 2017. Over 30 hours of interview data were collated, professionally transcribed verbatim for analysis using NVivo 11 software. The data was analysed to establish

conceptually consistent first-order themes. For lack of space, the results presented here will mainly focus on the evidence from the interview data.

Case Background

The case study used for this research is a water infrastructure project recently completed in the State of Victoria, Australia. The client organisation (name withheld for anonymity) has over $2.7billion worth of water infrastructure assets in Australia and suppliers water to over 300,000 permanent residents over 8,100 square kilometres. The project was initially estimated to cost $19.3 million but was eventually delivered at about $11.5 million in 2017. The project consisted of four main components - each package was tendered and awarded to a different principal contractor on lump-sum contracts. Additionally, an external coach (Frontline Coach Ltd) was engaged by the Client as the Project Facilitator to run a programme of on-site facilitated workshops during project delivery to engender strong leadership and optimum client-contractor relationships for enhanced project performance. Project Management services were undertaken by an internal team within the Infrastructure Delivery Department of the client organisation. Figure 3 illustrates the relationship between the main project parties on the case-study project.

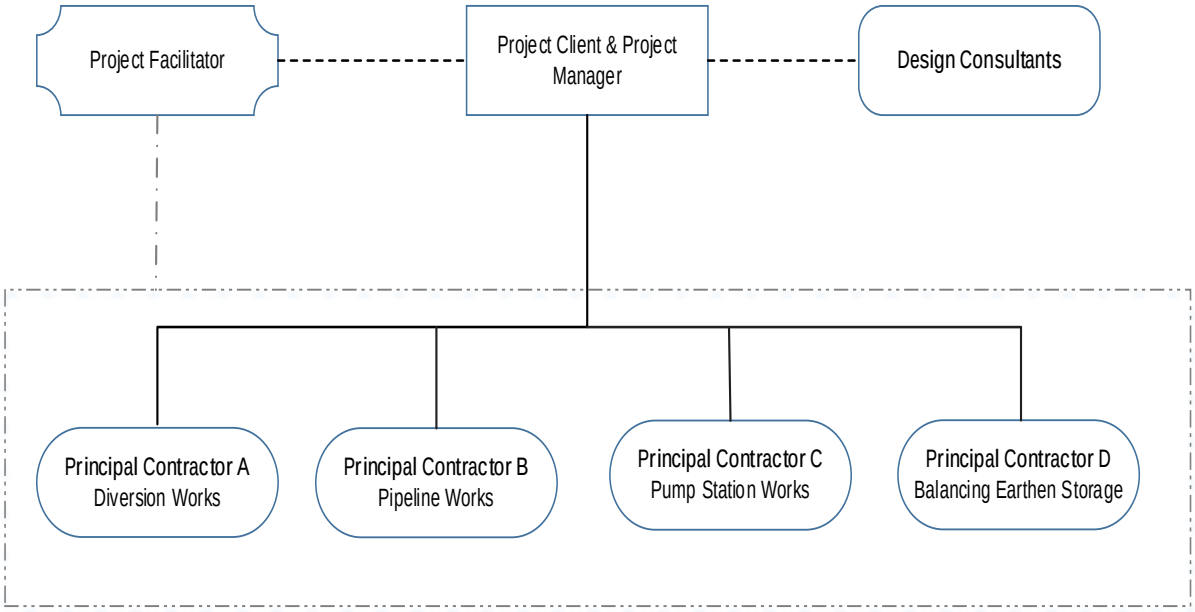

Figure 1 Main parties involved the case study project

FINDINGS

In this study, project facilitation is used in an attempt to coach the team towards developing effective and resilient relationships between clients and contractors personnel to support enhanced project

performance within a traditional design-bid-build contract environment. This section of the paper reports on the findings of the project facilitation process on the case study project described above.

The Facilitation Process

A post-project review of a recently completed high-value, high-profile project procured by the client organization in this study revealed a number of key lessons that may have led to significant delays, disputes and cost overruns. As a proactive measure, the client organization decided to experiment the use of facilitation model with the aim of *developing client and contractor relationships leading to enhanced project problem-solving*. Key themes under the program were the creation of a sense of team, collaboration, transparent communication and proactive problem-solving. The facilitation process was implemented as part of the overall project management framework by the client organization by engaging an independent Facilitator*, the Coach*. A key client requirement at the tendering stage was that the successful bidders had to commit to the facilitation program throughout the project delivery stage. Contractor's cost and time allocated to the program would be paid for by the client. This resulted in the implementation of two forms of "contracts": a traditional transactional contract in tandem with the relational "contract" (i.e. the facilitation program).

The facilitation process commenced with a 3-hour Kick-Off meeting at the beginning of the project between key members of each of the four Principal Contractors, the Client Project Management team, the Design Consultant (see Figure 1). The representatives from the contractors included personnel with traditional responsibilities and authority on the project, i.e. Contract Managers and/or Directors, along with their Project Managers, Superintendents and Construction Supervisors. The Kick-Off meeting was used to introduce team members working on different packages of the project, identify the needs and requirements of each party and jointly set project team *ground rules*- the policies or guidelines which a group establishes to help define and baseline behavioral model for its members in addressing how to communicate, cooperate or deal with problems. *Showstoppers*, the critical issues that can halt, threaten or derail the successful delivery of the project, were also identified by each party and discussed together as a group.

During the construction stage, the facilitation program was targeted at achieving two objectives – (1) engender effective working relationships between client and contractors; and (2) develop joint-problem solving capabilities through collaboration. This was done through monthly workshops, led by the Coach, to assess project team culture (the so-called "*team health checks"*) and review agreed ground rules and showstoppers. Several critical questions are asked at this stage – 'how is the team working together?", "What problems are being encountered?", "How effective is the current communication between the

different parties?" "What is inhibiting progress?", "What actions need to be taken?" etc. A crucial part of the team health checks included each team rating the other on the agreed ground rules and providing honest feedback on how the other team was performing in relation to the ground rule. This was sometimes confronting for some team members as it led to some robust discussions about performance and expectations. However, it afforded the opportunity to proactively identify areas of the team or project that needed attention. The role of the Coach is crucial at this stage to facilitate conversations towards a focus on collaborative and best-for-project outcomes.

The final stage of the facilitation process occurred soon after project completion to review lessons learnt during the delivery stage. The main objective at this stage was to address the following questions: "What went right and why?", "What did not go well and why?", "What changes need to be made?" and "What needs to be repeated on future projects?" These questions are particularly critical to support absorptive learning and process improvement (Cohen and Levinthal 1990) particularly if the team is delivering a program of works together.

Overall, the data collected from the project team supports a claim that the facilitation program provides the mechanism to develop team behaviours that support enhanced performance and create an environment less adversarial, and more collaborative than traditional contracting. The contractors and client staff indicated that the workshops provided an opportunity to build team relationships, maintain high morale throughout the team and enable a better understanding of each company's drivers. The facilitation workshops further provided a platform to work through site issues quickly, identifying diagnostic action points before they could snowball into major problems and disputes. The construction was completed within budget and within schedule[1]. The client team noted that the program was a 'good insurance policy to have for project which had a tight deadline and interfaces'. Ultimately, it helped to 'steer the project in the right direction' by resetting and refocusing the delivery team on best-for-project (BfP) principles.

Open and Honest Communication

The facilitated workshops helped to provide an environment for honest communication of project issues and develop a better understanding of each company's objectives. This is consistent with the observations pertaining to communication within other relationship-based frameworks like IPDs and alliances (Lloyd-walker *et al.* 2014, Hanna 2016). The facilitated workshops reduced some of the usual barriers to information sharing and interaction between project teams and supported inter-organizational

[1] Construction was delivered ahead of schedule and within budget. At the time of writing, the project was yet to be commissioned for operation

interaction. The team was somehow empowered to express their concerns in relation to emergent problems and progress. According to one of the project team members,

> *"The facilitated workshops were a valuable tool that formed a big part of the overall project success. They fostered an open and honest workplace that enabled all facets of the project to be dealt with efficiently."*

The usefulness of the facilitation model for engendering critical trust and open communication on the project is perhaps summarized in the observation by the Project Managers of one of the Principal Contractors, a relatively young construction company:

> *"As a new/young contractor, forming strong relationships with our client was a very important goal for us. By having your client's trust there is always a subtle positive shift in relationships on site and in the office. This shift has a significant impact on project delivery and the site dynamics."*

It is worth noting that the monthly facilitated workshops were different from the traditional site meetings. The weekly site meetings tend to be client-led with strict agendas identifying progress and issues that are usually resolved using emails. The workshops on the other hand, were led by the Coach, whose focus was on developing effective working relationships between client and contractor organizations towards successful project delivery and joint problem-solving. The actions points and continuous 'project health check' worked to keep parties accountable.

Best-for-Project (BfP)

A best-for-project (BfP) approach, is where project parties commit to behaviour and decision-making that consistently prioritizes the objectives and outcomes of the project (Lloyd-walker et al. 2014). The main values of a best-for project approach are:

- *A win-win culture* – 'we win together' or 'we lose together';
- *No-blame attitude* – 'we work through problems not by apportioning blame but by looking for solutions together'; and
- *Joint-problem ownership* – 'your problem is my problem'.

Of course, these principles are core to alliances and IPD frameworks but uncommon, if not completely absent, from traditional delivery contracts. BfP enables people to remain creative and engaged, rather than acting from a self-preservative and defensive position. The principles are highly linked to the concept of Psychological Safety (PsySafe) - the favourable 'perceptions of the consequences of taking interpersonal risks in a particular context such as a workplace (Edmondson and Lei 2014, p. 24). PsySafe sustains high-performance organizations requiring close collaboration and creativity to meet desired targets. It allows for the ability to speak one's mind, "moderate risk-taking, and sticking your neck out

without fear of having it cut off" (Delizonna 2017). Where PsySafe exists, team members become more open-minded, transparent in their communication, motivated towards improved performance and innovation and thinking outside the box (Baer and Frese 2003). Two characteristics are important for optimum psychological safety - a clear team structure where members understand their role on the team (Bunderson and Boumgarden 2010) and strong relationships between team members (Carmeli and Gittell 2009).

To provide an impetus for BfP and PsySafe, it was important to reinforce the tripartite need for a high level of trust, accountability and teamwork. The client must usually exemplify this behaviour for the rest of the team to follow as trust begets trust and collaboration begets collaboration. Where the project team perceives that the client, or their consultants, are aggressive or belligerent, they would usually revert to traditional adversarial behaviours as well. This is perhaps even more important when things go wrong. Blame and criticism almost very reliably escalates conflict and disagreement with defensive positions becoming even more entrenched.

The project team was coached to practice the use of *Humble Enquiry* – "the art of asking, instead of telling" (Schein 2013) in seeking out solutions to problems together as this approach disarms the opponent, illuminates blind spots in communication skills, according to Delizonna (2017). Feedback from the contractors suggests there had not always been the optimum team environment for delivering projects in the past with the client organization. They, however, indicated that their experience was better under the facilitation program. For example, a contractor noted:

> *"On previous projects, there was a 'them versus us' mentality that came from both sides and the relationships were really hostile. Whereas this [project] was completely different"*

A contractor's Project Manager indicated:

> *"The sense of teamwork that [the client] had with us on this project was completely different from other projects. I am not sure whether that was deliberate or because of the personnel involved but the [Client staff] really worked well with us"*

Ground Rules

Ground rules are policies or guidelines which a group establishes to help define behavioural expectations for its members in relation to communication, how to treat each other, cooperate or deal with problems. Some of the agreed ground rules include transparency regarding the sharing of information in a timely manner, commitment to working through challenges together, reporting all SQE incidents and the sharing of key lessons learnt during the project. Team ground rules can be a helpful way of enabling effective and productive team dynamics and behaviour. Setting ground rules was perhaps a recognition that successful

project delivery depends on managing both the technical aspects of the project as well as the often complex people and organization dynamics.

During the facilitated workshops, each contractor completed scorecards assessing themselves and the client on how they were each performing in relation to the agreed ground rules. The client also did the same for each contractor on a monthly basis. This allowed for feedback between the client and the contractors, as well as a level of accountability. It also provided an opportunity to discuss how performance on ground rules might be affecting project delivery.

DISCUSSIONS

There has thus been an emphasis on the importance of inter-organisational relationships in an attempt to harness the value of social capital for effective project delivery (Pryke 2012). Project Facilitation was adopted in this paper as a coaching model foster effective client-contractor and contractor-contractor relationships that might lead to enhanced project performance and innovation. The findings of the study so far suggests facilitation process and the role of the Coach was helpful in bridging the usual gap between clients and contractors, as well as attenuate the otherwise adversarial, “them versus us”, relationship between clients and contractors. This created the platform for transparent and honest communication within the project team in relation to drivers, expectations and project problems, as well as a display of quasi best-for-project ideals on a traditional lump-sum project. The following section of the paper attempts to make sense of some of the findings on the case study as well as identify some of the possible limitations of the model.

Psychological Safety (PsySafe)

The findings confirm that considerable value in encouraging the project team to communicate transparently, seek joint-ownership of problems, pursue best-for-project ideals and work towards win-win relationships. At their best, they help in creating an environment that enhances the efficiency and effectiveness of project delivery, as well as engender critical innovation. However, differences in contractor and client expectations, along with their differing commercial goals can generate misunderstandings and paradoxical tensions. Innovating the procurement route or project management approach alone may not always be enough as the project team, a coalition from client, contractor and the rest of the supply chain, needs to perceive psychological safety (Edmondson 1999). One of the empirically supported benefits of developing PsySafe in an organisation or team is that it improves the likelihood that a new process improvement initiative may be successful and also enjoy the input and buy-in from the team (Baer and Frese 2003).

PsySafe was promoted within the team in by 1) empowering the team to 'speak up' where there are issues; 2) approaching conflict as a collaborator rather than as an adversary; 3) replacing blame with curiosity and humble enquiry - the art of asking, instead of telling (Schein 2013). In most cases, the parties responsible for creating a problem often hold the keys to solving it also. Delizonna (2017) thus notes that a positive outcome to problem diagnosis and solution typically depends on their input and buy-in. The monthly project facilitation meetings afforded the opportunity to ask questions such as "why do you think this problem occurred?"; "How can the situation be improved?" or "How could I support you to solve the problem?" Essentially, this gave 'voice' to the project team – the ability to communicate transparently without the fear of being punished. The ethos of PsysSafe on the project is perhaps aptly summarised in the comment of one of the contractor Company Directors:

> *"Because of the commercial nature of hard-dollar contracts [lump-sum contracts], contractors often feel it may not be in their best interests to share too much information with the client. But…bringing someone in, like an independent facilitator, creates a level of trust that they can start to share information, knowing that they are not going to be harmed by sharing that information."*

However, it would seem that encouraging transparent communication, particularly in a lump-sum contract environment, was not always favourably perceived as 'good commercial strategy' by all team members. The invitation to 'speak up' and be honest may have raised *commercial dilemmas* – a simultaneous presence of apparently contradictory but interrelated dualistic messages for some of the project team members. Some project team members, particularly from contractors, were thus a bit reticent of being completely open and transparent as they were still unsure whether the information volunteered might be used against them later. This is understandable as it was the first time that all the Principal Contractors were involved in a project that used facilitation. They were perhaps cautiously suspicious in the beginning, often asking "I know you say 'trust me'. But, can I? Should I?' This kind of tension has previously been described as the "paradox of speaking up" by Cunha *et al.* (2018). The paradox may be heightened when the team is faced with intense schedule and cost pressure or when progress on site is seriously lagging. The possibilities are that some team members may simply revert to business as usual in construction delivery – old habits do not die easily, after all. The role of the coach is important to help the team navigate these tensions, using requisite imagination to anticipate and proactively attenuate possible reversionary tendencies.

Best for Project (BfP)

The alliance principles of a win-win culture, no-blame attitude and joint-problem ownership are somewhat integrated into the concept of BfP in the facilitation process. This helped in creating an environment of mutual compromise wherever possible, particularly when navigating difficult

conversations regarding change, cost, schedule and innovation. It is worth noting that while the principles of BfP were helpful in creating a team spirit on the case study project, it may be an unrealistic expectation, and even potentially risky, especially in lump-sum contracts due to competing commercial drivers. Clients usually pursue a built asset of the highest quality and functionality at lowest possible cost. For contractors, the ideal environment to foster a win-win mentality, for example, would be one with the opportunity of continuous and regular volume of work from clients that are sufficiently profitable. This is perhaps the case for only a small minority of large contractors. However, they too have to deal with the challenge of managing subcontractors and suppliers that are equally fighting for their survival in a highly competitive and fragmented industry, with generally low barriers of entry for new competitors and prolonged low-profit margins. Thus, even where there are relationship-based agreements at the inter-firm level of business transactions, this does not always translate into the social value expected at the personnel, cold-face level site.

It is no surprise, therefore, that client organisations have traditionally tried to achieve their goals through an arms-length transactional arrangement with threats of damages for non-compliance. Some members of the Client Project Management were thus concerned that pursuing BfP would mean 'letting contractors off the hook' for poor performance, ultimately damaging the client's interests. They feared that in the absence of a multiparty agreement, it may promote opportunistic behaviour. Cox and Ireland (2006, p. 251) note that:

> *"ideal forms of 'win-win' are only sustainable in a project environment under limited circumstances and that opportunistic forms of 'win-lose' and more restricted forms of collaboration are all that is achievable…"*

However, the overall benefits of pursuing best-for-project ideals, balanced with the requirements of accountability may outweigh the challenges, especially if complemented with a process akin to the facilitation process to continuously reset team culture and behaviour. Also, there will be cases where teams or companies just do not work well together and no amount of 'team building' or 'culture creation' would be useful – in these cases, the coach may be in a good position to help the team to focus their energies on delivering their contractual obligations in the contract. This is perhaps why it is important that key members for the facilitated workshops are carefully selected based on their ability to collaborate and energise their respective teams towards 'we are in this together' attitudes.

CONCLUSIONS

Project facilitation was used in this case study to coach the project team towards developing mutually beneficial and resilient client-contractor relationships that could support enhanced performance. The

facilitation process was applied on a water infrastructure project that involved four principal contractors working on traditional lump-sum contracts. Overall, the findings of research so far would support a claim that the facilitation program provides the mechanism to develop team behaviours that engender enhanced performance and create an environment less adversarial, and more collaborative than traditional contracting. Facilitation was incorporated into the traditional lump-sum transactional contract to provide the client with an extra '*soft insurance measure'* to influence the performance of the team. This in turn created the platform for transparent and honest communications for problem-solving, innovation and alignment of organisational objectives. The project was delivered within schedule and within budget with the model being rolled out on other projects by the client organisation.

Despite the possible benefits of project facilitation, it would be poor advice to recommend its adoption across all types of projects or client organisations. Relationship contracting may not always have the strategic strength to ensure compliance and performance, or even curb the traits of opportunism in transactional frameworks. It will generally be difficult to incentivise contractors and suppliers to make relationship related adjustments without a guaranteed return, usually in terms of repeat work or profitability. The facilitation model may thus be most suited for large clients with a continuous volume of work and regularity of relationship with the same partners. Such clients may be able to develop the conducive power and incentive structures to ensure that their project delivery partners are moved towards increased collaboration and best-for-project ideals.

The model may not be appropriate for clients that cannot be deeply engaged with the project delivery – it is impossible to outsource teamworking and collaboration. The success, or otherwise, of the project facilitation process may be contingent on the capabilities of the Coach and the perceived value of the process to the construction team. Finally, the results reported in this paper are also based on a single case study – they may not necessarily be transferable to other projects. The model is currently being rolled out on other projects by the client organisation. It is only after the wide application of the model on many projects that running themes become more evident.

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CONTRACTORS' LEARNING AND INNOVATION IN COLLABORATIVE ENVIRONMENTS: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Purpose – This paper aims to review the relationship between learning and innovation of contractor organisations and the impact of social capital on learning and innovation.

Design/Methodology/Approach – A comprehensive literature review was carried out to understand the concepts of learning, innovation, and social capital as well as their deployments in project-based organisations (PBO). Literature includes highly ranked journal articles, books, and broadcasts.

Findings – The study revealed that organisations improve their capability to innovate by prioritising learning and transferring knowledge (generated from learning) to different levels (i.e. individual, group, organisational). Learning is further explained by explorative and exploitative approaches. Adopting this explore-exploit dichotomy, a conceptual framework is proposed to explain learning and innovation at the project (group) and organisational levels.

Adopting the social capital perspective and the positive influence of collaborative environments (i.e. Partnering, New engineering contracts, PPP, Design and build, Management contracting) to implement explorative-exploitative learning is highlighted as well.

Originality/Value – This study points out the need for collaborative procurement arrangements to encourage learning and innovation of contractor organisations. Furthermore, contractors should foster innovation by learning from projects that could enhance the efficiency of the construction industry.

Keywords: Exploitation, Exploration, Innovation, Learning, Social Capital

INTRODUCTION

Innovation is a major research topic that features across many disciplines such as economics, management, engineering, and medicine. The concept has been recognised as a key factor for enhancing living standards, quality, and competitiveness. The historical assessment of innovation began with Schumpeter's 'theory of innovation' (Schumpeter, 1934). Schumpeter identified innovation as a factor of economic growth which creates temporary monopolies. Van de Ven (1986) defined innovation as, "the development and implementation of new ideas by people who over time engage in transactions with others within an institutional context" (p. 604). Schumpeter (1934) viewed the concept of innovation from an industry perspective, while Van de Ven's (1986) definition reflects an institutional context.

Damanpour and Evan (1984) defined innovation as "the implementation of a new idea for a product, device, system, process, policy, or service-that is new to the organisation at the time of adoption" (p.393). It highlights the idea of 'novelty' or 'newness' as innovation. In construction management

literature, the definition offered by Slaughter (1998) confirms the idea of novelty, which is "the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change" (p. 144). Following the definitions given by Damanpour and Evan (1984) and Kissi et al. (2012), this study considers innovation as the implementation of a new product, process, system, strategy, policy, or service in an organisation.

Innovation in the construction industry has been researched in recent years and has often been criticized for its lack of innovativeness (Blayse and Manley, 2004). Many barriers have been recognized such as poor rates of investment in research and development (R&D), fragmented and temporary nature of the industry, and fewer implementations of recommendations done by academia (Dubois and Gadde, 2002; Gann, 2003). In contrast, contemporary views suggest that non-suitability of traditional measurements of innovation, disregarding hidden innovation (Bygballe and Ingemansson, 2014; Winch, 2003), reflects negative responses on innovation in the industry. Thus, innovation in construction should be further researched and analysed.

In this study, the concept of learning (or organisational learning) has been adopted to explain innovation in the construction industry – particularly innovation in construction organisations. Learning is identified as a process of enhancing the ability of firms to innovate, which is explained as a series of learning processes in obtaining new knowledge, behaviour, tools, and values to enhance organizational capacity (Andriopoulos and Lewis, 2009). It provides the capacity of adapting to the changes caused by turbulent environments, sharing know-how and experiences, as well as facilitating innovative solutions (Styhre et al., 2004). The construction industry is project-based, and when applying the concept of learning, industry's project-based nature should be considered.

Referring to construction management research, it was found that explorative and exploitative learning has been adopted to explain innovation in construction Project-Based Organisations (PBO) i.e. (Eriksson, 2013). Exploration is a long-term learning approach, which is based on seeking new knowledge and technologies (i.e. innovation and strategic management). Exploitation on the other hand, refers to a short-term learning approach, which considers improving existing knowledge and technologies (i.e. efficiency and production) (Benner and Tushman, 2003; He and Wong, 2004; March, 1991). The need of balancing exploration and exploitation has been highlighted to achieve the corporate longevity of an organization. The ability of an organization to simultaneously explore and exploit is called 'organizational ambidexterity' (Davies and Brady, 2016; O'Reilly and Tushman, 2008). In the context of the construction industry, incorporating collaborative environments (i.e. collaborative procurement arrangements) has been recognised as a way of facilitating ambidexterity in construction projects (Eriksson, 2013). Accordingly, this research investigates learning and innovation in collaborative environments (i.e. Design and build, Partnering, New engineering contracts, Integrated project delivery, PPP, Management contracting). Moreover, the social capital perspective is also adopted to explain the impact of collaborative procurement arrangements on learning and innovation.

Based on this argument, this study attempts to answer the following research question: *"How are learning and innovation linked in construction contractors' organizations?"*

To answer this question, a comprehensive literature review was carried out to elaborate the concepts of learning and innovation. More specifically, the antecedents of learning, exploration, exploitation, and innovation are discussed. In addition, theoretical implications of social capital are reviewed along with the role of collaborative procurement arrangements for learning and innovation. Finally, a conceptual framework is presented, incorporating literature findings to explain learning at different levels (project and organizational levels) and innovation of contractors' organisations.

THEORETICAL BACKGROUND

Organisational Learning, Project-Based Learning, and Knowledge Transfer in PBOs

Organisational learning

The concept of organisational learning has been subjected to a great deal of research. Yet, various arguments and disagreements have emerged from analysing learning at different levels or units of an organisation (i.e. individual, group, and organisational). Some researchers suggest that learning is what individuals learn in organisations, while others argue that learning is more than that. A different idea was given by Fiol and Lyles (1985), where they claimed that organisational learning is not merely cumulative of individual learning, yet norms and systems have a specific influence on organisational learning. Moreover, authors have rejected the adoption of individual learning theories due to their non-applicability to unique and non-repetitive situations.

Another long-standing debate was that learning should involve either cognitive or behavioural change (Easterby-Smith et al., 2000). However, in recent years, this cognition-behaviour debate has receded, and has been considered as a change in an organisation's knowledge; and knowledge can be declarative (facts) and procedural (skills and routines) (Argote, 2012; Gherardi, 1999). Furthermore, researchers have agreed that learning is a broader concept and needs a broader definition, inclusive of both cognitive and behavioural focus (Easterby-Smith et al., 2000). Similarly, this paper agrees to the stance that learning should be explained by both cognitive and behavioural contexts. Accordingly, Crossan's 4I framework is adopted to explain learning as a change in cognition or behaviour. Moreover, the learning process is described in this framework (intuiting, interpreting, integrating, and institutionalising) by considering three levels (i.e. individual, group, and organisation) in an organisation, which is considered for this study.

The following premises (assumptions) are given to form the framework and support one central proposition (Crossan et al., 1999, p. 523).

Premise 1: Organisational learning involves a tension between assimilating new learning (exploration) and using what has been learned (exploitation).

Premise 2: Organisational learning is multi-levelled: individual, group and organisation.

Premise 3: The three levels of organisational learning are linked by social and psychological processes: intuiting, interpreting, integrating, and institutionalising (4Is).

Premise 4: Cognition affects action (and vice versa).

Proposition: The 4Is are related in feed-forward and feedback processes across the levels.

Table 1 shows how the learning process is mapped through three levels.

Table 1: Learning/renewal in organisations: Four processes through three levels

Level	Process	Inputs/Outcomes
Individual	Intuiting	Experiences
		Images
		Metaphors
Group	Interpreting	Language
		Cognitive map
		Conversation/dialogue
	Integrating	Shared Understandings
		Mutual adjustment
		Interactive systems
Organisation	Institutionalizing	Routines
		Diagnostic systems
		Rules and procedures

Source: Crossan et al. (1999, p. 525)

Intuiting, interpreting, integrating, and institutionalising all help to unite an organisational structure together in a coherent manner. **Intuiting** is the beginning of new learning, a subconscious process of past pattern recognition or developing insights. **Interpreting** is the subsequent phase of learning, which incorporates an individual's ability to explain insights, sensations, and feelings through language, discussions, and cognitive maps. This enables individuals to embrace a sense of shared understanding within workgroups. **Interpreting** is the change in the understandings and actions of individuals; this is vital in advancing the shared understandings among individuals. **Institutionalising** is the establishment of organisational learning in organisational systems, routines, structures, practices, and strategies. According to the framework, intuiting and integrating occur at the individual level. Interpreting and integrating take place at the group level. Integrating and institutionalising occur at the organisational level (Crossan et al., 1999).

This study focuses on the learning of contractors' organisations at group and organisation levels. Therefore, only interpreting, integrating, and institutionalizing processes are reviewed.

Project-based learning

Despite the concept of organisational learning as a major research area, applying this concept into complexities such as project-based organisations, within projects (project level), has rarely been discussed. PBO refers to organisations where all (or most) business activities function in the form of projects (Hobday, 2000). PBO has been considered as the best option for managing organisations that produce complex, heterogeneous, and innovative outputs in rapidly changing environments. Previous research has reviewed organisational learning as a critical performance driver in project-based organisations, as it generates innovative solutions to find new market opportunities (Brady and Davies, 2004).

Scarbrough et al. (2004) have used the term 'project-based learning' to represent knowledge creation and acquisition within projects and transferring such knowledge to the organisation. Bartsch et al. (2013) investigated the project teams' role over barriers for organisational learning in PBOs and

continuously used the term 'organisational learning in PBOs'. Likewise, many researchers including (Eriksson, 2013; Turner et al., 2015) have discussed the learning within project levels in PBOs in terms of the exploration and exploitation of knowledge. Chan et al. (2005) viewed the organisational learning in construction projects as 'learning networks' to emphasize the utilisation of knowledge from previous projects. Ayas and Zeniuk (2001) drew distinctions between project-based learning and learning in PBOs as different processes. They applied the term 'project-based learning' in the context of large and complex projects, where hundreds of people are involved. However, this study considers the concept of 'project-based learning' to explain the process of learning from projects and transferring knowledge (obtained from learning) into different organisational levels, in the context of a PBO.

Knowledge transfer in PBOs

A project has been explained as a temporary formation to achieve a specific task within a given time and cost, utilising resources such as human, financial and material (Turner and Muller, 2003). A PBO is organized with several projects, and projects are assigned to complete specific tasks. In completing these tasks, several relationships among different organisational levels can be recognized. Thus, knowledge gained from learning flows at different directions such as within the project, among the projects, and project to the organisation (Bartsch et al., 2013). Several empirical results suggest that learning and transferring knowledge obtained from learning in PBOs enhance the capability to innovate (Bygballe and Ingemansson, 2014; Eriksson, 2013; Liu and Chan, 2016). Following this argument, to investigate innovation, learning and knowledge transfer between project (group) and organisation levels are considered in this research.

Learning in the Construction Industry

The construction industry is project-based and consists of PBOs. Considering PBOs in this industry, intra-organisational learning (within a construction project) is found to be faster than inter-organisational learning (across construction projects) (Holmqvist, 2003). This is due to the ability of management to directly supervise employees, which is more straightforward in intra-organisational learning. In contrast, the same management would be reluctant to empower project teams (Chan et al., 2005). Thus, the practice of project-based learning in construction organisations tends to be difficult as organisations require more efficient inter-organisational learning. Yet, Groák (1994) argues that construction is misunderstood by not defining the site as the locus of production organisation. Groák further suggests that construction should be centralized around the project, not the firm. Embracing the temporary and discontinuous nature of the construction industry would be beneficial in reducing the difficulties of project-based learning.

DEVELOPMENT OF CONCEPTUAL FRAMEWORK

Exploration and Exploitation

In organisational learning, exploration and exploitation are two different learning approaches (He and Wong, 2004). Exploration refers to activities such as search, variation, risk-taking, experimentation, play, flexibility, discovery, and innovation. The opposite, exploitation refers to activities such as refinement, choice, production, efficiency, selection, implementation, and execution (March, 1991). In general, exploration entails looking for new opportunities, whereas exploitation is the improvement of existing certainties. Furthermore, He and Wong (2004) suggest that exploration and exploitation should be implemented by adopting different organisational conditions such as structure, processes, strategies, capabilities, and cultures. Furthermore, the results associated with each learning approach

vary depending on the type of learning. Exploration is associated with more variable and substantial outcomes. On the other hand, exploitation provides comparatively stable and consistent outcomes.

Organisational Ambidexterity

O'Reilly and Tushman (2008) highlight the importance of balancing exploration and exploitation, despite their mutual exclusiveness due to the nature of competition for scarce resources. The ability of an organisation to simultaneously explore and exploit is called 'organisational ambidexterity' (Davies and Brady, 2016; O'Reilly and Tushman, 2008). Explorative organisations are likely to suffer from losses due to experimentation without gaining any benefits. On the contrary, pure exploitative organisations are at risk of losing their market due to lack of competence. Rivals tend to take advantage of being explorative, producing quality products at lower costs (March, 1991). Despite mutual exclusiveness, an ambidextrous organisation can achieve both exploration and exploitation components, which may result in superior financial performances as well as a long-term competitive advantage. Making accurate decisions with respect to available resources and risk preferences is significant in this regard (He and Wong, 2004; Turner et al., 2015).

Exploit-explore Dichotomy and Innovation in Organisations

March (1991) clearly states that balancing explorative and exploitative learning is crucial to achieving corporate longevity. Similarly, previous literature on learning and innovation in construction constantly acknowledges the exploit-explore dichotomy (Brady and Davies, 2004; Bygballe and Ingemansson, 2014; Prencipe and Tell, 2001). Hence, it is necessary to explore what type of learning is employed in construction organisations as well as its impact on innovation. In addition, knowledge generated from learning in different projects and its transfer to the organisational level are studied in this research. Accordingly, the following conceptual framework is developed (see figure 1).

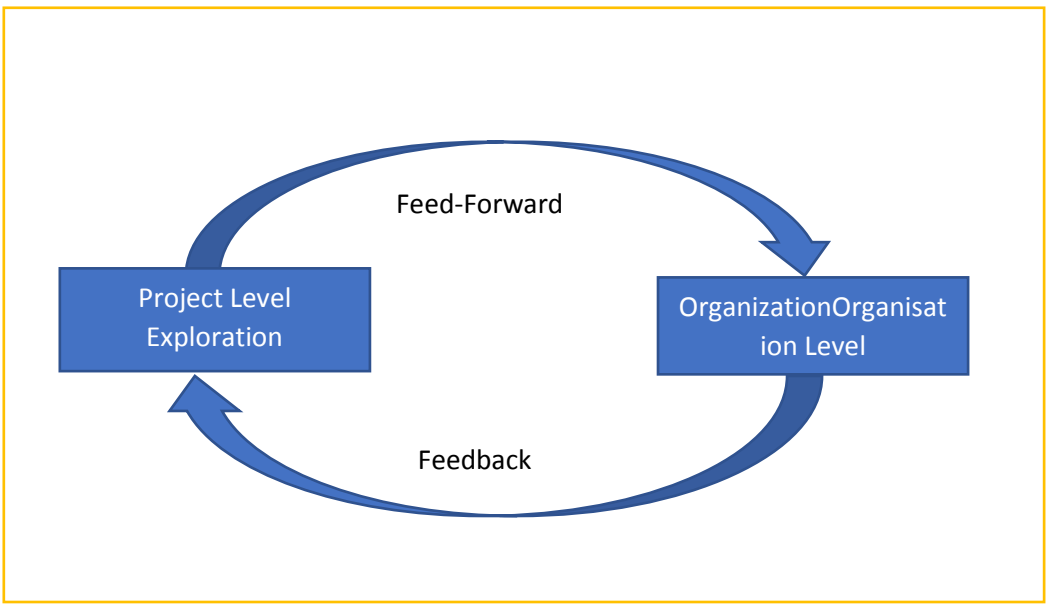

Figure 1: The proposed conceptual framework

Bygballe and Ingemansson's (2014) analytical model, which stipulates how new solutions are transferred between different organisational levels (project level, company level, and industry level) for the achievement of innovation, is adopted to develop this framework. Yet, the framework for this study is presented to explain and understand innovation in contractor organisations, incorporating the knowledge transfer from project levels to organisational levels.

Constructs Explanation

Explorative and exploitative learning are considered as the two primary constructs. In this study, Explorative learning is explained as the formation of the product or process (radical development), system, policy, or service innovation at project level. The utilization of these innovations at project and organisation levels will be examined as exploitative learning. Exploitation is further described as the combination of incremental development (continuous improvement of existing knowledge), knowledge sharing, and innovation diffusion across projects and organisation levels.

To explain these two constructs, the approach taken by Eriksson et al. (2017) was considered, where exploration is explained under two key learning themes: adaptation (dealing with uncertainty) and radical development (product or process development). Moreover, three major themes under exploitative learning has been adopted as well. However, exploration in this study refers to innovation aspects only (product, process, system, policy, or service), as the focus of this study is to investigate how learning and innovation are linked in contractors' organisations. Figure 2 further illustrates the conceptual framework with the constructs incorporated in this study.

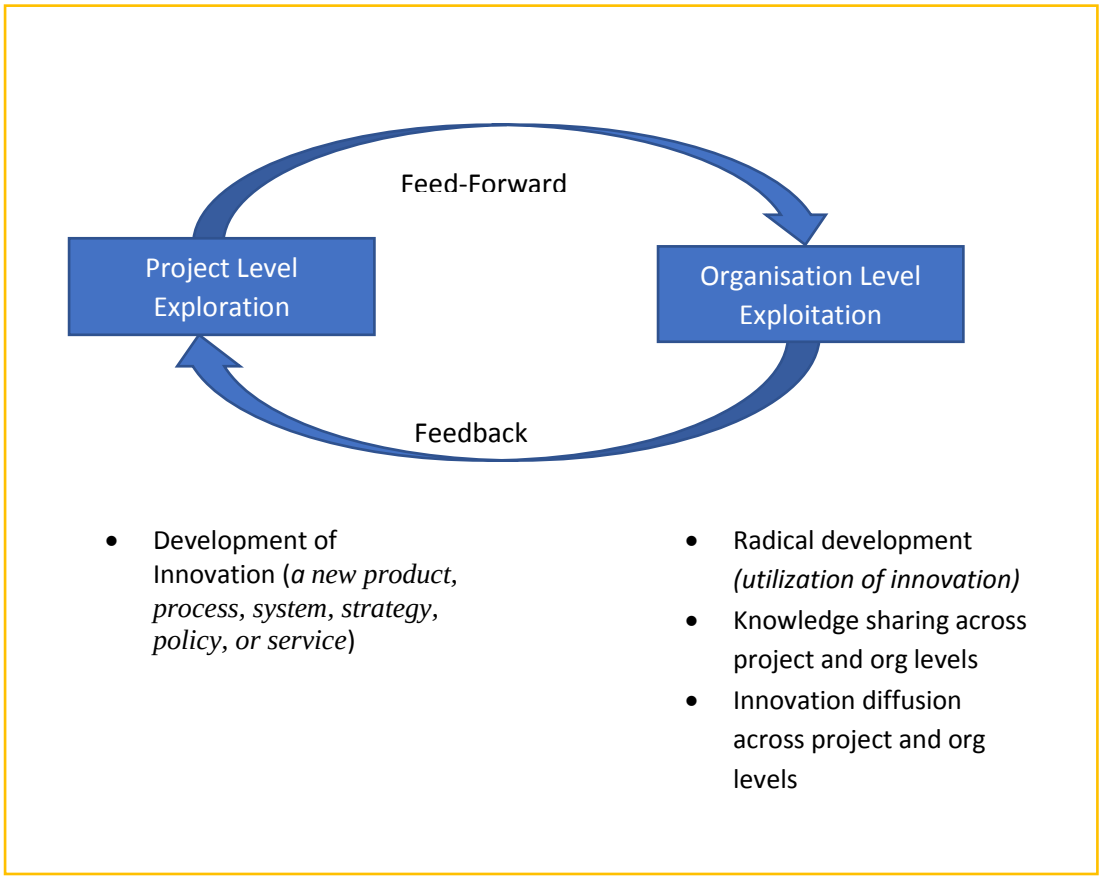

Figure 1: The proposed conceptual framework-detailed version

The Role of Collaborative Environments

The suggested framework should be applied in contractor organisations, where collaborative procurement arrangements exist. The role of collaborative environments highly influences the involvement and interaction of different actors (i.e. main contractors, sub-contractors, material and component suppliers, and consultants) in a construction project.
Theoretical and empirical research findings suggest that when collaborative procurement arrangements (i.e. Partnering, New engineering contracts, PPP, Management contracting, Design and build) are more stable, the possibilities for implementing explorative and exploitative learning are increased (Eriksson et al., 2017; Jansen et al., 2006). For example, a design-build contractor can exploit or apply explorative designs as well as integrate construction knowledge to design works, compared to the design-bid-build contractor. Accordingly, learning activities which highlight the client-contractor relationship in the context of collaboratively procured construction projects have been considered in this study.

Social Capital Perspective

The social capital perspective helps to explain the role of collaborative environments in organisations. This perspective provides theoretical implications of how social relationships and networks enhance the productivity of such organisations. Social capital is explained as a resource or a web of social networks and relationships which facilitates mutual benefits (Baker, 1990; Burt, 1997). In a broader view, not only relationships and social networks, but also the values and norms associated with them, are recognized as social capital (Portes and Sensenbrenner, 1993). This study adopts Nahapiet and Ghoshal's (1998) definition, that social capital is considered as knowledge embedded within an organisation, which is the "sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilized through that network" (p. 243).

Social capital has been further analysed in terms of structural, relational, and cognitive dimensions (Nahapiet and Ghoshal, 1998; Turner et al., 2015). The structural dimension refers to the pattern of ties among actors in the network, where ties can be either strong or weak. The relational dimension is understood in terms of the nature/characteristics of ties (i.e. strength can be measured by frequency, closeness, etc.). The cognitive dimension is the similarity between actors, which can be assessed by shared goals or common interests (Bartsch et al., 2013).

Social Capital and Innovation

Analysing conceptual (Adler and Kwon, 2002; Nahapiet and Ghoshal, 1998) and empirical research (Tsai and Ghoshal, 1998) carried out on the impact of social capital, Tsai and Ghoshal's (1998) argument: social capital influences the internal functioning by enhancing the innovation capability of an organisation, is considered in this study. Furthermore, Bartsch et al. (2013) submitted that social capital facilitates project-to-organisation learning in PBOs. The social capital of project teams (social ties outside the project, within an organisation) is able to overcome barriers that are incorporated with lack of opportunity, motivation, and knowledge management. Similarly, Turner et al. (2015) examined how that ambidexterity of an organisation is achieved by adopting intellectual capital (human, social and organisational), perspective, and the role of social capital, which is seen as being highly significant for the effectiveness of managers.

Therefore, this research is not confined to investigating learning and innovation only. It also adopts the social capital view, to particularly investigate the impact of collaborative procurement arrangements in the context of contractors' organisations.

METHODOLOGICAL IMPLICATIONS

Following the research question: "how are learning and innovation linked in construction contractor organisations?" and selecting the 'interpretivism' philosophical stance, this research intends to adopt a qualitative research approach. Multiple case studies employing semi-structured interviews and document analysis will be carried out with professionals (i.e. project managers, construction managers, commercial managers, site engineers, and other relevant project team members) who are experienced in learning and innovation in contractor organisations (contractor organisations being the unit of analysis).

Semi-structured interviews will be designed in order to capture how learning and innovation are linked at project and organisation levels. Exploration (*new product, process, system, strategy, policy, or service innovation*) at project levels will be investigated in terms of their purpose, function, cost, time consumed, process, risks, barriers, opportunities, benefits incorporated, actors, and nature of relationship involved. Exploitation will seek information regarding incremental development based on usage of innovation at an organisation level, process, purpose, cost, risks, barriers, opportunities, benefits incorporated, actors, and nature of relationship involved. Moreover, the processes of knowledge sharing and innovation diffusion will be investigated based on type of knowledge/innovation, modes and timing of sharing/diffusion, how knowledge is stored, risks, barriers, opportunities, benefits, actors, and nature of inter-relationships involved.

In addition, the role of social capital on explorative and exploitative learning will be questioned. Therefore, questions will be raised in terms of actors' inter-relationships within projects, between project and organisation levels, different networks/groups, and collaboration with external parties. Document analysis will be beneficial for obtaining useful information such as background, structure, and revenue/profit of the organisations over the years, which are not explicit from interviews. Company publications and official websites will also be reviewed as main modes of document analysis.

SCOPE AND LIMITATIONS

Data collection will be conducted in the context of Hong Kong's construction industry, where massive building and infrastructure construction projects take place. Moreover, large-scale contractor organisations who are experienced in large and complex projects as well as innovation and collaborative procurement arrangements, are considered as the unit of analysis for case studies. When investigating the explorative learning of contractors, only innovation practices will be concerned. Moreover, only group (project) and organisational levels have been considered to examine the processes of learning and knowledge transfer within an organisation.

CONCLUSIONS

To explain learning and innovation in contractor organisations, the concept of exploit-explore dichotomy was adopted. Accordingly, a conceptual framework has been presented, which illustrates that explorative learning occurs at project and exploitative learning can be detected at organisational level. Moreover, this study agrees that collaborative procurement arrangements can enhance the possibilities as well as implementation of learning and innovation in construction organisations., The social capital perspective has been applied to explain the role of collaborative environments for implementation/development of learning and innovation in contractor organisations. This research is

ongoing. Therefore, only theoretical arguments and findings on the concepts of learning and innovation have been presented thus far.

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COORDINATION OF INTERLEAVED CORPORATE SCHEDULES AS MULTIPLE PROJECTS COST CONTROLS

Dinko Bacun, Indicio D.o.o

Abstract

Emerging technological advancements produced a large number of software tools that help project managers in planning, project cost optimization, collaboration and information sharing. However, when works begin, unexpected situations develop that force project changes, resulting in delays and cost overruns. Cost overruns are quite common in construction projects and are not caused by a single catastrophic event, but rather by numerous small delays and disruptions which are not detected until their cumulative effect becomes financially significant. Those disruptions are often caused outside the project, by subcontractors or misaligned actions in different corporate departments or different project stakeholders.

This situation is multiplied in case of a contractor with concurrent projects. A detailed Project Communication Plan is mandatory, but it still addresses a single project.

In three decades of both inside and outside participation in large number of project, the author could not observe a measurable integration of project schedules and corporate business processes.

A schedule activity may initiate multiple requests for actions, materials or services which are often cause of schedule challenges. Each request may trigger a request to another department, creating a thread of events that may influence project activity duration and cost. Each request, at any level, has a direction (from Sender to Recipient) and a deadline or consequently, duration, which implies that it can be regarded as a self-contained activity. A thread of linked requests can be considered a separate corporate schedule, with its own resources. On site project activity is dependent on successful completion of chained requests. They are interleaved in a joint corporate effort across different projects.

This paper proposes a possible solution to the above problem based on the model of Multidimensional Preemptive Coordination.

Keywords: coordination, project controls, multiple project integration.

INTRODUCTION

In current harsh economic conditions, contractors are faced with more pressures to significantly cut the costs and optimize their business processes. Cost and schedule overruns proved to be a major issue for successful project completion. Detailed project analysis showed that a large portion of projects are late, and that there is a significant statistical correlation between cost overruns and delays in schedules. Flyvbjerg et al. (2004) analyzed 258 projects across 20 nations (America, Europe, Japan and 3rd countries). A large 86% of late project caused on average 28% of cost overruns. The findings showed that the delays were not caused by some catastrophic event, but rather by a number of small delays which went unnoticed until their cumulative effect became significant.

Bordat et al (2001) conducted a research for the Indiana Department of Transportation (INDOT) trying to understand the causes of cost overruns. It was found that 55% of all INDOT contracts experience time delays and the average delay per contract is 115 days. Time delays, cost overruns and change orders are caused by design errors, unexpected conditions, expansion in project scope, weather conditions and project changes. The dominant category for change orders was found to be “errors and omissions”. One of the root causes of Highway Construction Delays was found to be the lack of team accountability for timely project completion

In 1996 the Florida Department of Transportation (FDOT) ordered a review of performance in controlling cost overruns in transportation construction projects. The purpose of the review was to understand to what extent are construction cost overruns avoidable and what actions can be taken to minimize the cost overruns and improve accountability for these problems. The responsibility for cost overruns was found to be shared among consultants, third parties (that include utility companies, permitting agencies and local governments) and FDOT staff.

This is consistent with author's observation. The delays are often caused by factors external to the project, and the project manager is in a constant state of extinguishing fires that went undetected. In contractor companies the situation is worse, because there is a multi-project situation with insufficient resources, which force the management to prioritize without the time to evaluate consequences.

There is not much a company can do regarding external factors like government decisions, weather and industry conditions. Inside the company, though, a lot could be done in coordination and transparency between departments and different stakeholders, which would raise accountability across the enterprise.

This paper proposes a model which integrates project schedules and business processes inside the enterprise, avoiding delays buried in the corporate vastness that can influence the outcome of the project activity and schedule as a whole.

A review of literature is given first, the observation process is described next, findings and discussion and the model is proposed last.

LITERATURE REVIEW

Numerous authors researched scheduling in both single project and multi-project environment.

Hinze (2004) gives detailed information about construction planning and scheduling. Alzahrani and Emsley (2013) study the impact of contractors' attributes on project success from a post construction evaluation perspective to identify what are the critical success factors that impact the success of project. Weglarz (2012) discusses different models of project scheduling: classical models – exact algorithms, heuristic models that deal with interval capacity consistency tests, non-classical models like probabilistic and fuzzy models and lastly the extensions to the above models. Ke and Liu (2005) present a project scheduling problem with stochastic activity duration times trying to minimize the total cost under set completion time limits. Kolisch and Padman (2001) survey the literature in area of project scheduling decision support with a perspective that integrates models, data, and optimal and heuristic algorithms, for the major classes of project scheduling problems. Steyn (2002) explains why Theory of Constraints (TOC) was initially applied only to project scheduling. A second application of TOC is to manage resources shared by a number of concurrent projects.

Much of the reseach was done in schedule optimization with resource constrained situations. Hartmann and Briskorn (2010) give an overview of extensions to the resource-constrained project scheduling problem (RCPSP). Gonçalves et al (2008) present a genetic algorithm for RCPSP. Valls et al (2008) propose a Hybrid Genetic Algorithm for the RCPSP with a new way to combine the parents. Mendes et al (2009) present a genetic algorithm for RCPSP where the schedule is constructed using a heuristic priority rule in which the priorities of the activities are defined by the genetic algorithm. Van Peteghem and Vanhoucke (2010) present a genetic algorithm for the multi-mode RCPSP, in which multiple execution modes are available for each of the activities of the project. Debels and

Vanhoucke (2007) present a new genetic algorithm for RCPSP problem that is able to provide near-optimal heuristic solutions introducing a decomposition-based genetic algorithm that iteratively solves subparts of the project. Agarwal et al (2011) propose a hybrid of genetic algorithms and neural-network approaches. Tseng and Chen (2006) present a hybrid metaheuristic algorithm for the RCPSP in which they combine ant colony optimization genetic algorithm and local search strategy. Fang and Wang (2012) propose an effective heuristic based on the framework of the shuffled frog-leaping algorithm for solving the RCPSP problem. Drezet and Billaut (2008) research a project scheduling problem where resources are employees of different levels of skills and activity requirements are time-dependent. Furthermore, employees have different skills and legal constraints dictated by the French workforce legislation have to be respected. Ziarati et al (2011) analyse the performance of three bee algorithms for RCPSP. Bellenguez-Morineau and Néron (2007) use Branch-and-Bound method to solve a special case of project scheduling problem, where each activity requires special skill resources.

Many authors researched multi project environment, but focused mostly on resource allocation between different projects. Browning and Yassine (1010) address the static resource-constrained multi-project scheduling problem (RCMPSP) with two lateness objectives, project lateness and portfolio lateness. Herroelen and Leus (2005) conducted a survey to review the fundamental approaches for scheduling under uncertainty: reactive scheduling, stochastic project scheduling, fuzzy project scheduling, robust proactive scheduling and sensitivity analysis. Cohen et al (2004) examine the control mechanisms of Critical Chains and some alternatives. They demonstrate that such alternatives may give rise sometimes better, possibly much better performance. Kim et al (2005) propose a hybrid genetic algorithm with fuzzy logic controller to solve the RCMPSP problem with objective to minimize total project time and total tardiness. Hartmann (2001) discusses the resource-constrained project scheduling problem with multiple execution modes for each activity and makespan minimization as objective. Jarboui et al (2008) propose a combinatorial algorithm use it in order to solve a multi-mode resource-constrained project scheduling problem. Herroelen and Leus (2004) review possible procedures for the generation of proactive schedules protected against schedule disruptions in the case of unexpected events.

METHODOLOGY

The observations used for this paper are the result of author's inside and outside participation in project management mostly in construction industry over the period of 33 years. The insights were gathered in interviews, meetings and discussion with project managers, field engineers, estimators, investors, owner project managers, department heads and their subordinates, accountants, fleet managers, repair shop team leaders, site managers and ordinary field workers in an attempt to understand the workings of everyday life for successful implementation of an integrated information system. The work started with estimating department and gradually expanded as the shortcomings of communication at the previous business unit was revealed by business realities of the next. Notes, drawings and schemas were transformed into ever changing software segments.

Three distinct periods should be highlighted because of different environments and authors role in them. From 1981 to 1987 the author was CIO of a large facility and assembly corporation. Started ad 1940, in the eighties it had 3800 employees and an average of 40 construction sites yearly, both domestic and abroad, each lasting from few months to few years. A very meticulous record keeping in manual form was getting replaced by computer technology. A special team consisting of IT people and estimating professionals was formed to start the transition. Team members interviewed upper management and site management to get first draft, and expanded to other departments and corporate altitudes as the project progressed.

The second period encompasses from 1987 to 1990 when the author held the position of Project Manager for Complex Software Projects, in our largest electrical manufacturing and assembly company, leading a joint venture project with, at the time, one of the biggest European software companies. The project was software integration of the national gas station grid into the national gas oil company. For the purpose of this paper it is more important the meetings, conversations, notes and work done within different departments, teams and team leaders of the software giant.

From 1992 to 2013, the author was the CEO of a software development company specializing in software for construction companies. A total of 114, mostly construction companies, were processed, including two from the top ten construction companies in Croatia. Their employee number varied from few dozen to few thousand, the largest being 2500 employees. The companies had form under 10 project per year to up to 30, most lasted from a month up to 3 years. During the implementation phases, numerous interviews, schooling and software modifications were made based on user input.

RESULTS AND DISCUSSION

During the observed period the author did not observe significant transparency in corporate business procedures or collaboration between projects. The use of project controls are consistent with the findings of CMAA/FMI (2004) survey which states that project controls are executed in Execl tables more than 80%, scheduling software and office tools (about 70%) and plain phone call and faxes a little less than 70%.

Team meeting and corporate meetings govern corporate coordination efforts (weekly, monthly). Their efforts to increase the performance in project delays resolution were not impressive. Romano and Nunamaker (2001) found that corporate meetings in America take on average, 9.6 hours per week. Between 8% and 15% of personnel budget of the company is spent on meetings. There are 15 participants in a meeting (depending on a company size). The total cost of meetings is in range of US$50 million to US$ 70 million annually. Disappointing fact is that 73% participants questioned meeting effectiveness due to poor planning, 11%-25% of time was spent on irrelevant issues, 33.4% consider meeting time is unproductive and majority of surveyed executives concluded that 20%-30% of the meetings were unneeded.

Teams, as well as business units, are closed to outsiders and rarely volunteer the information. The author witnessed a situation where such an attitude failed to secure gains for the company. A small contractor had two construction sites, two private housing projects, just a few miles apart. At one site gravel and small boulders were excavated and transported to a public depo. At the other site, gravel was needed for levelling and was purchased and transported from a corporate supplier. The schedules, by chance, overlapped, although initially diverged in time, but could result in significant savings had there been enough project transparency and awareness at the proper corporate altitude. The project manager that was aware of this situation, didn't volunteer the information to upper management, he said he minded his own business. No apparent damage was done, as each of the projects proceeded according to their planned schedules, but the company failed to gain an unexpected opportunity,

In another example, in the largest local construction company, a tower crane was held on the construction site with various excuses for few extra months. Essentially, the project manager wanted to be sure that the crane would be available when he needed it in a later activity. Meanwhile, a needed crane at another site was subcontracted for the value of USD 65,000 per day.

Those observations are not particular to small and medium companies. In 1988 the author participated in numerous meetings in a large European software company (revenue of about EUR

200 million) in an attempt to coordinate gas station integration in the national gas oil company. The integration involved multiple divisions and multiple teams developing multiple products that had to converge in the final solution. The meetings were meticulously prepared, steps reviewed and decisions made. First milestones were met with ease. But, as a team leader of a junior partner, the author was allowed to contact different departments and team leaders directly, to familiarize himself with the workings of a big company. It soon became obvious that different departments and different teams had different priorities, which complied more with the organizational structure than with the project at hand. At the meetings everybody expressed wishful thinking. Fortunately, the author was able to reveal that the deadlines had no chance to be met, their internal detailed dispute confirmed it, and steps were taken to remedy the situation. Had it not been for sheer curiosity, the problem would remain undetected until it was too late. Extra resources would have been thrown into the project, the schedule would be met or not, but cost overruns would certainly appear.

Those events highlighted the significance of measurable corporate coordination and resulted in the model proposal in this paper.

First a description of the proposed model is given, then the base for the model is briefly explained, necessary model additions are discussed next and finally, the workings corporate interleaved schedules are explained.

MODEL PROPOSAL

The proposed model integrates everyday corporate activities into the schedule of every project, creating an infrastructure that coordinates the activity of multiple interdisciplinary teams in a multiple project environment. Each project activity may trigger multiple requests for some kind of action (requests for materials, for floating teams, for modifications, additional subcontractors, etc.) either as the result of regular activity or some unexpected event. Any of those mean that a sequence of actions has to be performed to remedy the situation.

Different teams and team members confront each of those requests. If a request is consequence of a regular activity, like supply chain, the request is confronted by a relatively constant team, although different team members might address a particular request. If an unexpected event occurs, a different team might be assembled, depending of the type of the event. It may have the same core, but different professionals might be recruited from other departments and corporate altitudes if required.

Each request triggers a sequence of steps (meetings, tasks, emails, quotes, contacts with suppliers, investors, outside parties) that have to be completed, traversing different corporate departments, different teams and different team members. Each step takes time (duration), has different participants and implies a direction of events. There are preceding steps that need be completed and steps following it, implying a thread of actions. Such a sequence can be considered constituent part of a distinct corporate schedule (business process) independent of the project schedule. Timely completion of such a schedule still influences the successful completion of the project activity and, hence, the whole project schedule.

Multiple requests from different projects intersect at different points of the Organizational Breakdown Structure (OBS), at different altitudes, different departments, different teams and team members. Ultimately, each team member is participant of multiple threads of activities that may influence multiple projects. From his/hers point of view, the participant is confronted with multiple activities that have to be attacked in particular order, each one, as we stated, with a duration and implied direction, some of them sequential, some parallel.

A particular project activity and consecutively project schedule can be delayed if those threads of action, schedules outside the project scope, get delayed. A project activity that is not on the critical path can change the critical path if it is sufficiently delayed, which happens often. Numerous small delays represent one of the biggest challenges for successful project completion.

How could we control better the corporate events which are not inside the project scope? There is no point in calculating critical paths for the schedules that are external to the project. But it would be highly useful if we could calculate the probability that those threads of activities would finish on time so that the flow of the project activity is not interrupted. If that probability is low, the project manager could be alerted that a particular activity is in jeopardy and that further action is needed, preventing possible delays. To be able to do that, we need to log the thread of external steps that might affect the outcome of the project activity. If we can log them, we can measure the time each step takes, its duration, and apply PERT techniques to calculate the probability that they will be completed on time for successful project activity completion.

All those steps, external to the project activity, are standard everyday corporate documents, so no extra work is needed. The Request for Material form is filled. If the material is not available, either quotes are requested or orders issued, delivery dates established, transport arranged, payment approved and executed and documents prepared. An unexpected event in this chain of events may introduce delays which are hidden from the project or site manager. Those activities are buried in the corporate structure and are not visible to the original requestor. They are not correlated in such a way that their cumulative effect can be measured, estimated and project stakeholders alerted.

The delays are not introduced only in regular business processes. Unexpected events occur on site that need project change, smaller or bigger, but involving a number of meetings, permits and modifications. Subcontractors might become unavailable or any number of reason. Every site manager is aware of such unexpected developments and all of them require a group of focused professionals from different corporate altitude to solve them.

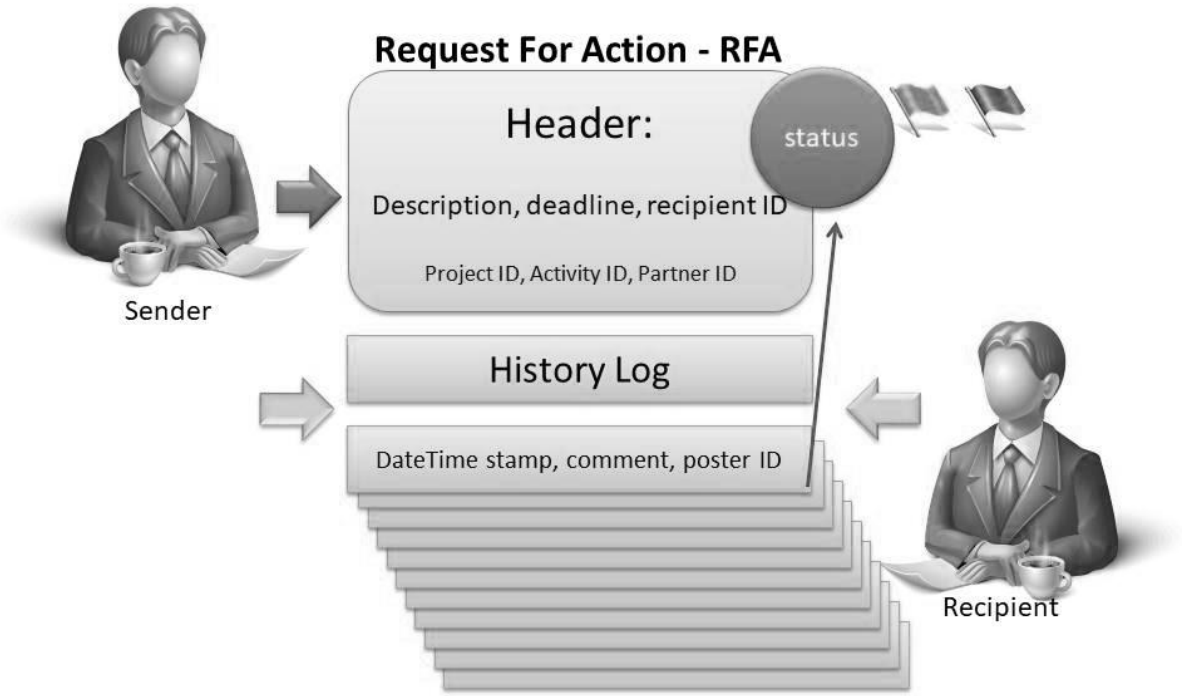
This paper describes a model of such an infrastructure based on the model of Multidimensional Preemptive Coordination (MPCoord). In the next section, the MPCoord model is briefly described. Additions to the model, necessary for its integration in project schedules are described next. The plausibility of concurrent interleaved corporate schedules is discussed last.

Multidimensional Preemptive Coordination (MPCoord)

Unexpected events are unavoidable certainty of everyday corporate life. They are faced by a designated professional or ad hoc assembled task force, a team of professionals at different corporate altitudes. They may request involvement of additional resources, across different departments to tackle the problem. Regular business processes follow the same pattern, they usually cross department boundaries where teams are constant inside a single department. If there are multiple team members in a team, a particular professional might not participate in every instance of a business process.

Multidimensional Preemptive Coordination is an infrastructure framework that coordinates such multidisciplinary interdepartmental task force, logs all actions taken and alerts all the participants of new comments, status changes and approaching or missed deadlines. It is conceived as a closed corporate social network visible only to the participants focused on resolving a particular problem. The alerts are propagated both horizontally, among the participants, diagonally across the depth of the request thread and vertically towards the upper management of each participant. It was first described by Bacun (2013) and later expanded (Bacun, 2014) to allow safe inclusion of stakeholders external to the enterprise.

Figure 1 Simple Request for Action



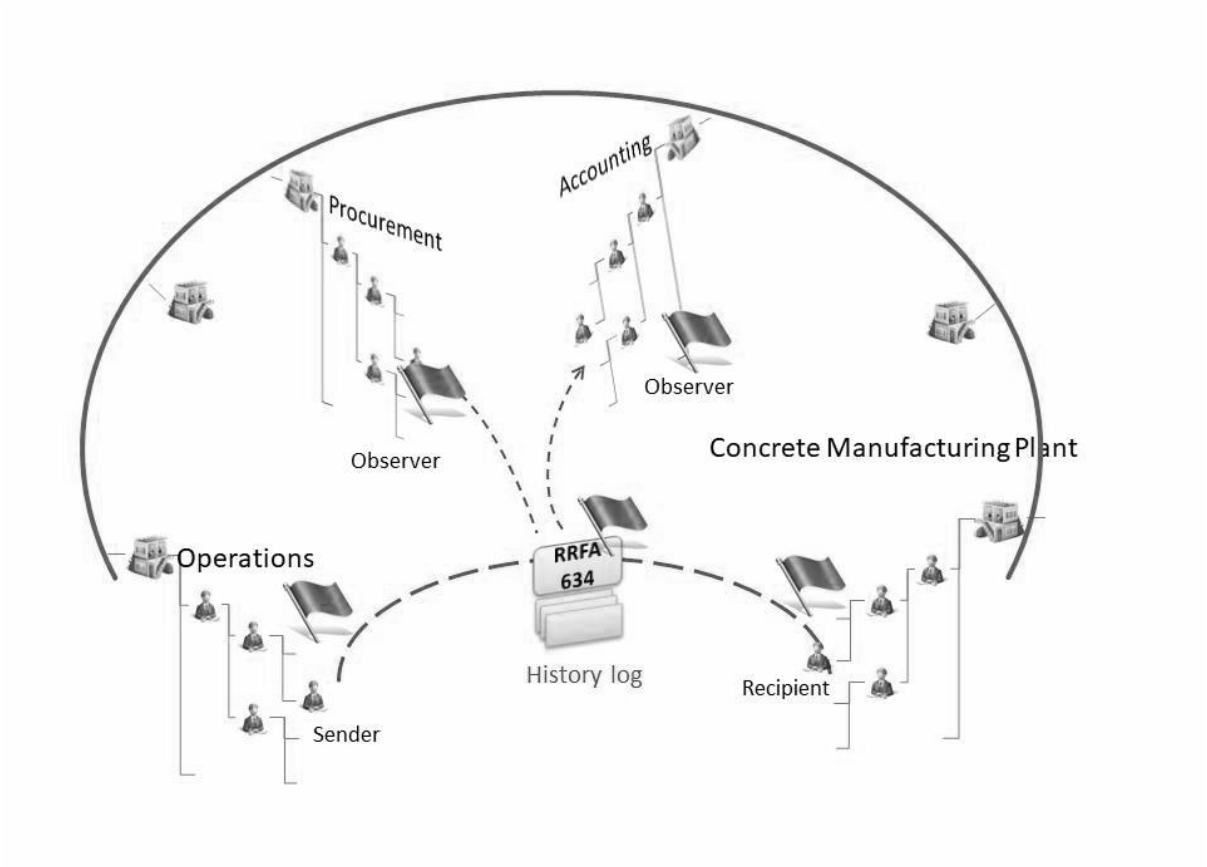
The simplest MPCoord element (Figure 1.) is a single Request for Action (RFA) with two participants: the Sender who issues the request to the Recipient, implying direction of the element. It has a Header, History log and Status. The Header is owned by the Sender. The Recipient cannot change its details. Both parties use the History log to exchange messages, comments, report progress and discuss ideas. Log records are time stamped and uniquely identified creating an audit trail of work done. It can optionally contain effective hours worked. Neither one can change log entries. The system may also post to the log in case of any change to the header or other events like approached or missed deadlines. Both participants use status to alert the other party of new developments. The status is configurable, and represents actual business situation (in progress, waiting for subcontractor response, etc.). The Header contains the request description, the deadline and an alert window period. The system monitors whether the request was read and flags it if it wasn't opened for a predetermined number of days.

The Sender may decide that further help is needed to resolve the issue. He may invite other stakeholders from any department or corporate altitude to join the discussion and observe the progress. Their arrival to the group as well as leaving is logged. They can post messages and be alerted of status changes and system alerts as any other participant.

Upper management of each participant is included in the discussion by default (Figure 2.). When any user logs onto the system, his/her position in the Organizational breakdown structure is established. Users external to the enterprise are identified by lack of corporate HR record. The Sender's upper management inherits Sender's rights, so they can change the header data, like deadline, description or Recipient, but these changes are logged. The Recipient's upper management cannot change the header data, but may change the employee that received the request, transferring the work to

another individual they consider a better fit. Any upper level participant can post comments and will be alerted of status changes.

Figure 2 Upper management is included by default



The sender or his upper management are the only participants that can close the RFA, declare the problem solved. The difference between the issuing date and closing date gives the duration. The sum of effective hours recorded in the posts give actual effective duration. Posts with no effective work data are just comments, instructions or opinions.

The request might generate a sub-request which might be issued by any participant. Consider a project activity involving concrete pouring. The project/site manager would issue a RFA to the Concrete Production Plant that would route it to Planning. Once the Planning was done, another RFA would be issued to Transport Management that would be routed to their planning. If the concrete production needed resupply in the process, a RFA would be issued to Procurement Department where either quotes were collected or direct orders issued for known suppliers. In traditional corporate life, the original Sender was shielded from any events that occur after the initial request to manufacturing. If any unexpected event puts the concrete delivery (or part of it) in jeopardy, he will probably be notified at the last minute.

A sequence of chained sub-requests forms a topic, a thread of actions that must be completed to make concrete delivery on time to complete to project activity. The system combines History logs of all RFAs in the thread into a single billboard with horizon of visibility tailored for each level. Participant's visibility at any level is limited to the thread altitude he/she was introduced to and any sublevels, so that he/she is presented only with data relevant for his/hers involvement. The initial Sender sees the full thread and will be alerted if any unexpected event, deeper in the thread, occur. The thread trespasses multiple departments and multiple corporate altitudes, each request with its

own duration. As all actions are logged, in case of recurring type of requests, like Request For Materials, expected, pessimistic and optimistic durations can be easily provided form corporate database. But more importantly, the effect of a delay that occurs somewhere in the thread depth is automatically communicated across the thread and its influence easily estimated.

Messages, comments, posts and other data are not visible to other employees outside the thread. Even inside the thread, participants have tailored visibility to their scope of work, so there is no data overload. It is a closed corporate social network where a multidisciplinary group of professionals is focused on resolving a particular business problem. They have an inherent alert infrastructure that propagates status changes, flags missed deadlines or small delays in other departments which may jeopardize project outcome. Upper management is automatically kept informed. Actions are logged so they can be audited and actual durations became part of the corporate knowledge base.

There are multiple concurrent closed corporate social networks coexistent in any particular moment in time, addressing different business problems, each one with arbitrary number of participants. Each professional is participant to multiple networks and he/she interacts with those networks via two personalized views, specifically tailored for his/hers horizon of visibility: My Requests and My News Wall.

In My Requests view the participant sees all the requests he/she issued, all requests that he/she was a Recipient and all the requests that he/she was an Observer. By default, only active request are shown. From a selected request, the thread can be followed to any depth, activity examined, comments posted or statuses altered. If the participant is also a manager, the first level of subordination from the Organizational Breakdown structure is showed by default, to avoid data overload. Further sublevels can be expanded as necessary. If any RFA of a subordinate is flagged, his structure position is also flagged. The manager can review all the requests for any subordinate, and intervene with a message, recipient change or status alteration. This view can further be filtered by date interval, status, project or partner.

My News Wall shows the posts from his/hers horizon of visibility, from any open RFA that he/she participates in. By default, posts from level the participant was introduced in the thread are shown, but status changes and flags are shown from the current level and thread downstream. Selecting a particular post, the participant will easily respond, and the system will route it to appropriate RFA, while maintaining conversations structure within the RFA. My News Wall can be filtered by date interval, status, participant or topic/request.

MPCoord integration into project schedule

Beside the basic information elements a RFA contains, it has a number of additional attributes used to enhance the functionality of the model. Partner Code enables tracking and measuring of suppliers, subcontractors or any other project stakeholder and evaluating their performance data at the corporate level. The Project Code in a RFA allows coordination of any action at the project level. Scheduled Activity Code entry in a RFA will allow tracking of corporate processes pertinent to a particular schedule activity. There may be multiple RFAs that are attached to a single project activity. A RFA can have attachments that determine its *type* which allows for integration with corporate Business Process Management.

Any number of documents can be attached to a single RFA, generally in PDF form or one of the image types. They can result from an internal corporate information system report, like a PDF report of a Request for Materials, or a scanned image of an external document. In case of internal attachments, there is a single attachment declared primary that defines RFA type. If the RFA thread is a standard corporate process, a recognizable type of a RFA may be considered an element of a

Business Process Model (Bacun, 2017). In that case, the following standard steps are known, as well as organizational position of the Recipients. This introduces a possibility of automatically generate standard business process steps, timings and durations, with additional benefits of the MPCoord model. Such a generated thread could be easily modified by the participants while maintaining an auditable trace of the changes. Rigidity of designed business process models proved to be one of the major obstacles in Business Process Management adoption,.

Assigning a RFA to a specific project schedule activity is the method to integrate standard corporate processes into the project schedule. They present the requirements for fluent activity completion. There may be an arbitrary number of RFAs assigned to a single activity. This, in fact, depicts the reality. In the concrete pouring activity example, there will be a RFA issued to Concrete Production Plant, probably a Request for Materials issued to Procurement for other materials required for the activity duration, a RFA to the leader of the floating team of carpenters and possible another Request for Modification that needs approval. Each one of those RFAs addresses different group of professionals, at different corporate altitudes. Some of them need to be fully completed if the project activity is to be completed on time and within the budget, others might be less constrained. That means that their cumulative effect should be aggregated differently. The Sender, in the example case the project/site manager, issues a RFA to Concrete Production setting the deadline. In case of multiple RFAs he would also set its aggregate switch. The Recipient will set the estimated time, as well as pessimistic and optimistic time and issue any sub-requests. The same principles will apply to the sub-requests.

The resulting RFA thread represents a corporate business process and can tentatively be called a schedule, as all of them have start, deadline, duration, direction and necessary resources. In the RFA thread, there may be a chain of dozen or few dozen of activities so they cannot be compared to a full-fledged project schedule of few hundred or few thousands activities. However, considering the fact that there might be multiple RFA threads per activity, their number might come close to the number of schedule activities. If any unexpected development occurs in any of the RFAs, proper stakeholders will be notified immediately allowing preventive actions. As a side effect of RFA practice, every action taken is logged and audited, so it becomes a part of corporate knowledge base usable long after participants are no longer present.

The model adoption does not introduce any extra work in the everyday business process. Material Requisition Forms are written daily, Change Requests are always in writing as well as any other document needed to justify a project action. Sometimes they are written by hand, sometimes keyed into the information system and sometimes sent via accompanying email, but generally without the confirmation of receipt. There is no reason why such a message couldn't be posted on RFA History log so that all the stakeholders would be noted immediately. If the Recipient didn't see the new message, the system would alert. The Sender could then elevate the status to critical, alerting not only RFA participants, but also upper management.

Corporate interleaved schedules

Integration of regular business processes into project schedule creates a net of concurrent activities across the enterprise. In a multi-project environment the number of activities is elevated exponentially. Activities from different project schedules require resources at the same time. Resolutions are made on corporate meetings, generally inside a single department. The requirements are prioritized without enough time to evaluate time or cost consequences. Project leaders are possessive of their projects, highlighting their accomplishments but not boosting the shortcomings.

It is easy to imagine two projects competing on concrete delivery about the same time. If both projects had their RFA schedules in place, they would intersect at arbitrary altitude points in the Organizational Breakdown Structure. A forgotten obligatory maintenance check in the delivery fleet, not visible at the project level, might cause delays that might be significant for one or both projects or it might not be significant at all. With RFA business process schedules in place in both projects, we can evaluate its influence. We would not be forced to recalculate the whole grid, it would be enough to recalculate variances across the thread and re-evaluate the changes at the schedule activity, flagging the RFA chain if needed. If the activity is on the critical path, financial consequences might be imminent. If the activity is not on the critical path, the delay can be significant enough to change the critical path.

Integration of RFA business schedules and project schedules introduces an enterprise wide net of interleaved schedules executing concurrently. The activities are transparent across departments, monitored and audited. The complexity of such grid is managed by custom tailoring the horizon of visibility for each participant. Although Organizational Breakdown Structure is observed and upper management is kept in the loop with ability to intervene, this approach is problem oriented rather than business unit oriented. New developments are easily addressed with quickly created teams with members engaged per need basis.

CONCLUSIONS

Cost overruns and schedule delays represent one of the most serious problems in construction today and are not getting radically better across years. There is statistically significant correlation between schedule delays and cost overruns. Numerous delays are caused by events external to the project itself, often inside the contractor enterprise, in different departments. Lack of communication, low transparency across the enterprise and confined business unit processes lengthen the time needed to resolve an emerging problem.

This paper proposes a model integration of standard business processes into project schedule based on Multidimensional Preemptive Coordination. A business process step, represented by RFA, has direction and duration. A sequence of such steps can be considered a schedule. Integrating one or more business processes with project schedule activity, we describe business reality, because any business activity is dependent on different corporate business processes.

In a multi-project environment those schedules intersect at different organizational points and corporate altitude creating a grid of concurrent schedules. The proposed model coordinates those schedules, provides an alert infrastructure and provides an auditable trace of events increasing corporate accountability.

Although the basic model was implemented in Carpio-ERP Information System it wasn't tested with a larger amount of data so the effect of data aggregation on system performance couldn't be assessed. The next steps will involve the design of a simulation environment of about 50 projects with 500 to 5000 activities per project, 10 to 20 participants per RFA, and a daily message load for a period of one year.

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COST ENGINEERS AND POLITICIANS – THE PERFECT PARTNERSHIP

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Purpose

The purpose of this paper is to highlight the opportunity to improve investment outcomes for the Australian public.in public infrastructure projects. Cost Engineering and Risk Engineering are specialized areas of engineering however they do not fall within the traditional curricula at Australian Universities and are not well known by the general public as areas of engineering practice. There is an opportunity for Cost Engineers and Risk Engineers to have greater involvement in project assurance and control of public infrastructure projects to help ensure that appropriate analysis is performed prior to projects being selected, that appropriate budgets are allocated and to ensure that value is protected and costs controlled appropriately during execution.

The Department of Infrastructure, Regional Development and Cities has a very wide remit. It is at the forefront of the Australian Government's efforts to secure Australia's economic future and improve living standards. It achieves this through infrastructure planning, strategic investment in transport infrastructure, transport system reform, regulation of transport safety and strategic development of policies and programs. Politicians also carry a significant amount of power when it comes to government spending yet they do not have the same levels of education in engineering economics, project planning and risk management as professional cost engineers and economists. This combination of decision making power and limited knowledge could lead to inefficient use of public money if appropriate governance processes are not established. There is clear evidence that projects that are announced early by politicians tend to lack appropriate assessment by decision making bodies, result in less benefits being delivered for the community and significant cost blow-outs. The purpose of this paper is to examine the current governance processes for investments in public infrastructure and to explore the opportunity for cost engineers and risk engineers to have an appropriate role in the analysis of investments in projects.

Design/methodology/Approach

This paper first examines the existing research conducted on public infrastructure projects both globally and in Australia. The outcomes from these studies was then considered within the Australian context. The governance processes that currently exist in Australia were examined for potential imperfections and opportunities for improvement. Some of the opportunities for improvement in governance processes have then been developed further into practical steps that may be taken to help improve project selection processes and investment outcomes.

The analytical processes that are currently used in Australia, including those of the states and Territories, were examined to identify potential imperfections and opportunities for improvement. Some of the opportunities for improvement in analytical processes have then been developed further into practical steps that may be taken to help improve project selection processes and investment outcomes.

The required skills and competencies required of professionals who perform the analysis was also considered. Opportunities have been explored for providing assurance that those who are performing project analysis have the specialised skills and abilities required for analyzing potential investments. Some of the opportunities for improvement in analytical processes have then been developed further into practical steps that may be taken to help improve project selection processes and investment outcomes.

Findings/Results

The findings from existing research on problems associated with cost overruns generally followed two trains of thought. Firstly is the idea that strategic mis-representation is the cause of cost overruns versus poor estimating, planning and performance.

There is evidence of problems caused by both of these factors. In particular the research by the Grattan Institute provides compelling evidence that premature political announcements cause cost performance on projects to be vastly different to the expectations or promises made to the public.

From a performance perspective there is also a school of thought that it is natural for complex undertaking such as projects to be poorly estimated by virtue of the fact that their complexity makes them difficult to fully understand and predict, whereas simple projects are more predictable. extends the beyond the intellectual capacity were generally 2 paths – Bent Flyvberg – strategic misrepresentation.

The review of the current governance processes identified opportunities for improvement such as ensuring that politicians are not permitted to commit to a project until it has been analysed, passed an assurance review and only iof it is included on Infrastructure Australia's list of priority projects.

The review of analytical processes identified a number of opportunities for improvement including less reliance on P50 and greater reliance of the mean or expected value for economic analysis and funding so that the skewed distribution is better considered during assurance reviews and so that delivery agencies are not placed under unnecessary financial and reputational pressure during project delivery.

There is an opportunity for greater recognition and certification or registration of engineers with specialised skills in risk analysis, probability and statistics to help provide greater assurance that the analsysis is robust. By employing professional cost engineers and employing appropriate estimating processes, decision making frameworks and project control processes the outcomes on projects could be significantly improved.

There is an opportunity for greater organization of data, recording and data and use of data for estimating future projects.

There is an opportunity for significant savings and improved use of capital by managing contingency at the portfolio level rather than at project level. By managing contingency at portfolio level the same level of confidence can be achieved with a lower level of funding required.

Implications/Originality/Value

The implications of this paper could provide widespread benefits for Government seeking to get the

maximum benefit from its investment in infrastructure by improving the decisions that are made, improving the assessment and allocation of contingency, improving the outcomes from projects as they are executed more effectively with the right processes and people and establishing a system of data collection and feedback so that project analysis improves in the future.. This would also result in improved outcomes, economics and living standards for communities as the right projects are selected and delivered in a more effective and professional manner. Last but not least the Cost Engineering profession would benefit with greater recognition, certification and registration of key competencies for project economics, risk analysis and project controls. The status of the profession would be improved and early career professionals would have a clearer pathway for professional development.

The value of these changes could be profound. Not just enabling a significant improvement in investment decision making in Australia. This is a global problem. These recommendations could potentially help mitigate the risk of cost overruns globally on private commercial projects as well as publically funded projects. These changes may help raise the profile of cost engineering globally and help us attract talent to our profession early in their career with a clear pathway with well recognized credentials. This paper proposes changes for consideration which may offer improvement in the current governance processes and may help resolve problems associated the lack of clear competency standards for cost and risk engineers.

Keywords: Risk, Economics, Cost Engineering, Decision Making, Project Control

CULTURAL BASIC ASSUMPTIONS OF CONSULTANT SUB-CULTURE IN PUBLIC SECTOR CONSTRUCTION PROJECTS: CASE STUDIES IN SRI LANKA

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Culture creates thinking and behavioural differences among construction project participants, which brings in risk of conflicts, relationship problems, innovation and knowledge sharing issues, and resistance to change. Cultural awareness becomes the initial step in the process of overcoming the aforementioned issues in project management. Among various cultural manifestations, basic assumptions are the essence of any culture. Knowledge on basic assumptions could help to predict the behaviours of project participants in a given situation and assist in project management processes. Consultant, being a dominant construction project participant, this research aims to derive the cultural basic assumptions of consultant in public sector building construction projects in Sri Lanka. This aim was approached through a case study research design. Three public sector building construction projects were selected based on theoretical sampling. Data were collected from each case using nine semi-structured interviews, two meeting observations and documentation per case. Data were analysed through code based content analysis. The findings revealed the existence of a dominant consultant sub-culture. The underlying basic assumptions of the consultant sub-culture were derived related to eleven cultural dimensions such as nature of human relationships, nature of reality and truth, nature of human nature, nature of human activity, nature of time, acceptance on homogeneity or diversity, motive for behaving, gender, unknowable and uncontrollable, state-individual relationship and, organization's relationship to its environment. Consultants in Sri Lankan public sector building construction projects believed more in; individual role authority, individualism, contract dominance, fate and uncontrollability, objective tests and processes and a mix of competition and cooperation. They further considered nature of human nature as evil and the precedent rights and responsibilities should accord the nation. Knowledge on these basic assumptions of the consultant could be effectively used during negotiations with the consultant and in conflict situations during project management, especially for relationship management.

Keywords: basic assumptions, consultant, construction project, culture, Sri Lanka.

INTRODUCTION

Culture is considered as the collective values and behaviours of a social group (Tijhuis, 2011). Culture carrying complex human behaviours and values and construction involving complex human activities in design, execution, occupation and disposal processes, together create culture in construction a complex phenomenon (Fellows and Liu, 2010). Construction project teams are formed with different participants from different organisations for a temporary period of time, which are called temporary multi organisations. These participants mainly include consultants, contractors, clients and other stakeholders (Ankrah et al., 2009).

Many difficulties seem to arise due to the conflicts of different business objectives, lack of sensitivity and differences in tolerance between these project participants, which are pertaining to cultural differences of the project participants. This brings out the importance of understanding organisational culture for successful project management (Fellows et al., 2007). Adi and Musbah (2016) indicate that cultural difference among construction project team members become one major factor negatively impacting the knowledge flow among the team members, which contributes to adverse project performances. Further, Langford et al. (2013) highlight how differences in cultural attitudes of project

team members create unsuccessful safety systems in construction projects. As per the findings of the research carried out by Kivrak et al. (2009) in United Kingdom about 'impacts of cultural differences on project success in construction', cultural awareness is a significant factor in determining the success or failure of a project. Accordingly, it is of paramount importance to understand the cultural orientation of construction project participants for improved project management.

There is only a limited number of popular studies to highlight the specific cultural behaviour of construction project consultant, who is a dominant (Othman et al. 2018) project participants. Lee and Cullen (2018) explain the cultural differences of the quantity surveying professionals, when working for consultants and contractors in the construction industry in United Kingdom. This highlights the importance of studying the consultants as a separate sub-culture. Further, most of these cultural studies focus on understanding the consultant's culture at organisational level, without a focus on their cultural existence at project level (refer Rameezdeen and Gunarathna, 2003). Hofstede indicates the importance of differentiating the level of culture in a cultural study by deriving distinct models of culture to understand culture at national level (Hofstede, 2001) and culture at organisational level (Hofstede, 1998). Kumaraswamy et al. (2002) elaborate organisational culture as a constituent of culture at project level in construction projects. Schein (2009) highlights the importance of studying the basic assumptions in a cultural setting out of other cultural manifestations for better understanding of the culture. Schein (2009) explains basic assumptions as the essence of any culture. Thus, this study aims to derive the cultural basic assumptions of consultant in public sector building construction projects in Sri Lanka. This paper presents a part of a bigger study, which attempts to derive the basic assumptions of client, contractor and consultant in public sector construction projects in Sri Lanka.

SUB-CULTURAL EXISTENCE AND CONSULTANT SUB-CULTURE IN CONSTRUCTION PROJECTS

Analysis of members in the construction industry unveils basic four levels of culture such as professional culture, business culture, national culture and family culture. This professional culture is considered as a social group within an industry segment (Tijhuis, 2011). In addition, Kumaraswamy et al. (2001, 2002) indicate that construction project culture consists of four basic types of sub-cultures such as organisational sub-culture, operational sub-culture, professional sub-culture and individualistic sub-culture. The interpretation of professional culture by Tijhuis (2011) is more in line with the Kumaraswamy et al. (2001, 2002). The latter authors explain that professional sub-culture in a construction project culture is influenced by the factors such as type of task or function, type of members and origin and history. Thus, it could be argued that the different members within the construction project team, such as contractor, consultant, client and other stakeholder contribute to the emergence of unique professional sub-cultures depending on the unique functions they preform and unique origins and histories they possess.

Studying on generic organisational culture, Schein (1996) elaborates that occupational sub-cultures generally dominate within the organisational context. Schein (1996) identified three types of occupational sub-cultures that could exist in any generic organisation such as 'engineering sub-culture', 'operator sub-culture' and 'executive sub-culture' related to three common types of occupations within any organisation. According to Chapman et al. (2011), engineering sub-culture (technocrats) includes individuals, who design and monitor the technology supporting of an organisation's operations; operator sub-culture includes individuals, who deliver products and services and, executive sub-culture includes individuals, who primarily focus on financial performance. Schein (1996) states that failure to understand the differences of these three basic occupational sub-cultures could negatively impact the effectiveness of organisational communication, learning and innovation. Applying the three sub-cultural interpretations to a public sector urban water agency in California, Rodger (2014) brings in empirical evidence on possibility of enhancing the capacity of organisational learning by strengthening each of engineering, operator and executive sub-culture.

Ankrah et al. (2005) indicate that construction projects could be considered as short-life organisations, similar to the interpretation of construction projects as temporary multi organisations as argued by Fellows et al. (2007). According to these authors, a construction project is different to an organisation, more or less due to its one-off or temporary nature only. Accordingly, with regard to the construction project context, it could be argued that engineering, operator and executive sub-cultures of Schein (1996) are coherent to the consultant, contractor and client sub-cultures in a construction project context. The engineering sub-culture is more in line with the consultant sub-culture, because, consultants are involved with design and related technical aspects (Othman et al. 2018) in a construction project. The operator sub-culture is more in line with contractor sub-culture, since contractor and their representatives involve in physical realisation (Kumaraswamy, 1996) of the construction product. The client sub-culture is more in line with the executive sub-culture because, clients are more involved with financial matters (Newcombe, 2003) in a construction project. The

Moreover, Schein (1996) claims that these occupational sub-cultures are dominant over all other levels and categories of sub-cultures within the organisational cultural context. Accordingly, it could be argued that the professional sub-cultures could be dominant over other sub-cultures such as organisational, operational and individualistic sub-cultures as indicated by Kumaraswamy et al. (2001, 2002) in a construction project. Figure 1 demonstrates a map between the three occupational sub-cultures proposed by Schein (1996) with the consultant, contractor and client sub-cultures of a construction project.

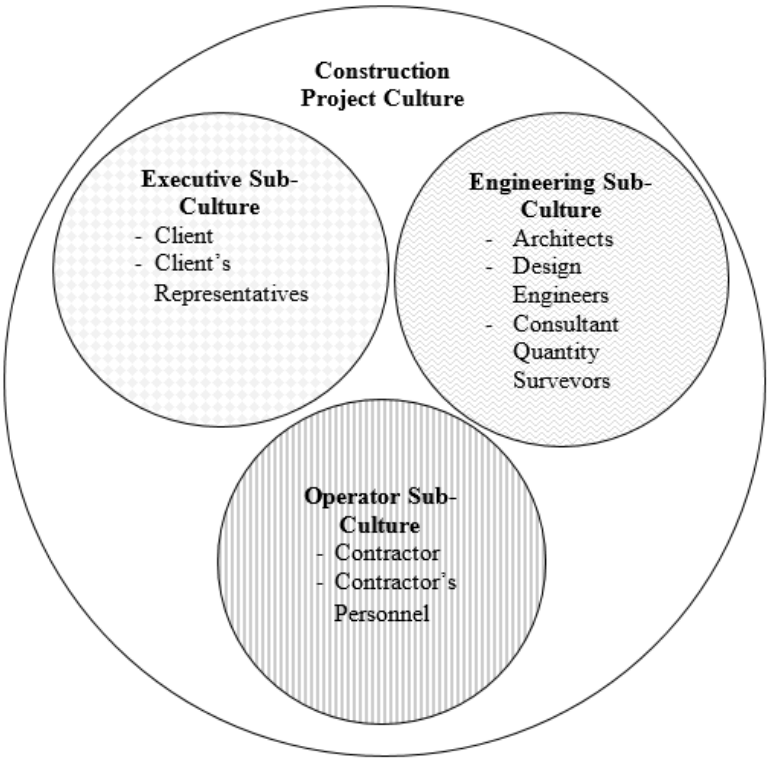

Figure 1: Three dominant sub-cultures in a construction project

Othman et al. (2018) highlight the importance of the role of the consultant in a construction project by indicating that construction projects could be successful only by having a good and proper engineering design and management, which need a decent knowledge and expertise by the consultants in the industry. There are only a limited number of studies among extant literature highlighting the specific cultural features of consultant. Further, these studies highlight the culture of

consultant at their organisational level in contrast to the project level. In comparison of organisational culture of contractors and consultants in Sri Lankan context, Rameezdeen and Gunarathna (2003) indicate that consultants in Sri Lanka prefer team work, group based reward systems, open communication; value loyalty and traditions and, participative in conduct. Further, leaders of consultants act a role of mentors. According to a Scotland based organisational culture study by Ankrah and Langford (2005), architects as a member of consultant's social group are very informal, highly tolerate ambiguity, relationship with mangers does not represent a source of power and achieve control and coordination through informal methods. In addition, Liu et al. (2004) indicate that ethical climate of consultant's quantity surveyors are focused on law and professional codes, where ethical climate of contractor's quantity surveyors are focused on personal morality. However, none of these studies elaborate the cultural orientation of the consultant in a project environment, during liaising with contractor, client and other stakeholders. Thus, knowledge created about the cultural orientation of consultant sub-culture would add more value to the effective management of construction projects.

UNDERLYING BASIC ASSUMPTIONS AS THE CULTURAL MANIFESTATION

The long list of cultural manifestations include behaviours, norms, symbols, histories, rituals, stories, formal practices, heroes, language to name few (Martin, 2002; 2004). Many researchers have attempted to interpret culture using values and underlying basic assumptions, considering their importance (refer Rokeach, 1979; Hills, 2002; Schwartz, 1994). However, Rousseau (1990) indicates basic assumptions as the core of any culture. Going in line with that Schein (1983) and Martin (2004) elaborate that it is the basic assumptions that need to be deciphered, if a cultural context to be understood properly. According to the interpretation of those authors, knowledge on basic assumptions could be used to better interpret all the other cultural manifestations. Kluckhohn and Strodtbeck (1961) introduce the Value Orientation Theory (VOT) to understand the basic assumptions in a cultural context. According to the VOT, there are limited number of common human problems for which we need to find solutions, and there could be a variability of for such solutions. These solutions for the common human problems are termed as cultural orientations or basic assumptions (refer Schein, 1990).

Schein (1983, 2009) identifies a set of such underlying basic assumptions of organisational culture, which are summarised in Table 1. Hills (2002) too identifies some underlying basic assumptions of culture at individual level, which are not included in Schein's (1983, 2009) work (refer Table 1). However, there is no such attempt popular for identifying the basic assumptions at project culture level in the extant literature. According to Table 1, Schein (1983, 2009) indicates possible cultural orientations (basic assumptions) for some cultural dimensions such as; the organisation's relationship to its environment, the nature of human activity, the nature of reality and truth, the nature of time, the nature of human nature, the nature of human relationships, homogeneity vs. diversity and unknowable and uncontrollable. Similarly, Hills (2002) indicates possible cultural orientations for some cultural dimensions such as; gender, the state-individual relationship and motive for behaving.

Table 1: Underlying basic assumptions of organisational culture

Cultural Dimension	Common Human Problems	Cultural Orientations (Basic Assumptions)
Adapted from Schein (1983, 2009)		
The organisation's relationship to its environment	Does the organisation perceive itself to be dominant, submissive, harmonising, searching out a niche?	- Dominant - Submissive - Harmonising - Searching out a niche

The nature of human activity	Is the "correct" way for humans to behave to be dominant, harmonising, or fatalistic?	- Dominant - Harmonising - fatalistic
The nature of reality and truth	How do we define what is true and what is not true; and how is truth ultimately determined both in the physical and social world? By pragmatic test, reliance on wisdom, or social consensus?	- Pragmatic test - Reliance on wisdom - Social consensus
The nature of time	What is our basic orientation in terms of past, present, and future, and what kinds of time units are most relevant for the conduct of daily affairs?	- Past - Present - Future
The nature of human nature	Are humans basically good, neutral, or evil, and is human nature perfectible or fixed?	- Good - Neutral - Evil
The nature of human relationships	What is the "correct" way for people to relate to each other, to distribute power and affection? Is life competitive or cooperative?	- Competitive - Cooperative
	Is the best way to organise society on the basis of individualism or groupism?	- Individualism - Groupism?
	Is the best authority system autocratic or participative?	- Autocratic - Participative
Homogeneity vs. diversity	Is the group best off if it is highly diverse or if it is highly homogeneous,	- Diverse - Homogeneous
	Should individuals in a group be encouraged to innovate or conform?	- Innovate - Conform
Unknowable and uncontrollable	Do we tend to believe in fate/god or not?	- believe in fate/god - do not believe
Adapted from Hills (2002)		
Gender	How should society distribute roles, power and responsibility between the genders?	- Male - Female - Both
The state-individual relationship	Should precedent right and responsibility be accorded the nation or the individual?	- Individual - Nation - Both
Motive for behaving	What should be the motive for behaving? Taking part in a purposeful activity (doing), take time to reflect and appreciate the meaning and value in what is done (being) or strive to develop, change, grow and be better (being-in-becoming)?	- Being - Being-in-becoming - Achievement (Doing)

Schein (2009) elaborates that basic assumptions emerge within a group, when the group members try to find solutions for internal integration and external adaptation problems. These Internal integration problems (those that deal with the group's ability to function as a group)include; language, boundaries, power and status, intimacy, rewards and punishments and ideology, while external adaptation problems (those that deal with the group's basic survival) include; strategy, goals, means of accomplishing goals, measuring performance and corrections. For example, an internal integration problem would be 'what way to share power among group members?' and an external adaptation

problem would be 'what means to be adapted to accomplish goals?' (Schein, 1990). Highlighting one important advantage about unveiling the basic assumptions of a group, Hills (2002) indicates that knowledge on basic assumptions could be effectively used during negotiation processes. The author brings in empirical evidences about an American native tribe, who effectively used the knowledge on cultural basic assumptions of major Americans to make their negotiations successful. This is because, basic assumptions unveil the unconscious processes in mind (Smircich, 1983) that guide other cultural manifestations such as behaviours.

METHODOLOGY

This research aims to derive the cultural basic assumptions of consultant in public sector building construction projects in Sri Lanka, carrying the research question of 'what are the underlying basic assumptions of consultant sub-cultural group in public sector construction projects in Sri Lanka?' However, this research paper presents only a part of a bigger study, which aims to derive basic assumptions of contractor, consultant and client sub-cultural groups in public sector construction projects in Sri Lanka.

Saunders et al. (2009) explain that a proper research strategy should be selected based on research questions and objectives, the extent of existing knowledge on the subject area to be researched, the amount of time and resources available and the philosophical underpinnings of the researcher. Yin (2003) elaborates, "what" type of research questions are appropriate with exploratory case study designs. Accordingly, case study was selected as the research strategy of this research, considering the type of research question and availability of limited time and access to construction projects. 'Construction project culture' was identified as the main unit of analysis. According to Eisenhardt (1989), number of cases should be decided based on theoretical sampling and not on statistical sampling. Considering the robustness of the data collection techniques used with proper data triangulation and expecting theoretical replication (Yin, 2003), three (03) number of cases (Project A, Project B and Project C) were selected for this study. The high data saturation experienced during data analysis justified the adequacy of the number of cases selected. All selected cases were building construction projects procured under the traditional procurement method with measure and pay contracts. Table 2 presents background details of the selected cases. Cultural specificity with regard to the national boundary (refer Kumaraswamy et al., 2001) and sectoral culture in terms of public sector and private sector (refer Nutt, 2005) are considered improving validity of research findings. As government was the major client to the construction industry, all cases were selected from public sector construction projects, expecting a higher worthiness of the research output. Considering the accessibility, cases were restricted to Sri Lankan construction industry. Past working history was allowed for the project participants in selected cases. Accordingly, Contractor and Consultant had worked together for a previous building project in Project A, Consultant had worked for a previous renovation project of the same Client in Project B and Contractor had worked for a previous renovation project of the same Client in Project C. Every project team consisted of a public sector client, government consultancy organisation and a private contractor organisation.

Table 2: Background details of the cases

Case	Project A	Project B	Project C
Type	Extension to a ministry headquarters	Government hospital building	Administration building of a government commission
Project Cost (Sri Lankan Rupees)	1317 millions	500 million	800 million
Project Duration (Construction Phase)	21 months	24 months	30 months

Physical construction progress by the time of data collection	65%	70%	60%

With regard to the data collection techniques, interviewing three personnel from each sub-cultural group of client, contractor and consultant from each case (total of 27 semi-structured interviews), observation of two progress review meetings for each case and documentary review of meeting minutes and contract documents were carried out in order to derive rich, in-depth qualitative data. Interview guideline and progress review meeting observation guideline included questioning and observing on internal integration problems and external adaptation problems. A pilot study was carried out to refine the interview and observation guidelines and to practise indirect questioning of internal integration and external adaptation problems to derive underlying basic assumptions. Code based content analysis was utilised to rigorously analyse qualitative data derived from the interviews, meeting observations and documentary review.

CASE STUDY FINDINGS

All three cases (Project A, Project B and Project C) contained evidences for the existence of dominant sub-cultural groups of consultant, contractor and client. These evidences included each party trying to defend themselves collectively in sub-cultural groups during project matters and each sub-cultural group had aspects they were reluctant to disclose to the other sub-cultural groups and kept only among the sub-cultural group members. These evidences were divulged both during progress review meeting observations and through the interview data.

The similarities and differences of the basic assumptions across the three cases; Projects A, B and C for consultant sub-cultural groups are analysed related to the eleven (11) cultural dimensions identified in literature review. Contractor, Consultant and Client of each of Project A, Project B and Project C are indicated as Contractor A, Contractor B, Contractor C, Consultant A, Consultant B, Consultant C, Client A, Client B and Client C respectively. Figure 2 presents a summary of basic assumptions of consultant sub-cultural group across Projects A, B and C.

Basic Assumptions of nature of human relationships – Consultants in all three cases held the basic assumption of 'individual role authority' as the best authority system within the construction project. They did not believe in a leader-centred, single point of authority. Consultant believed that project participants of contractor, client and consultant were under obligations to perform different tasks as per the construction and consultancy contracts thus, nobody was required to overlook the work of others and guide accordingly. They believed that perfect performance of individual roles would bring in project success. This could be an assumption stemming out from their role performance as professionals. They expected everybody to work as professionals, who could take the responsibility of the assigned roles. None of the construction or consultancy agreements identified a role as a Project Manager to lead, monitor, and control. Nevertheless, each case had an appointment as a Project Manager from consultants' personnel, despite being a contractual requirement. However, in all three cases, Project Manager's role was restricted to coordination only. Project Manager did not have full authority over all the works being carried out in the project. Individual consultant's personnel such as, architect, quantity surveyor, structural engineer, electrical engineer had the relevant authority within their area of work. Moreover, consultant witnessed that client's autocracy was governing in Projects A and B resulting negative outcomes. This amounted to the disappointment of the consultant, since it was against their belief on 'individual role autocracy'. Consultant considered it as an unnecessary intervention of the client, which led to demotivation as professionals. This behaviour was evident only with the politically powerful and highlight professional clients only. In Project C, where client was a layman depended on consultant's advice, did not demonstrate such client's domination.

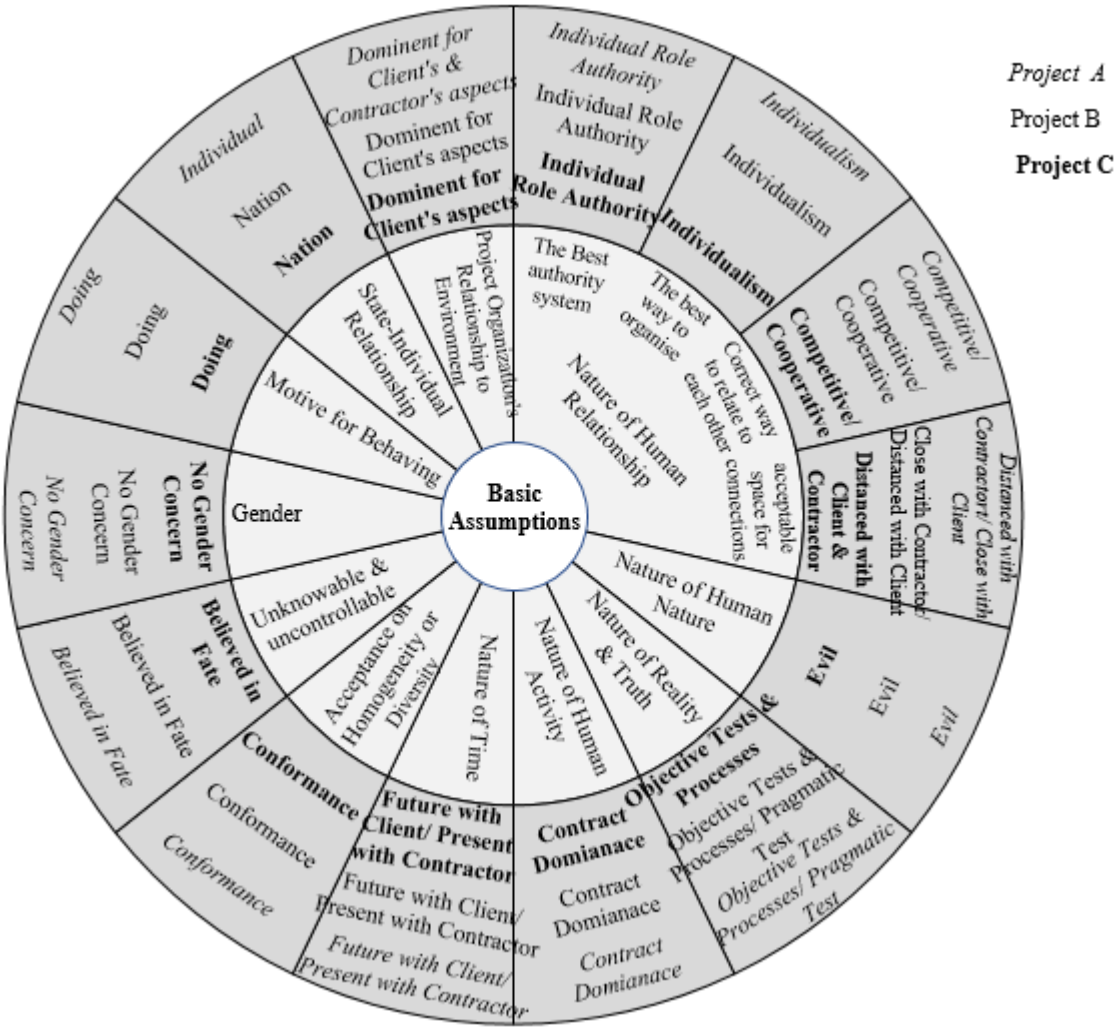

Figure 2: Basic assumptions of consultant sub culture in Projects A, B and C

Consultants in all three cases assumed 'individualism' as the best way to organise project society. This was mostly due to the project organisation structures of consultants in all three cases being less projectised and more matrix in set-up. Majority of consultants' personnel were not engaged fulltime in the project work and they worked in other parallel projects undertaken by the respective consultancy organisations. Contractors and clients complained over the lack of dedication of consultant's personnel due to this part time involvement with matrix project organisation structure.

Consultant held a mix of 'competitive and cooperative' assumptions on the correct way to relate to each other, to distribute power and affection within project context. They were mostly in competition with the contractor and mostly in cooperation with the client. Client generally tried to be cooperative with the consultant by depending on them as the technical advisor. However, there were situations in all three cases, where consultant was in some competition with the client, such as when highlighting mistaking of each other during progress review meetings. All the competitive assumptions had resulted due to power struggles within the team. Consultant tried to control the client by indicating lapses of the client, when client acted in too much domination over the team. A similar approach was taken towards the contractor too, to keep the contractor under the control of consultant. However, this competitive nature with the contractor was reduced when consultant had developed close connections with the contractor in terms of sharing privacy between the two. Consultant further believed that it was difficult to solely depend on formal methods of communication with the

contractor and client, if communication was to happen effectively and efficiently. Mostly, architects indicated the difficulty in conveying their designs to contractors only based on formal written communication modes, thus expecting some cooperation from team members to adopt informal communication modes.

In addition to the three perspectives demonstrating nature of human relationships such as the best authority system, the best way to organise project society and the correct way to relate to each other, to distribute power and affection another perspective could be identified for the determination of the nature of human relationship out of case data. This was about looking into what was the acceptable space for cognitive, emotional and behavioural connection by the consultant. The acceptable space could be either close or distanced. The preference of the consultant over close or distanced connections with other team members for cognitive, emotional and behavioural connections was unpredictable in all three cases. Consultant A had a 'close' connection with the Client A and Consultant B had a 'close' connection with the Contractor B. As per the three cases, such close connections were free from the effects of previous work experiences together and organisational strategic competitive advantages on long term relationship building. Consultant C had no close connections with the Client C, although they had the organisational strategic competitive advantages on long term relationship building. It could be argued that such connections had occurred solely due to personnel preferences of the two parties engaged in.

Basic Assumptions of nature of human nature – Consultants in all three cases held a strong basic assumption of nature of human nature as 'evil'. Consultant had no practice of appreciating the work of the contractor. Appreciations were very rare. Lapses of contractor were notified by the consultant in writing. Meeting minutes were full of issues and lapses. Since consultant was mostly in competition with the contractor, consultant and contractor were portrayed as enemies in a cold battle in most occasions. This was apparent during progress review meeting observations by the researcher. A lack of trust between consultant and contractor was highlighted. For example, consultant believed that contractor was requesting all instructions in black and white due to lack of trust over consultant.

Basic Assumptions on the Nature of Reality and Truth – Consultants in all three cases mostly believed in 'objective tests and processes' as the means of determining reality and truth in construction project context. They believed better quality of construction output could be achieved, when documentation of contract conditions, specifications and drawings were done right at the beginning of the project than by chasing behind the contractor and monitoring time to time. Further, they believed that government consultants had a competitive advantage over other private sector consultants due to having all contract documentation done informatively. However, they had realised that solely depending on objective means did not work and assumed 'pragmatic tests together with objective tests and processes' as the best way reality and truth to be defined in the project context.

Basic Assumptions on the Nature of Human Activity – Consultants in all three cases assumed 'contract dominance' as the "correct" way for humans to behave within project context. They believed that the ultimate controls in a construction project were the contracts and everybody happened to obey the construction and consultancy contracts. Consultant A experienced Client A overriding the contract dominance with client's dominance due to being a politically powerful client. Expectation of the consultant was at providing a professional service to the client and too much interventions by the client had made them more disappointed.

Basic Assumptions on Nature of Time – With regard to the assumptions on nature of time unit, 'past' was not an important time unit for the consultant. Consultant A and Consultant B had past experience with the Contractor A and Client B respectively. However, Consultants A or B did not consider using the previous experience in any decision making of the current projects. For example, both Consultants

A and B had ended up appointing a completely a new team to work with Contractor A and Client B respectively, regardless of using the previous teams again for the Projects A and B. In contrast, it was evident that Contractor A appointed the same previous team for the Project A in order to use the learnings from past team work. Thus, 'past' was not a relevant time unit for the consultant and they did not consider past learnings having any advantage for their design efforts and subsequent construction supervisions. Consultant considered either 'future' or 'present' as the most relevant time unit for the conduct of daily affairs within the project context. Their selection of a time unit as relevant in decision making mostly based on the consultant's organisational strategic competitive advantage. If strategic competitive advantage was long term relationships with clients or contractors, consultant had the tendency to consider 'future' as the relevant time unit for daily affairs with clients and contractors. If consultant found no relevance of any team member supporting their strategic competitive advantage of long term relationships, 'present' was considered as the relevant time unit with those. In Projects A, B and C, consultants held the organisational strategic competitive advantage as long term relationship building with clients only. Therefore, they always behaved to strengthen the continuing relationships with clients in their daily affairs. However, they found contractors had no such advantage for them. Therefore, 'present' was the relevant time unit to conduct daily affairs with contractors.

Basic Assumptions on Acceptance on Homogeneity or Diversity - Construction project teams were inevitably diverse in nature. Therefore, team member had to accept the diversity of team composition without any hesitation. However, consultants in all three cases assumed that project team members were encouraged to 'conform' in public sector construction projects. Interview participants indicated two reasons why they failed to do innovations within the project such as fund restrictions in public sector projects and time restrictions. However, in Project A, which had no restriction for funding and in Project B, where time was not a restriction had no practice of innovation. As indicated by the Project Architect of Project C, innovations were deterred in public sector consultancy organisations, since the risks of such innovations happened to be borne by their superiors along the tall hierarchies in such organisations. Further, there were knowledge gaps in public sector structural design practices in Sri Lankan context to make all fabulous architectural designs a reality. Clients A and B indicated how much they were scared of getting adopted to new building services and systems such as Building Management Systems in new public sector buildings in Sri Lanka, having the maintenance of existing buildings and the related services were a challenge for them with existing staff. It was observed the project team deciding to omit the Building Management System of Project C, considering the difficulty for the Client C to adopt it. Accordingly, innovation had been restricted in Sri Lankan public sector building construction projects, when government consultancy organisations were involved and due to fear of adopting to new systems by clients. Further, strict adherence to given contract specifications as approved by the client was expected from the contractors by the consultants, which was the most risk averse for the consultants.

Basic Assumptions on Unknowable and Uncontrollable – With regard to unknowability and uncontrollability, all consultants in three cases highly believed in "uncontrollability and fate". They considered decisions made by public sector clients were mostly uncertain and they had embraced that uncertainty in their behaviour and thinking too. According to case evidences, change of decision makers in client's representatives made the project environment uncertain with changed decisions mostly. Such situations were experienced in all three cases. There were evidences from all three cases on failed efforts of consultants trying to freeze the designs at early stages of the project to reduce such uncertainties. Thus, consultants naturally believed on fate and uncontrollability and had a tendency to help clients along changed decisions for better client's satisfaction, without much objections. This behaviour of consultant was criticised by the contractor, indicating consultant could not control the change initiatives by client disrupting the smooth execution of project.

Basic Assumptions on Gender – Consultants in all three cases 'did not consider gender' in distribution of roles, power and responsibilities in project society. They held the belief that knowledge and ability were the major considerations for the involvement in a construction project and gender was insignificant. Consultants' teams in all three cases comprised of many female members at higher authority levels of each project. According to the explanations of many female team members of consultants, they were able to argue and justify their ideas without any difficulty among male members of the teams.

Basic Assumptions on Motive for Behaving – The dedication for project work was restricted for the consultant, when the project organisation structure was more matrix and less projectised. Majority of the consultant's personnel were not fulltime project staff and they had parallel other project works at the organisation too. Thus, when the organisation structure was less projectised, only focus of the consultant's personnel was to carry out the individually assigned tasks mostly individually indicating 'doing' as the motive for their behaviour. They were always in a hurry to finish off work and move on to the next project work. However, when the dedication of the consultant's personnel for the project work was high with a more projectised structure, they were more into 'being' by trying to provide a better service to the client and the contractor, taking time to reflect and appreciate the meaning and value in what they were doing.

Basic Assumptions on State-Individual Relationship – Being a government consultancy organisation and moreover, working for public sector construction projects, Consultants B and C indicated that they considered the precedent rights and responsibilities should be accorded the 'nation' always. They wanted to deliver the right quality for the public sector construction product, rather than satisfying individual client interests. However, Consultant A, who worked under a politically powerful client indicated following the precedent rights and responsibilities to be accorded the 'individual client'. This was because, they were was massively controlled by the client. More importantly, these public sector clients in all three cases could influence the consultant more than the contractor, since consultants were from public sector organisations.

Basic Assumptions on Project Organisation's Relationship to its Environment – All consultants in the three cases believed that the project organisation's relationship to its external environment was 'dominant', with regard to the aspects under the control of the client. They experienced public sector clients getting legal concessions in design and construction approvals. However, with regard to the aspects under the control of the contractor or consultant, project organisation's relationship to the environment was mostly 'submissive', if contractor's or consultant's organisational issues were not under proper control. Such contractor's organisational issues included lack of resources, poor systems and processes, finance issues and procurement issues etc. Similarly, consultant's organisational issues included lack of staff, poor systems and processes etc. However, there was a speciality when the client was politically powerful. For example, in Project A, consultant did not feel any submissiveness of any project aspect to its external environment, since all aspects were under the client's control. The lack of labour for the contractor was also sorted out by this client by providing labour from a government security force. Nevertheless, that was a very special scenario occurring in a project.

DISCUSSION

In pattern matching, basic assumptions of consultant at project culture level, identified through the case study had both similarities and differences to the cultural orientations of consultant at organisational level, as identified in extent literature. According to Rameezdeen and Gunarathna (2003), consultants in Sri Lankan construction industry preferred team work, open communication, participative working environment and believed in reward systems based on group, rather than individual. However, consultants at project level believed in individualism as the best way to organise project society, competition as the correct way to relate to each other and distribute power and

affection with the contractor and individual role authority as the best authority system. Though the consultants demonstrated collective thoughts and behaviours at organisational level, they held more individualistic orientations at project level with client and contractor. Case study findings indicated that consultant believed the project team members are encouraged to conform at project level. However, according to Rameezdeen and Gunarathna (2003), consultants held innovative orientations at organisational level. According to Ankrah and Langford (2005), architects as a member of consultant's social group were very informal in their orientation and had a high tolerance of ambiguity at organisational level. However, case study findings indicated that consultants at project level were very formal believing in contract dominance as the correct way for humans to behave and believed in conformance, without tolerating the ambiguities in the processes. With regard to the similarities of the case findings with popular literature, consultant believed in gender equality in distribution of roles, power and responsibilities among genders encouraging females to participate in decision making similar to male members at project level, which was more in line with the focus of the consultant for development of the human resources for achieving goals at the organisation level as described by Rameezdeen and Gunarathna (2003). The cultural orientation of the consultant at organisational level, believing relationship with the manager not bringing with it any influence and power in the organisation as described by the Ankrah and Langford (2005) was more line with the consultant at project level giving priority to task than relationships by believing on individual role performance, contract dominance and no gender concern.

CONCLUSIONS

This research intended to answer the research question 'what are the underlying basic assumptions of consultant sub-cultural group in public sector construction projects in Sri Lanka?' The research findings indicated the existence of dominant sub-cultures of consultant, client and contractor in construction project setting in Sri Lanka.

With regard to the underlying basic assumptions of the consultant sub-cultural group related to nature of human relationships, consultant believed: individual role authority as the best authority system; individualism as the best way to organise project society; a mix of competition and cooperation as the correct way to relate to each other, to distribute power and affection within project context and, acceptable space for cognitive, emotional and behavioural connection with other team members to be either close or distanced situationally. In addition, consultant believed that the nature of human nature as evil and strongly believed that that project team members were encouraged to conform in public sector construction projects in Sri Lanka. Moreover, they highly believed in uncontrollability and fate and did not consider gender in distribution of roles, power and responsibilities in project society. Consultant further held the basic assumptions that project organisation's relationship to its external environment as 'dominant', with regard to the aspects under the control of the client; contract dominance as the correct way for humans to behave within project context; 'future' or 'present' as the most relevant time unit for the conduct of daily affairs within the project context; objective tests and processes as the means of determining reality and truth; 'doing' as the motive for their behaviour and, the precedent rights and responsibilities should always be accorded the 'nation'.

These findings could be used during negotiations, where knowledge on basic assumptions of consultant could be used tactfully to make the negotiations successful by another party such as client or contractor. This is by not hurting or trying to change such assumptions of the consultant, but by purposefully supporting and tactfully using such assumptions during negotiations. For example, as the consultant believes on objective tests and processes as the correct way to define reality and truth, a negotiation should be supported with facts with concrete evidences rather than based on pragmatic tests for a negotiation to be successful with the consultants. In addition, this awareness of basic assumptions of the consultant could be used during conflict situations during project management, especially for relationship management. Further research directions include unveiling the basic assumptions of other project stakeholders in a construction project.

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Data Mining, Benchmarking to Achieve Cost Intelligence

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Extended Abstract:

Keywords: Big Data, Data Mining, Data Warehouse, Benchmarking, Business Intelligence, Cost Intelligence, Data Searching, Data Analysis, Data Comparison, Cost Modelling, Elemental Analysis

Purpose

After many years' practice, medium-to-large cost estimation companies have accumulated hundreds of estimation projects, and the repository continues to grow every day. For cost planners, how to utilise this valuable data asset to improve estimation productivity and quality is one of the most significant differentiators for cost intelligence performance.

This paper explores a number of analytical methods to illustrate practical ways for building and utilising the large volumes of business information effectively and efficiently based on modern Data Mining and Benchmarking techniques to contribute to the accuracy of the current cost estimation, such that an ultimate cost intelligence can be achieved.

Approach

Data Building Method

In order to have a genuine, trustable, high quality data repository for data mining purpose, it is vital to establish a dedicated, lean and clean data warehouse managed by a disciplined process. As a rule of thumb, only the Project Tenders and/or Final Account can be submitted to this data warehouse. In addition, special user permission needs to be defined and granted to users who and only who can submit data to the data warehouse.

Data Searching Method

In order to find similar projects efficiently from the data warehouse, a comprehensive data filtering mechanism needs to be established. The following are some of the standard key properties which need to be defined and attached to each estimation project before it is submitted to the data warehouse:

- Completion Date
- Type (school, hospital, apartment building, office building, etc.)
- Location (National or International)
- Gross Floor Area (GFA)
- Client Name
- Architect Name
- Final Cost

Additional customised properties need to be definable by users such that an estimation project can be associated with any tags based on the corporation's standards.

When a search is being performed, various filters can be specified for a combined search to quickly narrow down the matching result.

Data Analysis Method

In order to perform meaningful data comparison, a standard Elemental Analysis process needs to be conducted. In addition, a functional unit price could be very useful for comparison. In conjunction with the usage of Gross Floor Area (GFA), the following are typical data analysis results.

Typical Elemental Analysis Result:

- Upper Floors per m2
- Substructure per m2
- Roof per m2

Typical Functional Unit Result:

- Price per Bed (for a hospital project)
- Price per car park (for a card park project)
- Price per km (for a railway project)

Data Comparison Method

Flexible options need to be available when comparing cost plan data.

- Project Cross Reference

  Comparison performed within a single estimation project. E.g. Columns per level for a multi-level office building. This can also act as a bulk check.

- Projects Cross Reference

  Comparison performed among several estimation projects. E.g. elemental unit rates for similar cost plans. The lowest, highest, and average information will also be presented. In order to have a genuine comparison, the price values in different cost plans need to be automatically adjusted based on a nominated base line index before comparison is carried out.

Data Modeling Method

From the historical cost plan data, data points from similar estimation projects can be generated to compose a cost model, the data points of the current estimation project can be added to the model to reflect its cost position, e.g. above the trend line, below the trend line, on the trend line, etc. This not only verifies the accuracy of the current cost plan, but also predicts the future cost direction.

Findings/Results

Highly positive feedbacks have been received by a number of early adopters after the above methods are used for real estimation projects in production.

Iterations of enhancement have been applied and will be continuingly applied to the above methodologies to achieve better outcomes.

As different cost estimation tools are used by different cost estimation companies, there is an

overhead to import the historic estimation project data into the chosen tool to perform the data mining and benchmarking experiment. Microsoft Excel becomes an intermediate data format to support the import, that is, the historic estimation project data is exported from various tools into Excel documents, which have been subsequently imported into the chosen tool.

Conclusion

With a proven methodology, the ever growing cost information can be transformed into highly valuable business asset. The data mining and benchmarking techniques provide comprehensive, flexible and efficient methods to search and analyse the information which can significantly improve the quality of the cost planning practice.

DESIGN FOR MANUFACTURING & ASSEMBLY
PREFABRICATED PRE-FINISHED VOLUMETRIC CONSTRUCTION
(DfMA – PPVC)

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ABSTRACT

The Singapore government has been pushing for further improvement in the construction productivity level through the second Construction Productivity Roadmap since 2015 and have set aside 2nd tranche of S$450m of Construction Productivity Capability Fund (CPCF) as part of the Roadmap. A S$150m Public Sector Construction Productivity Fund (PSCPF) was introduced in February 2017 to spur the adoption of innovative and productivity solutions for public sector projects. This is further push with the Construction Industry Transformation Map (CITM).

The government is steering the Singapore's construction industry towards the direction of having more projects to adopt Design for Manufacturing and Assembly (DfMA) to achieve higher productivity through:

- Building a higher quality workforce
- Higher capital investment
- Promoting a better integrated construction value chain
- Improved quality of construction.

This paper reviews the various measures implemented by the authorities to facilitate the higher adoption of DfMA technologies in projects such as imposing mandatory technical requirements in land sales programme, stipulating technical guidelines on DfMA technologies, introducing key CITM initiatives enabling stakeholders' transformation towards the productivity targets.

The principal focus of the paper will be on the adoption of Pre-fabricated Pre-finished Volumetric Construction (PPVC) in Singapore, which fully embrace off site modular manufacturing technologies and pushes for better integration between the design and construction stage.

To fully release the benefits of DfMA - PPVC, the industry needs to understand the unique challenges and limitations involving offsite manufacturing model and adapt changes to the conventional delivery/construction work process. DfMA – PPVC requires a different approach to procurement, in which design decisions towards offsite factory construction must be made at the very onset of the project. The process requires early involvement of the builder to work together with the designers during the design phase. Constructability Input from the builder can then be seamlessly incorporated into the design to attain a more effective and holistic technical solution. Thereby avoiding additional costs and time due to late induction and/or changes in detailing. It encourages the builder to involve in the project early through Early Contractors' Involvement.

It will share some of the key consideration from the procurement, contractual and cost perspective, which are considered for PPVC projects. As DfMA-PPVC differs from the traditional project as substantial amount of the work is undertaken off-site including overseas, there will be a need to look at some contractual implications such as the payment mechanism and project insurance arrangement.

The industry is still going through the learning curve of adopting PPVC, inevitably there are many other considerations that need to be thought through and resolved, such as alignment of the procurement and construction contract conditions with offsite manufacturing practices in mind. Hence, such projects would provide an opportunity for the professional quantity surveyors to lead on this key aspect.

Keywords: DfMA, PPVC, Procurement, Cost, Payment, Early Contractor Involvement.

DEVELOPING NEW STANDARDS OF MEASUREMENT FOR BUILDING WORKS IN MALAYSIA

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Purpose: Many industry players in Malaysia realize the need and importance of embracing BIM to be able to compete and win new construction projects. BIM is a time saver and cost saver as it allows those involved in the architecture, construction, quantity surveying and engineering field to identify problems even before construction begins. Realising the 5D BIM exigencies resulted in 3D models authored by designers, quantity production exercise is inevitably required some changes from its current practice. After years of efforts in understanding the effects BIM has on quantity surveying professions, Royal Institution of Surveyors Malaysia (RISM) has taken a well needed step to update and change the existing 18-years old Malaysia Standard Method of Measurement of Building Works for Quantity Surveyors also known as SMM2 and acknowledged that a more BIM-friendlier standard of measurement is direly to be established.

Design/methodology/Approach: A taskforce by the name of Standard Method of Measurement 3 (SMM3) Committee was set up by RISM which aims is to produce the new standards of measurement within an allocated time frame. The taskforce consists of around 25 members mainly from RISM and also representatives from public and private agencies or institutions such as the Malaysia Institute of Architects, The Institution ofEngineers Malaysia, Association of Consulting Engineers Malaysia, Construction Industry Development Board, Public Work Department, developers, contractors, sub-contractors, suppliers as well as QS academias fom different universities. The committee's first task was to make comparison between standards established by other countries i.e United Kingdom, Australia, Singapore and Hong Kong which have aligned their standards to the BIM requirements. This was followed by establishment of standard methods suitable to Malaysia's needs which majorly surrounds on the determination of a perfect and well justified formattings. Trades and elements were then identified and divided amongst the committee members for further study and development according to the established format. Focus group meetings and workshops were organised to validate the draft of standards developed by group members. It is now towards the end of the development stage, which upon completion, the draft will be presented to the industry for feedbacks before its publication.

Findings/Results: 3D modelling has provided not only a clear visualisation of a building design but also simplify the components that the designers have decided to include in the building. This simplicity however is heavily riched with information that is useful for quantity surveyors in producing quantities for costing. Hence, the approach taken for the new standards of measurement adopts the simplicity offered by this 3D models. Tabulated method is found to be the way that not only it clearly signifies the information required for each item, but also the flow it should be written in a standard bill of quantities. The format for every trades or elements can be divided into two sections where the first one highlight the rules to be adhered and the second one is on the measured item. The rules highlighted as guidance in the first section are 1] information that should be provided in the specification; 2] information to be input into the 3D model by the modeller; 3] specific rules of measurement; and 4] works and materials deemed included and to be stated in the Preambles. As common as the abovementioned rules seems to be, no 2 however emphasises the information that the 3D model should have in order to allow auto-generation of quantity according to the standards. This somehow leads to a new paradigm that quantity surveyors have to adopt a new set of skills in modelling to enable them to input the required family parameters into the models. The second

section breakdowns the detailed information on items or works to be measured and the cascading features that guide users on how to describe the item in the bills of quantities. It includes types of categorisations of the measured work, sizes, method of installation or fixing and the like.

Implications/Originality/Value: 5D BIM overwhelmingly demands quantity surveying to be more dynamics, innovative and acclimatise to the new technology available which is widely adopted by other designers otherwise quantity surveying will be trailing behind them in term of productivity performances. The new standards of measurement determined to shy away from the long phrases and clauses that the SMM2 has been known for. It marks the sustainability of the profession in the new era of construction industry where BIM is given the priority to enable the efficiency being effectively restored in a construction project. This new standards of measurement is hoped to be a sufficient guidance to quantity surveyors in quantity production and it is also would help to spur the adoption of BIM in quantity surveying profession.

Keywords: BIM, 3D models, 5D BIM, standard method of measurement, new rules of measurement

EVALUATION OF THE IMPACT OF CASH FLOW ON SUSTAINABLE CONSTRUCTION PROJECTS PERFORMANCE IN THE NIGER DELTA REGION OF NIGERIA

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ABSTRACT
Management of cash flow is fundamental to a successful and sustainable project delivery. There is no construction activity without an element of cost implication that metamorphoses to cash flow. Sustainable Construction projects' cash flow has been a source of great concern to industries' participants. There have been a lot of project surprises in terms of poor performance of construction projects in the industry during construction project execution. This paper aims to study cash flow impacts on successful and sustainable construction project performance. The study reviews cash flow impacts on 60 projects in the 6 core Niger Delta States of Nigeria. These projects represent the actual cash flow pattern in the construction industries and can be generalised. Ten (10) cash flow impacts from literatures formed the basis for analysis. These include project delays, abandonment, cost overrun, environmental hazards, users' restiveness, unemployment, inflation, poor quality, disputes and claims. Data were obtained through 180 structured questionnaires administered to construction projects' stakeholders and analysed using Relative Importance Index and Spearman's Rank Correlation Coefficient. The study reveals that there is a strong correlation between cash flow impact and sustainable construction project delivery where cash impacts are greater than 0.5 in all cases and the p -value for two-tailed test of significance is greater than 0.0005 .The impacts of cash flow must be given adequate attention to curb the menace. The study concludes that construction projects' successes and sustainability can only be achieved through prompt cash flow culture in the projects' life cycle. The study recommends that construction projects participants must plan for the impact of cash flow identified in this study and take proactive measures for sustainable construction projects performance through cash flow sustenance in the life cycle of the projects
(Keywords: Cash flow, Construction projects, Evaluation, Impact, Niger Delta).

INTRODUCTION
Construction projects are unique with distinct set out objectives with the integration of scarce resources and technologies to achieve desired goals. The construction industries unprecedentedly contribute greatly to the Gross Domestic Product (GDP) thus, its sustainability. Sustainability subscribes to living in the now and keeping for tomorrow. Sustainability in project context has been a growing concern due to resource constraints, increased number of stakeholders involved and the balanced requirement of environmental, economic and social activities (Martens and Carvalho, 2017, Schropfer et al. 2017, Banihashemi et al.2017, Siew 2016). It is crucial to integrate the tenets of sustainability which include environmental, social and economic factors into project process. These will challenge the project deliverables and process if the projects' goals must be achieved (Gareis et al.2013, Marcelino et al.2015).

The Nigerian construction industry continues to contribute greatly to the economic growth of the nation necessitating the need for effective cash flow sustainability through efficient financial management. Financial management is an important management tool and economic indicator of any business process. Financial management is an important indicator and sustainable cash flow is inert and most important resource to any construction projects' success and survival. Insolvencies and

bankruptcies are majorly attributed to poor financial management Nonetheless; the construction industry still suffers a lot of financial hiccup due to unsustainable cash flow. This can be likened to inadequate attention to cash flow management (Harris and Mc Caffer, 2001, Boussabaine and Kaka, 1998 and Calvert, 1996). Insolvency is the end product of inefficient cash flow management therefore; there is need for adequate cash flow forecast to circumvent cash traps (Harris and Mc Caffer, 2001). Proper cash flow management according to them will serve as predictive and preventive measures taken in good time. To embark on a successful project, there is need to understand the cash inflows and outflows for that project. The Niger Delta Region of Nigeria is characterised with a lot of activities especially in construction. As volatile as it can be viewed from the eyes of the world, it is the hub of commercial activities and the bedrock of our natural resource endowment. Though, this identity of its nature cannot be overemphasised owing to the many benefits accruable from the region in construction activities.

The construction industry is one sector of the economy characterised with construction activities cutting across in magnitude and size from public or private organisation. Construction projects are complex and full with uncertainties involving many stakeholders and have profound impacts on society(Van et al. 2008 and Chang et al. 2016), therefore stakeholders collaboration will enhance projects' deliverables to be met and at the same time ensuring high-level sustainability,(Kivila, and Vuorinen 2017, Silvius et al, 2012).

Huge capital outlay is involved if the project must be successful but more often than none; cash flow is usually a problem as project participants face a lot of cash traps in the course of projects' execution. Since the inception of construction activities, continuous cash flow has always been the challenge leading to project stalments and subsequently abandonment. The more cash an organisation generates, the more sustainable the project. Consistent and increased cash flow guarantees sustainable project performance.

Cash flow is paramount to sustainable construction project performance. It is the continuous inflow of liquid cash in the projects' life cycle. Management of these projects for sustainability is also important (Carvalho and Rabechini 2017). A serious challenge is imminent when there is any delay in the life cycle of the project due to cash trap. So, sustainability cash flow eliminates all these fears. Projects operatives must embark on extensive cash flow analysis spreading over the projects' duration to achieve sustainable projects' performance. Cash inflows help you to plan your financial commitments on the project.

Estimating cash flow of a project is necessary and one of the most crucial parts of capital budgeting There are lots of uncertainties and risks surrounding expected cash flows. These include not just economic factors but also the nation's policy on borrowing in terms of interest rate, technological and social factors. Cash flow impacts on all sphere of construction projects implementation programme. It is often used for forecasting for projects' execution, shortage or delay in cash flow could lead to project failure. There are available mathematical models in form of S-Curve to forecast cash flow with limited data, forecast and actual progress in linear distribution over residual duration of the project, (Navon, 1995). A proper Cash flow management plays a strategic role even when the firm is not facing financial stress (Yang et al., 2013).

Cash flow management is crucial in providing day-to-day support for construction activities during building projects, (Navon, 1996). This is so because; construction is often subjected to constant changes in delivery time, costs and available resources. It is important to understand the timing of liquid cash income and expenditure to the operating life cycle of the project.

Cash flow is the icon of all projects no matter the magnitude, its projection in terms of inflows and outflows is key and must be synchronised for sustainable construction project performance. This

paper aims to study cash flow impacts on successful and sustainable construction project performance in the Niger Delta Region of Nigeria.

CONCEPTUAL FRAMEWORK

The definition of Sustainability is widely disputed, and definitions vary depending on the context of its application, but here, sustainable development can be defined as "meeting the needs of current and future generations through the integration of environmental protection, social advancement and economic property. It is a process of embarking on development without neglecting the privileges of future generation. People must have right to safe and generally satisfactorily environment favourable to their development – conservation. Sustainability aims to ensure that renewable resources are not depleted and use of non-renewable resources are minimized

Sustainability could also be defined as the management of natural resources to support continued social and economic development in such a way that renewable resources are not depleted, and the impact of extraction and use of non-renewable is minimized. This allows for development but not at an acceptable cost to the natural environment.

Sustainability is relatively a new concept but one that has been widely accepted as a powerful way to envision the future and to move forward. The concept is a challenge to do things differently and to look for opportunities to improve in construction activities beneficial to the environment, society and economy at the same time rather than accepting trade-offs between them. Sustainability is seen as the only way forward for development. It provides the basis of hope for the future and vision for quality of life. The transition to a sustainable future is a long-term agenda that requires rethinking the way we live, use resources, govern and do business. Existing resources must be optimized and involvement of interest groups. In planning for construction projects, there must be deliberate consideration of how to maintain the quality of the environment, human well-being, and economic security in terms of cash flow projections

EVOLUTION OF SUSTAINABLE DEVELOPMENT

Sustainability concept was introduced in 1987 during a book launch. According to Brundtland (1987) in his book entitled "Our Common Future:" he defined Sustainable development as "meeting the needs of the present without compromising needs of the future generation to be met." He highlighted three fundamental components to sustainable development which includes environmental protection, economic growth and social equity. Construction activities seek to promote economic and social advancement that must avoid environmental degradation .His commission identified the apparent conflict between development and the environment, and came to the conclusion that while there ought to be development, It must be 'sustainable' that is, development pursued in ways that would protect resources and ecological integrity over the long term, while greatly improving human well-being, especially among the poor in infrastructure. Adequate and continuous cash flow is paramount to achieve this sustainable construction project performance.

The MDGs provide a set of global targets in economic, environmental and social development adopted by the UN in 2000 and are also crucial step in the progress towards sustainability. Managing these resources for sustainable development means using, conserving and enhancing the natural resources in such a manner that the ecological processes that underpin the quality of life are not compromised but managed to at least maintain and possibly enhance the total quality of life for every citizen. National resources are conserved, managed and used sustainably for the common good and in world renowned for been *clean, green and sustainable*. An environmentally informed and educated community is involved in transparent management and planning processes.

Understanding Quantification is one key to delivering environmentally sustainable assess – Mark Quinn 2003 – Gen 54. Seeking to prove financial (bankable) benefits of sustainable design rather than

less objective benefits, taking holistic approach to design evaluation and exploring all avenues for design evaluation are all environmental issues and principal impacts.

TEN (10) PRINCIPLES OF SUSTAINABILITY

ASHE Green Building Committee (2015) highlighted the sustainable principles into project delivery process. Projects are controlled to achieve the goals of sustainability, (Silvius and Schipper 2014). A construction projects becomes sustainable when it has integrated design, site design, water, energy, indoor environmental quality, materials and products, construction practices, commissioning, operation/maintenance and innovation. A construction projects adheres to these principles with there is an adequate and positive cash flow in the process. Cash they say answers to all things

CONFLICTS BETWEEN THE ENVIRONMENT AND CONSTRUCTION ACTIVITY

Construction clients and government recognize the significant impact the design, construction and occupation of buildings have on the environment and society. The construction industry and government have a central role in driving sustainable development agenda. Good sustainable design can deliver buildings with low running costs, an attribute that is highly attractive to both the society and business (Ochieng et al., 2018)

The impacts of construction industry should be brought into harmony with the environment and its contribution to overall economic growth should be exploited, all to the advantage of society at large. Similarly, the UN conference on Environmental Development (UNCED) held in Rio de Janeiro in June 1992, while understanding the importance of construction sector activities for overall socio-economic development, has included in its Agenda 21 a separate section titled: “promoting sustainable construction industry activities”. The agenda recommends a set of actions to be taken to reduce the impact of construction activities on the environment.

The agenda has placed such an importance on sustaining construction activities and practices within the environment since the construction industry is a major contributor to the overall socio-economic development in every country and a major consumer of natural non-renewable resources on the other hand, a significant polluter of the environment.

Recent studies showed that one-tenth (1/10) of the global economy is devoted to construction and operation of residential and office buildings and one-sixth (1/6) to one-half (½) of the world’s major resources are consumed by construction and related industries (Rainer Nordberg (2001). Building industry alone consumes 40% of the world’s energy, 25% of forest timber, 16% of world’s fresh water. 7% of sulphur oxides produced by fossil fuel combustion are produced through generation of electricity used to power homes and offices. 50% of Co_2 emissions (mainly in industrialized countries) are as a result of operations in building-in-use (heating and cooling). Indoor air quality is inadequate in 30% of buildings around the world. Current practices in construction industries are tilting towards a better living condition in a sustainable manner.

Industrialized countries have taken steps to arrest the implications of resource depletion and environmental degradation caused by construction activities, developing countries have made little progress in this regard.

It is however patently clear that some very relevant developments may influence the present future. The professions should understand this and be prepared to participate in a pro-active manner. Society must be assisted in developing the skills and desire to serve its own need aimed at sustainability through positive cash flow.

Countries are desperate considering that many of them do not have resources and capacities to improve their technologies and many are faced with a fragile environment, involving natural disaster such as desertification, earthquakes, storms, aridity, flood occurrences etc. not to mention the rapid population growth and the associated social, economic and environmental problems.

SOURCES OF CASH FLOW FOR SUSTAINABLE CONSTRUCTION PROJECT PERFORMANCE

There are many sources of cash inflow to contractors in project execution which include mobilisation, loans as debenture, overdraft and generated certificates, (Nnadi et al, 2017).

Construction projects are well known for their high risks, complexities and ambiguities entailing huge capital outlays and intricate site conditions. This calls for effective cash flow management to truncate incidence of business surprises. A lot of construction projects experience difficulties in project execution due to cash flow. Cash is king and *Cash flow is the life wire of any construction project. Being able to manage cash flows differs from success or failure of the project thereby culminating to sustainable construction project performance.* Managing cash flow is of great concern even under favourable condition; cash flow could still suffer due to timing of inflows and outflows. Usman et al (2016) asserted that it is difficult to effectively and effectively plan, forecast, monitor and control cash flow at the project or corporate level. This means that no particular cash flow method or model can effectively eliminate the impact of cash flow on construction projects. They also opined that, failure of prudent cash flow management can result to business failures, penalties, loss of opportunities, cost and time overruns. Hoseini et al. (2015) asserted that financial supply is the most critical challenge that always confronts contractors in all construction stages.

Cash is could be received in form of loan, claims, retention funds, change orders etc. In all these, the interest rate and payback period are crucial to the proper management of cash flow for sustainable construction project performance. When there is any delay in the flow of funds, the net cash flow becomes negative (Paul and Devi 2012).

FACTORS AFFECTING CASH FLOW FOR SUSTAINABLE CONSTRUCTION PROJECTS

Once there is any delay or disconnect in cash inflow, the projects' life cycle suffers drastically. There must be a connection between inflows and outflows Odeyinka et al. (2008) was able to identify and assess the extent of occurrences and impacts of risk factors responsible for the variation between the forecast and actual construction cash flow. They concluded that cash flow deficit could be resolved when industries operators embrace the use of developed software to aid cash flow forecasting (Odeyinka et al, 2003).

This is very much peculiar to this sector of the economy. Babil (2012) opined that the construction sector is experiencing an excessive rate of business failure than any other sector of the economy with 20.10% globally. The Niger Delta Region of Nigeria also has its fair share due to accessibility of funds at good interest rates by construction projects operators in addition to delay in contract awards, payment and actual construction.

Cunningham (2013) has highlighted some of these difficulties in the area of delay and underpayments by the clients and poor management of cash flow on the parts of the contractors leading to poor performance, low profits, increased overheads, diminished credit rating, deprived new opportunities and business failure. Planning, forecasting, monitoring and controlling cash flow is vital to achieving successful construction projects. Contractors' inabilities to manage their cash flow were strongly supported by some classic researchers around the globe.

Khalil et al (2012) revealed in their study the negative cash flow trends, patterns and their impacts on construction performance in various contracting organisation in the United Arab Emirates (UAE). They revealed that contractors can effectively and efficiently plan cash inflows in all phases of the projects to ensure successful and profitable projects.

Inadequate cash flow can be caused by several factors. These include; government policies, improper understanding of bank conditions, procedures and terms, delay in payment of interim certificate, mismanagement of funds, economic depression, inflationary trends, high cost of construction materials, high cost of borrowing capitals, cash retention, cash purchases fixed assets, investment in joint ventures, cash diversion and embezzlement, cash advances and loans to employees, overstock of inventory, bureaucratic bottleneck, (Nnadi et al. 2017)

Nuruddeen et al. (2106) highlighted twenty-five (25) factors affecting cash flow. These include; problem with foundation, change in progress payment duration, inclement weather, receiving front payment, archaeological remain, accident and theft, extent of float contract schedule, retention, delay in payment from client, lack of adequate insurance, loan repayment, weather condition, dispute between contract and chart, consultant instruction, delay in settling claims, materials delay, worker attitude, estimating error, renting and buying equipment, delay in agreeing variation, provision for phased handover, strikes, level of inflation, fluctuation and change in interest rate. The factors also include work stoppage, loan repayment etc. It is crucial for contractors to push their projects profitably and the ability to prepare adequate cash flow to execute the project with minimal financial expenses, (Elazouni et al, 2004).

The main factors affecting cash flow in construction is timing between cash inflow and outflow. Financial gap could also emanate from delayed payment , inaccurate cash forecast and cash flow management deficiencies (Paul and Devi 2012). Most construction projects suffer grossly after contracts have been awarded to possess the site for project commencement due to delayed payment to proceed to site in accordance with the agreement entered by projects' operatives. There seems to be a consensus amongst projects' stakeholders that payments are untimely by clients irrespective of explicitly laid down rules in the standard agreement forms and general provision (Abdul-Rahman and Kho 2013). Cash flow is all about timing. It is important to note these periods of cash movement within the mobile projects' life cycle.

In an attempt to reach a reliable level of liquidity, to run a sustainable business and to model the real business environment in the construction industry, it is essential to develop a financially sound analysis of the expected cash flow during all project stages (Hans and Park 2014)

Cash flow is what people deal with daily and a major point of contention on every project but its forecast can help drive a project to its logical completion or its prevention from happening. Kim and Grobler (2013) demonstrated how automated cash flow forecast was possible based on the information received from Building Information Modelling(BIM) using a prototype .Other school of thought developed a new stochastic simulation based framework for cash flow forecast of construction project at the tender stage in terms of payment delays from project owners(Hoseini et al, 2015). Cash flow forecast is paramount. Owing to the intrinsic importance of cash flow, cash flow analysis model was developed that can be applied by the contractor's at the project portfolio level.

STRATEGIES TO IMPROVE CASH FLOW IN CONSTRUCTION PROJECTS

Cash is king if business must be successful. It is important to inculcate well capitalised and proper cash management structure for construction project performance. The construction industry is well characterised and magnified by the peculiar and complex cash management challenges. Management of cash ought to be conceived before the actual implementation of the construction project.

Important decisions are crucial when considering a business proposal. The availability, accessibility and functionality of cash flow are some factors to consider before embarking and committing to any construction project to achieve sustainable project performance. Retainage, and Job financing are some of the strategies to improve cash flow for sustainable construction projects' performance.

RETAINAGE

This is the amount of billings which the client, contractor will have to hold back until a job is completed. There is a usually 15% retention at every interim payment stage of the project. In a situation where it is a challenge to keep aside this bill till project completion, it becomes a requirement for such money to be paid before project completion. It is healthy and beneficial for contractors to negotiate retainage in their project or mitigate its impact when interim payments are paid at which some part of retainage is paid too.

JOB FINANCING

Cash flow requirement is diverse for different projects. A lot of factors influence cash flow especially the client and other stakeholders on the project. It is pertinent to envision the time frame and resource available to commit cash to a project. Arranging for a job-level cash flow analysis by retrofitting the job schedule for the construction purpose will provide a vital data in ascertaining the cash impact a new project will have.

Project-level cash flow can be a great tool for understanding if a project could create an unsustainable cash crunch. It is critical that management of finances understands all the factors that impact their cash situations because mismanagement of cash can be a fatal flaw even when sustainable construction performance is imminent.

IMPACT OF CASH FLOW ON CONSTRUCTION PROJECTS

Cash flow impacts all aspects of construction projects implementation process. Cash flow shortages can lead to project failure and business bankruptcy, (Khalil et al. 2016). Some of the impacts of cash include the following but not limited to; project delays, abandonment, cost overrun, environmental hazards, users' restiveness, unemployment, inflation, poor quality, disputes and claims. Chakraborty et al (2015) and Wu (2017) opined that optimisation of resources, planning strict schedule and concurrently achieving sustainability-related objectives under such various challenging constraints is vital especially for large engineering construction projects.

METHODOLOGY

To justify the set objectives, literature reviews of related researches and quantitative approaches was employed.180 structured questionnaires were administered to construction projects' stakeholders operating in the core Niger Delta States. The population were construction projects carried out between 2008 to 2017 and respondents were construction professionals and contractors that were involved in the selected projects.

The questionnaires were sent to Quantity Surveyors Architects, Engineers, Builders and contractors. To eliminate bias according to Leed, (1980), systematic approach was employed in the companies' selections. 130 questionnaires were appropriately filled and returned representing 72.22% response rate which agrees with the 30% minimum response generally held for any area of interest in quantitative approach (Sheldon, 2016).

The questionnaire was developed using the factors affecting cash flow and the impacts of cash flow impacts on sustainable construction projects on 60 projects in the 6 core Niger Delta States of Nigeria elicited from previous literature. These projects represent the main categories of Nigeria construction industry in terms of cash flow. The preliminary section of the questionnaire dealt on the background information of the respondents while the other section focused on the factors affecting cash flow and impact of cash flow on sustainable construction project performance.

The findings from pilot survey showed the number of professionals and contractors, that is; Quantity Surveyors, Architects, Engineers, Builders and contractors that were involved in the projects to be one

hundred and thirty (130) in Rivers, Bayelsa, Delta, Akwa Ibom, Cross River and Edo States and analysed using Relative Importance Index and Spearman's Rank Correlation Coefficient. Chan and Kumaraswamy ((1997) and Kometa et al (1994) used the Relative Importance Index (RII) Method to analyse the data collected from the questionnaire survey. Analysis was carried out for each group of respondents. . Relative Importance Index was used to rank the factors affecting cash flow and the impact of cash flow on sustainable construction performance. The indices were then used to determine the rank of each item. These rankings enable factors to be compared the relative importance as indicated by the operatives. The weighted average for each item for the five groups of operatives was determined and the Ranks (R) were assigned to each as indicated by the five group of respondents. The RII was calculated for each item according to (Lim and Alum, 1995).

Relative Importance Index (RII) = $\frac{5n5+4n4+3n3+2n2+1n}{5n}$ (1)

n5 = Respondents for Strongly Agree
n4 = Respondents for Agree
n3 =Respondents for Neutral
n2 = Respondents for Disagree
n1 =Respondents for Strongly Disagree

The projects' operators were requested to score on a likert scale of 1-5 the severity of the impact of cash flow on their construction project performance with scale 5 representing strongly agree (SA), 4 represents Agree, 3 represents Neutral, 2 represents, and 1 represents strongly disagree. The stratified random sampling techniques were used. The questionnaires were structured in closed question and opened response manner. According to Wheather and Cook (2003), closed questions and opened response manner give respondents the opportunity to express other variety of opinions. Some closed-ended questions were easy to ask and quick to answer. They had a set number of responses. They required no writing by either respondent or interviewer, and their analysis were straight forward, (Nachimias and Nachimias, 1996). Frequency distribution and percentiles were used for the analysis of the preliminary data on the various groups that is, type of company or organization, years of experience of the respondent in construction and the respondent's professional background.

The statistical technique of Spearman's rank correlation coefficient was used for the evaluation of impact of cash flow for sustainable construction project performances. The spearman's rank correlation co-efficient is expressed as follows: Where d, is the difference between the ranks within each pair of data points and is the number of data paired.

$$Rs = \frac{1-6\sum d^2}{n(n^2-1)} \quad (2)$$

DATA PRESENTATION AND DISCUSSION OF FINDINDS

Prior to data collection , views were obtained from experts who were involved in construction industry and the results of a pilot survey carried out in selected sites. This was done to validate the contents of questionnaire for its relevance with Nigerian construction industry. The breakdown of the 130 questionnaires in terms of the nature of organisation, profession, professional body of affiliation, type of professional membership, highest academic qualification, nature of project executed, years of working experience, value of projects and the coverage of the study area are shown in table I. Rivers State recorded the highest number of respondents because the largest proportion of construction activities in the Niger Delta Region was available there.

Table I: SUMMARY OF BACKGROUND INFORMATION OF RESPONDENTS

Category	Classification	Frequency	Percentage (%)

Organisation type	Public client	54	41.54
	Private client	10	7.69
	Consultant	30	23.08
	Contractors	25	19.23
	Others	11	8.46
		130	100
Profession	Engineer	28	21.54
	Architect	24	18.46
	Quantity Surveyor	22	16.92
	Builder	26	20.00
	Contractors	30	23.08
		130	100
Professional Body	COREN	23	17.69
	ARCON	26	20.00
	QSRBN	22	16.92
	CORBON	30	23.08
	Others	29	22.31
		130	100
Professional Membership Type	Fellow	40	30.77
	Member	70	53.85
	Probationer	20	15.39
		130	100
Highest Academic Qualification	Ph.D.	25	19.23
	M.Sc./M.Tech/M.Eng	32	24.62
	PGD	25	19.23
	B.Sc./B.Tech/B.Eng	48	36.92
		130	100
Years of Working Experience	1-5 years	32	24.61
	6-10 years	29	22.31
	11-15 years	20	15.39
	16-20 years	25	19.23
	Over 20 years	24	18.46
		130	100
Contract Sum of projects executed within the last ten(10) years	1-10 Million Naira	35	26.92
	11-20 Million Naira	19	14.62
	21-30 Million Naira	22	16.92
	31-40 Million Naira	21	16.15
	41-50 Million Naira	18	13.85
	Over 50 Million Naira	15	11.54
		130	100

Table II Type of Construction Projects undertaken by Respondents

Projects	No.	Percentage (%)
Civil(Road/Bridge)	40	30.77
Sand filling and Shore protection	15	11.54
Heavy Eng.	5	3.85
Building	48	36.92
Electricity	11	8.46
Water	7	5.39
Others	4	3.08
Total	130	100

Table 111 Questionnaire Distribution within Study Area

State	Initial	Returned	Valid	(%) of valid questionnaire
Rivers	30	35	25	19.23
Bayelsa	30	27	23	17.69
Delta	30	30	22	16.92
Edo	30	25	22	16.92
Cross River	30	20	18	13.85
Akwa Ibom	30	30	20	15.39
Total	180	167	130	100

Table IV Summary of Survey Conducted

Parameter	Value
Number of questionnaire distributed	180
Number of responses returned	167
Number of valid responses	130
Percentage of responses	93
Percentage of valid responses	72

Table V Factors that affect Cash flow and ranking by the different respondents

		Engineer		Architect		Quantity Surveyor		Builder		Contractor		Weighted Average	
S/No	Factors	RII	R	RII	R	RII	R	RII	R	RII	R	RII	R
1	Problem with foundation	0.66	14th	0.88	5th	0.86	6th	0.81	12th	0.56	18th	0.75	10th
2	change in progress payment duration	0.72	12th	0.81	8th	0.71	14th	0.77	15th	0.95	2nd	0.79	7th
3	inclement weather	0.62	17th	0.65	14th	0.80	10th	0.75	16th	0.88	6th	0.74	12th
4	receiving front payment	0.85	6th	0.90	3rd	0.77	12th	0.95	2nd	0.97	1st	0.89	3rd
5	archaeological remain,	0.48	23rd	0.50	20th	0.62	19th	0.45	25th	0.50	20th	0.51	21st
6	accident and theft	0.55	21st	0.68	11th	0.70	15th	0.55	22nd	0.84	8th	0.66	17th
7	extent of float contract schedule	0.64	15th	0.77	9th	0.82	9th	0.65	18th	0.51	19th	0.68	16th
8	Retention	0.88	5th	0.62	15th	0.65	18th	0.68	17th	0.75	12th	0.72	14th
9	delay in payment from client	0.93	3rd	0.95	1st	0.95	2nd	0.90	6th	0.93	3rd	0.93	1st
10	lack of adequate insurance	0.51	22nd	0.56	18th	0.50	23rd	0.61	19th	0.67	16th	0.57	21st
11	loan repayment	0.56	20th	0.82	7th	0.67	17th	0.57	20th	0.45	21st	0.61	20th
12	weather condition	0.60	18th	0.67	12th	0.56	21st	0.46	24th	0.40	23rd	0.54	24th
13	dispute between contract and chart	0.59	19th	0.56	18th	0.90	4th	0.80	13th	0.73	14th	0.72	14th
14	consultant instruction	0.84	7th	0.85	6th	0.91	3rd	0.78	14th	0.85	7th	0.85	4th
15	delay in settling claims	0.81	8th	0.70	10th	0.88	5th	0.90	6th	0.81	9th	0.82	6th
16	materials delay	0.74	11th	0.52	21st	0.69	16th	0.88	9th	0.92	4th	0.75	10th
17	worker attitude	0.77	10th	0.66	13th	0.73	13th	0.85	10th	0.79	11th	0.76	8th
18	estimating error	0.63	16th	0.45	23rd	0.85	7th	0.56	21st	0.60	17th	0.62	19th
19	renting and buying equipment	0.80	9th	0.61	16th	0.55	22nd	0.83	11th	0.41	22nd	0.64	18th
20	delay in agreeing variation	0.70	13th	0.57	17th	0.78	11th	0.95	2nd	0.80	10th	0.76	9th
21	provision for phased handover	0.40	24th	0.49	22nd	0.45	25th	0.93	5th	0.30	25th	0.51	21st
22	Strikes	0.25	25th	0.40	24th	0.48	24th	0.50	23rd	0.35	24th	0.40	25th
23	level of inflation	0.90	4 th	0.30	25th	0.83	8th	0.94	4th	0.70	15th	0.73	13th
24	Fluctuation	0.97	1st	0.89	4th	0.98	1st	0.97	1t	0.75	12th	0.91	2nd
25	change in interest rate.	0.95	2nd	0.93	2nd	0.59	20th	0.89	8th	0.90	5th	0.85	4th

The questionnaire listed 25 general factors that affect cash flow, 10 impact of cash flow peculiar to the Niger Delta Region. Each respondent was asked to rate and rank each issue based on his or her professional judgment. The impact of cash flow were analysed and ranked according to their responses. As shown in Table V above, 25 factors that affected cash flow were tabulated and ranked accordingly to their relative importance indices from the various professionals This was later weighted all every professional ranked the factors from their professional expertise. The first 5 of the weighted average forms the basis for analysis.

Delay in payment by client ranked first (1st) with a relative importance index of 0.93, which shows that owners greatly influence cash flow with incessant cash traps. This was followed by fluctuation ranking

(2nd) with an RII of 0.91, which indicates that Nigeria has a track record of serious fluctuation in government. Change in interest rate and consultants' instruction ranked (4th) respectively with an RII of 0.85. Consultants must adhere to the terms and conditions of the contracts before issuance of instructions.

Table VI Relative Importance Indices (RII) and Ranks (R)) of ten (10) factors that affect cash flow peculiar to the Niger Delta Region

C1	DATA	C2	C3	C4	C5	C6	C7	C8	C9	C10	SUM	RII	RANK
		5		4		3		2		1			
1	Variation order	56	280	50	200	10	30	10	20	4	534	0.82	3
2	Fluctuation in prices of materials and labour	52	260	45	180	5	15	18	36	10	501	0.77	5
3	Procurement method	60	300	30	120	10	30	10	20	20	490	0.75	6
4	Delay	30	150	20	80	50	150	10	20	20	420	0.65	10
5	Size of project	20	100	40	160	30	90	20	40	20	545	0.84	1
6	Selection of incompetent contractor	60	300	50	200	10	30	5	10	5	545	0.84	1
7	Lack of proper project appraisal	55	275	40	160	20	60	5	10	10	515	0.79	4
8	Lack of proper analysis of tender	40	200	40	160	30	90	10	20	10	480	0.74	7
9	Government laws and policies	50	250	25	100	26	78	20	40	10	478	0.74	7
10	Unrealistic representation of client's needs and status	48	240	22	88	30	90	25	50	10	478	0.74	7

In the Niger Delta Region as shown on Table VI above, size of project and selection of incompetent contractors ranked (1st) with an RII of 0.84, followed by variation order ranking (3rd) with an RII of 0.82. Lack of proper project appraisal ranked (4th) position respectively with an RII of 0.79 while fluctuation in prices of labour and material ranked 5th with RII of 0.87. Size of project and contractors' selection are important elements of cash flow pattern.

Table VII Ranking of Impact of Cash Flow and its effects on sustainable construction project performance

	Factors	Impact of Cash flow		Cash flow on sustainable construction project performance		Weighted Average	
S/No.		RII	R	R11	R	RII	R
1	Project delays	0.98	2nd	0.95	1st	0.97	1st
2	Abandonment	0.97	3rd	0.91	2nd	0.94	2nd
3	Cost overrun	0.99	1st	0.85	3er	0.92	3rd
4	Environmental hazards	0.65	9th	0.77	6th	0.71	7th
5	Users' restiveness	0.60	10th	0.64	8th	0.62	10th
6	Unemployment	0.82	6th	0.82	5th	0.82	6th
7	Inflation	0.90	5th	0.84	4th	0.87	4th
8	Poor quality	0.70	8th	0.62	9th	0.66	9th
9	Disputes	0.75	7th	0.59	10th	0.67	8th
10	Claims	0.95	4th	0.70	7th	0.83	5th

Negative cash flow on the table ranked 1st with an RII of 0.97. This is closely followed by project abandonment ranking 2nd with an RII of 0.94. Cost overruns ranked 3rd with an RII of 0.92. These are negative impact on construction performance that must be viewed adequately from projects' inception in cash flow plans.

Table VIII Occurrence of negative cash flow in the projects' life cycle

Project Life Cycle	Frequency	Percentage (%)
Initiation and concept(feasibility)	15	11.54
Design and development(Design)	35	26.92
Implementation& commissioning(Construction)	80	61.54
Handover	-	-
Total	130	100

It is obvious that negative cash flow occurs majorly at the projects' implementation stage as depicted on table VIII. Cash flow management must be in force prior to this stage in construction.

Table IX CORRELATION OF IMPACT OF CASH FLOW ON SUSTAINABLE CONSTRUCTION PROJECT PERFORMANCE

S/No.	Impact of Cash flow	Data 1	Data 2	Rank 1	Rank 2	d	d^2
1	Project delays	0.98	0.95	2nd	1st	1	1
2	Abandonment	0.97	0.91	3rd	2nd	1	1
3	Cost overrun	0.99	0.85	1st	3rd	2	4
4	Environmental hazards	0.65	0.77	9th	6th	3	9
5	Users' restiveness	0.60	0.64	10th	8th	2	1
6	Unemployment	0.82	0.82	6th	5th	1	4
7	Inflation	0.90	0.84	5th	4th	1	1
8	Poor quality	0.70	0.62	8th	9th	1	1
9	Disputes	0.75	0.59	7th	10th	3	9
10	Claims	0.95	0.70	4th	7th	3	9
							$\sum d^2 = 38$

Using Spearman's rank correlation coefficient for the evaluation of impact of cash flow for sustainable construction project performance, whilst the student's test formed the basis for the hypotheses testing, which was to ascertain if significant difference exist between the rankings of the factors impacting on cash flow as accessed by projects' operators. The spearman's rank correlation co-efficient is expressed as follows: Where d is the difference between the ranks within each pair of data points and n is the number of data paired.

Spearman's Rank Correlation Formulae: $Rs = \frac{1-6\sum d^2}{n(n^2-1)}$

$$Rs(p) = \frac{1-6(38)}{10(10^2-1)} = \frac{228}{990} = 1 - 0.23 = 0.77$$

INTERPRETATION OF RESULT

Correlation varies between -1 and 1
Close to -1 = Negative
Close to 0 = No linear correlation
Close to1 = Positive Correlation

From the result, it shows that there is a strong positive correlation as the value of ρ moves toward 1 recording ρ = 0.77. This means that cash flow impacts positively on sustainable construction project performance.

CONCLUSION

Cash flow projection gives you a clearer view when there is cash inflow and outflow, allows you to plan and forecast for expected inflow and outflow. Positive cash flow accelerates the capital outlay for the organisation. The essence of this working capital must be well understood as it is crucial to the financial analysis and management of such construction projects. Cash inflow and outflow must be in tandem with the actual cash available for such projects.

Careful consideration should be given to cash flow implication when a project is in view and management of cash flow should be given top priority in the minds of projects' operatives throughout the projects' life cycle. This will enhance a positive cash return to clients and all stakeholders to truncate cash flow pitfalls. Job –level analysis can equally provide information at the feasibility stage and help maximise cash flow in the projects' life cycle. It is key to have cash management structure in place to be able to analyse and forecast cash expenditure in future cycle of the project.

RECOMMENDATION

Cash flow knowledge by projects' operatives is the lifeblood of any construction project and to effectively manage cash flows on projects. Below are some recommendations to successfully manage cash flows on a project to ensure it remains profitable from start to finish to achieving a sustainable construction project performance.

1. Your client must be known. Check out the creditworthiness of your potential client by getting a financial statement. There must be an assurance that they have the financial capability of paying you for works executed.
2. Realistic and profitable estimate. Project that's not going to be profitable should not be given a second thought. Managing cash flows is difficult enough on profitable projects. Do not rob Peter to pay Paul or take out unnecessary lines of credit to keep an unprofitable project going.
3. Cash flow forecast or projection. Create a reasonable cash flow projection or forecast for your project. Depending on the duration of the project, plan out how much work will be completed each week or month and the cost implication. Check how much you will be paying out to subcontractors and suppliers so you can have a general idea of how much cash you will have at any stage during your project. Compare your estimate to actual disbursements and receipts so you can make better forecasts in the future and in turn better manage cash flows.
4. Favorable contract terms. Payment terms and schedule must be in your best interest. Upfront costs of project mobilization must be recorded timely. Retention to be spread out as the project progresses or phased out completely with evidence of performance bonds.
5. Timely collection of payments. Documents must be ready as at payment due date for collection without delays.
6. Stay on top of change orders. Change orders can have a big impact on your cash flow so it is pertinent to know what you can and cannot charge for. Change orders should be clearly established in the contract. Keeping on top and document the extra work completed is essential.
7. Close out the project. Closing out a project and collecting final payment can be enforced. Effectively managing the final cash outflow can improve the timeliness of the final payment for project handover.

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FUNDAMENTAL CONCEPTS OF BUDGETING AND THE IMPORTANCE OF MATRIX BUDGET USE IN THE CONSTRUCTION INDUSTRY

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Abstract

Being a fundamental tool for the business growth and sustainable development, the budget presents itself to the inexperienced as a vast and complex field. Therefore, this article supports those who seek clear and direct understanding of the introductory concepts of budgeting. Moreover, it also presents some key points about the importance of the matrix budgeting methodology for the construction sector. It was developed aiming to contribute to the academic literature by gathering underlying information, through bibliographical research, about the initial fundaments of budgeting. The study begins by shading some light upon the purpose and importance of this tool. Further, it permeates with clarity the differences between the various types of budgetary methods, explains the financial records used as support for the process and gives a notion of the importance of the budget control for the sustainability of the business especially when it comes to infrastructure and civil construction firms. Furthermore, the aim of the research is reached by the simple explanation and consolidation of the basic theory behind the budgetary process and the clarification about the great importance of matrix budgeting for costs and general expenses control in the building business sector.

Keywords: budget, strategic planning, budget control, construction.

INTRODUCTION

Business budgeting is a valuable financial tool for all organizations of any size and area, including those in the building sector. Its application motivates the departments to achieve the strategic objectives, defines the responsibilities of all those involved within the corporate hierarchy, allows performance evaluation, maximizes decision assertiveness, provides the projected information manager that allows anticipating possible problems, and promotes a considerable improvement in the result due to increased control and constant revisions of existing expenditures.

The objective of this article is to contribute to the academy by compiling information about this powerful tool, evidencing the fundamentals, requirements, techniques, methods so that it can be deployed to plan and control activities. Then, among the approached methods, the matrix was taken with the purpose to highlight its importance in the expenses' control in large building corporations.

The sessions of this work were developed in order to present the importance, the fundamental concepts of the business budget and to succinctly describe the budgets that make up the budget process. In this sense, in addition to this introduction, the work is composed of seven sessions, the first one developed with the purpose of contextualizing the budget within the business plan and emphasizing the importance of translating the strategies into feasible plans. The second session presents and consolidates the fundamental concepts of the budget. The third one shows the benefits and advantages which are generated by the implementation of the budget. Session four, as a counterpoint, clearly sets out the obstacles and constraints of the budget. The fifth session brings the budget methods, followed by the sixth that exposes the importance of the matrix method to large construction corporations in relation to the management of its expenditures. The seventh presents the basic structures that permeate budget routines, such as its main reports, the Balance Sheet, the Statement of Income for the Year and the Statement of Cash Flows. And finally, a conclusion is presented. The goal of developing these items in this paper is to introduce the reader into the budget

subject, subsidizing it with tools and basic understandings that will help in building a solid foundation for further study on the subject.

The importance of business planning

It is reasonable to affirm that the planning does not represent a future decision making. However, business planning shows the results that can be obtained in the future by decision making at the present time. That means, one of the problems encountered by executives in making decisions is not what the company is going to do in the future, but rather what they should do today in order to prepare the company for the uncertainties of the future.

At the moment that a plan is being drawn up, one looks to the future and try to anticipate, today, the actions that will be executed over time, aiming at certain objectives. As these do not guarantee success nor the elimination of risks but allow greater assertiveness on the decisions (Sá, 2014).

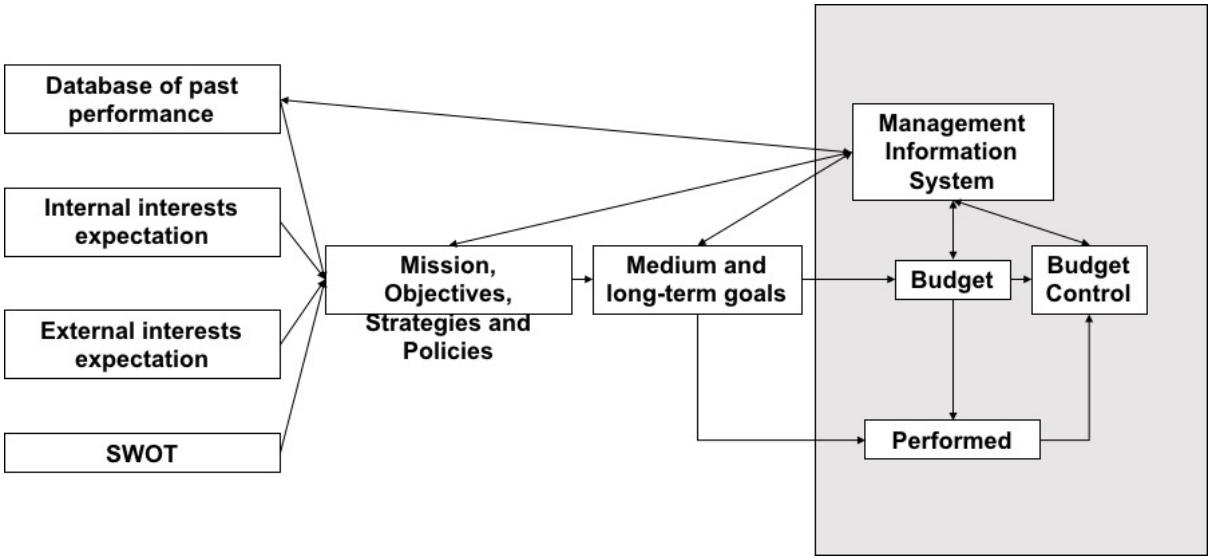
For example, in 2016, in Brazil, several companies, in response to the crisis, could be seen seeking cost cuts as a way of counterbalancing the result against falling sales. However, it was already known that 2016 would be an unfavorable year for the economy predicted by the outlook for 2015. Most financial institutions had already forecasted GDP to fall for the following year. It is unclear why so many companies cut costs in 2016. But one thing is sure, if well developed, applied, and followed up, the budget would allow companies to seek such cost reductions, not only when sales fall, but anticipated way to the facts creating a margin of safety against scenarios like the one occurred.

Business planning is a process that consists, among other activities, in the systematic analysis of the strengths and weaknesses of the company and the opportunities and threats of the external environment. This analysis leads to the establishment of objectives, strategies, and actions that allow an increase in business success. The business planning process is quite broad, being divided into strategic, tactical and operational planning. In strategic planning, company fundamentals are created such as mission, values, vision, among others (Cunha, 2000). It is also at this level that the strategic objectives of the organization are drawn in the short, medium and long-term. In tactical planning, there is the unfolding of strategies into goals, creating conditions for them to be realized. And there is also the alignment so that people, processes, and resources are directed towards the same goal. At the level of operational planning are the people who perform the actions and goals traced by the tactical level to achieve the aims of strategic decisions. The associates of this level are the technicians, operators, among others. They are the ones who execute the operations so that the strategies are drawn, and the objectives are reached in an efficient and effective way.

It is observed that the three levels are part of the business planning and are equally important, relying on its objectives and agents involved and active for the organization to achieve its results. In order to better understand the whole process of business planning and where Budget and budget control is inserted, note Figure 1:

Figure 1

Business Planning



Source: Adapted from Steiner (2014).

Figure 1 shows the relationship between the several elements that compose the organization planning process. The first element is the organization's database that offers past performance information. It represents one of the foundations for the development of the planning process. The expectations of external interests (of shareholders, clients, community, government, etc.) and internal ones (executives, employees, etc.) are sometimes conflicting and need to be considered in pursuit of the organization's objectives. The organization's long-term vision precedes short-term actions and plans. Thus, mission, vision, long-term goals, strategies, and policies must be defined and revised to allow consistency of attitudes and consistency throughout the planning time.

Defined, the strategic vision of the business, medium and long-term goals, it is possible to draw up the budget for one or more exercises of the organization. The budget is the instrument that implements the decisions of the strategic plan within a time horizon. For example, a particular company may aim to gain 10% market share and, at the same time, make profitability 25% pa.

After the medium and long-term goals and targets are defined, the company must set short-term goals, establishing the policies and actions of the various departments. Example:

- Sales department: as the goal is to gain market share, the average price will be reduced by 8%;
- Marketing department: marketing campaign will be held in January and March as a way to encourage increased sales;
- Purchasing Department: as a way of achieving the profitability target, one must seek raw material that maintains current quality standards but is less costly;
- Production department: to raise profitability and market share, the volume of production must be increased by 20% - there is a need to hire more employees and invest in new machinery; and
- Commercial advisory: as the current market does not allow the absorption of this new level of production, new markets will be sought to commercialize the production from commercial representatives in other states and countries.

It is important to note how important budgeting is to coordinate, balance departments, for a larger goal. Communication between departments is key to integrating decisions. The impact of one's decision will influence the other.

After the preparation, analysis, approval, and disclosure of the budget, it is time to follow up or control the budget. Budget control is how to monitor the organization's strategic plan within the corresponding budget period. This step is intended to correct deviations and to feedback your planning process. Therefore, the tools needed for business planning are strategic planning, annual budget, and budget control.

Fundamental Concepts

Budgeting

Budget is the formal quantitative expression of a strategic plan, the budget process being a statement in numbers of the desired level of a company's activities aligned with the short-term objectives. For Sanvicente and Santos (2012), planning is to plan in advance the actions to be carried out, estimate the resources to be used and define the corresponding attributions of responsibilities in relation to a given future period, so that the objectives set by the strategic plan for a company and its various units.

Consequently, the budget summarizes the objectives of a company, as it quantifies sales, production, cash generation and any other objectives desired by top management. It is the instrument capable of communicating and guiding business activities in pursuit of a larger goal, motivating those involved in the budget process to find possible deviations and solutions to achieve the goals.

The budget should not be understood as an exercise in using past data to project the future since it would only have incremental and inflationary vision. The budget is the technique of efficient allocation of resources and a powerful tool that assists managers in the decision-making process.

For example, the budget does not aim to project how much you spend in the budgeted period but how much you should spend versus what the manager projects from the scenario. In this sense, there are three basic decisions:

- Financing decision: how the company will raise funds;
- Investment decision: how the company will apply such resources; and
- Operational decision: how the company will use such resources to generate future benefits.

When executing the budget, in each one of these decisions, the manager will allocate looking for the efficient use of resources. Below are examples for the three decisions mentioned here:

- Funding Decision: It may be that funding source A is cheaper than B, but since source A is pegged to the dollar and the manager's perspective is for the dollar to appreciate, then it will use source B. Repair, reader: it may be that, in practice, the dollar does not have the expected valuation, but, at that moment, against the existing risks, the decision was successful.
- Investment Decision: In 1996, the Central Bank, through Resolution 2,283, reduced the mandatory amount that banks should have from permanent assets from 60% to 50% of banks adjusted net worth. Immediately, many banks sold their branches in auctions because they realized that with the proceeds from the sale of fixed assets, they would get more return by applying it available in their operation (for example, by borrowing);

- Operational Decision: For a given period, hotel managers can conclude that due to the high variability of revenue, it is not recommended to have a cleaning team of their own. It would be more interesting to hire an outsourced company because in the downturns the company would have less fixed expenses.

It is worth noting that the budget will not provide the manager with accurate data. Many see the budget as a tool that seeks accuracy. And on the other hand, there are those who are discouraged, claiming that the subjectivity of the budget does not make it a practical tool. However, a budget exists to chart a path to follow. In his book Powershift: Alvin Toffler (2003), he says, "In spite of everything, as we move toward the unknown land of tomorrow, it is better to have a general and incomplete map, subject to revisions, than not having a map none."

The word budget is used to describe an organization's overall business plan over a time horizon, in quantitative terms, in physical units of transaction volume, and in monetary units for the assessment of financial performance. It is important to highlight to approaches of budgeting: **investment budget and other special projects** - covers variable periods, since each project has a time dimension of its own, such as construction and expansion of physical facilities, abandonment of product lines or markets, campaigns for new products or services, training for application of new technologies, process re-engineering, transfer of activities to new location, research projects, pre-operational expenses, equipment exchange, among others. Note that it is not just capital or investment budgets that will be recorded based on their useful life and expected returns, but other special projects that will be posted as an expense for the period. This concept is broader and covers both capital and investment projects as well as all other special projects of the company that will have management and own budget and will become expenses of the period. These budgets should be presented and analysed by management, taking into account the economic feasibility study as well as the best time to implement them.

Projects must be planned for the entire period of their execution or duration, also known as project life cycle, and should be considered as special projects, although they must necessarily be integrated with other activities and operations of the company to establish the overall budget. For better understanding, we can define projects as a temporary effort undertaken to create a unique and exclusive product, service or result. The project life cycle comprises the time elapsed since its initiation, planning, execution, and closure. For efficient project management, large and medium-sized companies adopt, for example, the PMBOK - Project Management Body of Knowledge. The PMBOK is a guide that disseminates the best practices in project management based on the knowledge of professionals in the field. **Operational budgets** - cover periodic planning, usually annual, presenting the allocation of financial resources necessary to attend a certain level of activities. It allows the analysis of the results and the planned performances in this period. Note that periodic budgets are represented by a period of time in which all projects and operations in progress are measured, portrayed and contemplated.

After presenting the general concepts of the function of the budget in business planning, it can not be omitted that, in order to achieve the objectives measured in the budget plan, it is essential to use it as a control instrument.

Budget control

Exercising control over the budget is essentially tracking activity execution as quickly as possible by comparing the actual to the viable performance planned for the company and its departments or

subunits. Control is not the simple accompaniment; involves the generation of information that will serve to make decisions and eventual correction of performance achieved.

The budget will not achieve its objectives if during follow-up monitoring does not verify that the responsibilities, objectives, and targets are being properly met. Thus, the annual budgets should have a follow-up that can be bi-weekly, monthly, quarterly and semi-annual at the level of operations and activities represented in budget control reports.

It is important to emphasize that we must structure the budget planning and control according to the identifiable centres of responsibility in the organization. The usefulness of the control will only become a reality as the follow-up clearly points to the persons responsible for a particular type of specific performance or decision. Hence, control is based on an information system, whose products are the reports that provide timely and prompt indications for taking corrective measures.

Budget advantages

There are many advantages to adopting a budget planning for companies. It is important to establish clear goals to be achieved, based on the strategic plans and long-term objectives established for the whole company and for each responsibility centre or departments. Padoveze (2005) and Oliveira, Perez Júnior and Silva (2002) cite as advantages of adopting the budget:

- Define the responsibilities of executives, creating a commitment to think in accordance with business objectives;
- Shape the strategic plan, allowing prior analysis of future expectations, which makes it the best basis for comparison and evaluation of superior performance;
- Assist managers in coordinating efforts so that the organization's overall objectives harmonize, allowing the integration of activities, departments, and centers of responsibilities in the company;
- Standardize and formalize a communication tool, since each employee observes how their activities contribute to internal goals and the company's overall objective;
- Provide the organization of an operational control instrument, allowing the comparison of the results achieved with the pre-established objectives;
- Provide performance parameters that will serve as a benchmark for assessing business performance.

Despite the advantages highlighted in this part, the budget also has obstacles and limitations, which are exposed below.

Budget obstacles and limitations

The budget, like any other management tool, presents its limitations that should be considered by management, especially:

- The results of the budget process can be slow and this can cause frustration for those involved;
- The budget needs to create certain standards. When created in excess leads to a lack of flexibility, which may impede the creativity and entrepreneurship of sector managers and may lead to conformism, fear or dissatisfaction;
- The difficulty of using this tool in situations of variability above the expected budgeted scenario;
- Part of the budget process depends on the judgment of those involved. This subjectivity makes many think it is a process of advancement in terms of predictions of future quantitative data;

- The budget process consumes a lot of time and resources, and may also create an excess of accounting routines;
- Reliability in the budget system is a time-consuming process. Until the company creates a budget culture, innumerable difficulties, both of a technical nature and of the order of motivation of those involved will happen;
- The pursuit of goals may motivate some to have unethical behavior;
- Use of inappropriate information technologies.

It is important for the reader to know that budgeting, like any other management tool, is a constant learning exercise and can only be developed and achieved to a degree of effective use if practiced and improved in each period. All the problems or difficulties that arise in the process must be analysed and solutions found, thus making the process fit the structure and demand of the organization. The budget is a tool to help the manager. Therefore, it should be tailored to your needs as well as to the particular context of the company. To do so it must take different forms depending on the particularities of each company. This highlights the importance of the next session that offers the different budgeting methods.

Budgetary methods

An important issue in the implementation of budget and business control is to decide by the budget method that is most recommended to the economic activity, purpose or management model and organizational culture.

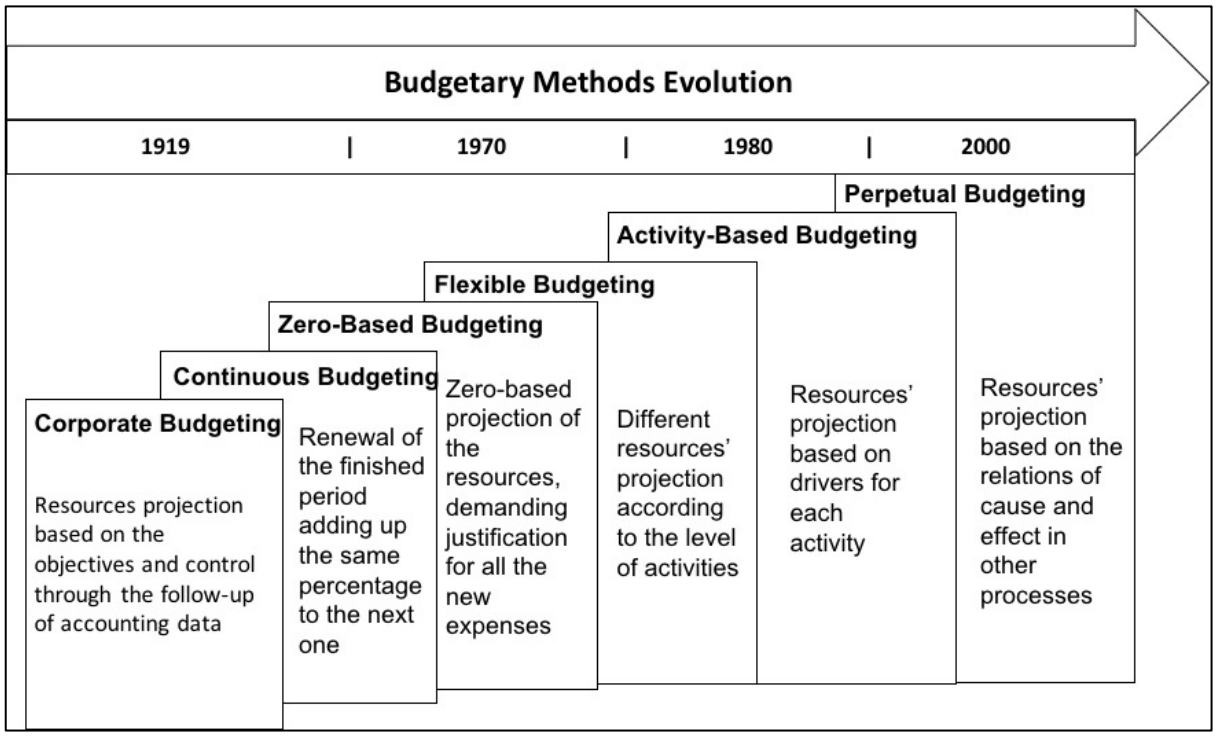
The purposes of the budget should determine its coverage period, and it is more usual to work annually by dividing it into months and/or quarters. The organization can establish the budget, considering the following functions:

- Unit of measurement - operational budget, project budget and financial budget;
- Transaction classification method - budget by resources, budget by activities, budget by departments or cost centres;
- Costs behavior - fixed budget, flexible budget;
- Planned analyses - business budget, flexible budget, by activities;
- Preparation form - zero-based budget, continuous budget, traditional budget.

The more traditional methods were presented by Lunkes (2010) on an evolutionary scale, starting with the business budget that emerged in 1919, following the perpetual budget that emerged from the year 2000. Figure 2 below shows the evolution of budgetary methods.

Figure 2

Budgetary methods evolution



Source: Lunkes (2010).

In the first phase, we observe the predominance of the so-called corporate budget, which focused on the projection of results for later control. The business budget is a plan containing the operational goals of the different areas to be controlled in the next period and takes into account a level of activity. It is designed to meet a level of activity for the next period (month, quarterly, yearly, etc.).

Then came the continuous budget which has as its emphasis on continuous review. The central objective of the ongoing budget is to continually update the operating budget. It is desirable and necessary that the replanning of the projections take into account the market circumstances and/or volatility of the macro environment. This removes data for the period just completed (month, quarter, or year) and adds budgeted data to the next period. So, for example, as soon the month of January is gone, the January budget for next year is prepared and so on. Therefore, the company will always have a budget for a 12-month horizon.

In this sequence, it came the emergence of the zero-based budget in which, for the projection of the data, it is considered as if the operations were starting at zero, and thus includes the need to justify all the expenses. In the zero-based budget, managers estimate and justify budgeted expenditures as if the company was starting operations (Sardinha, *et. al.,* 2008). So, it can be said that this budget rejects the traditional view that takes into account past data adding an additional. It aims to rediscuss all expenses whenever the budget process begins, questioning the need of each one of them. After all, it is not because the expense has occurred that it will have to occur later. The benefits of zero-based budget are:

- Allows more efficient allocation of resources because it questions the existence of past expenditures, allocating efforts in proven activities;
- Encourages managers to seek continuous improvement and highlights the activities that have the best cost x benefits;
- Helps detect the inflationary behavior of past expenditures;

- Causes greater communication between cost centres; and
- Shows managers the most essential activities and allows them to be more precisely correlated with strategic objectives.

However, there are some disadvantages that must be noticed:

- For starting from scratch and questioning all activities, the time consumed in the budget process is much greater;
- The justification for the importance of certain activities may be subjective in some respects. In addition, the determination of the various activities can be complex - especially when the company does the first time the implementation of the zero-based budget - including, many recommend that, in the former, the decision packages are surveyed more comprehensively;
- Requires that managers be committed and trained specifically for this type of tool because of the complexity of the budget process; and
- In small companies, the cost of implementation may be more expensive than the benefits. Already in a large company, the volume of information is so high that it can detract from the analysis.

The fourth budget is the flexible one, which is based on knowledge of cost behavior patterns and stands out by projecting data from budget pieces at various levels of activity. Flexible budgeting is prepared to cover a range of activities, so it can be used to estimate costs at any level of activity. That is, it can be adjusted according to changes in the actual activity level or revenue generation and compared to the actual cost for control effect. The flexible budget leads managers to calculate a broad set of changes in the business budget. Using the flexible budget in control we can highlight the operational and commercial efficiency that occurred during the period considered.

Activity-based budgeting emerges from activity-based costing (ABC) studies. This type of budget, for cost management, unfolds the centres of costs or responsibilities of the company in activities. The main function of an activity is to convert resources into products and services. According to Frezatti (2006), it represents a projection of the resources in the activities and the use of drivers to estimate and control the results. The activity budget uses the information about the drivers in the planning and evaluation process.

Finally, we have the perpetual budget that provides for costs and use of resources based on the analysis of cause and effect relationships. For the perpetual budget in the occurrence of a key event, the budget process must be suspended, and a new planning must be done. Based on the analysis of cause and effect, the expenses for new market opportunities caused by the event should be redirected. The budget process is reformulated to meet new needs.

Application and importance of matrix budget in the construction sector

In addition to all types of budgets presented here, there is also the matrix budget. In 1998, AMBEV developed this type, aiming at the 1999 budget. The project had surprising results generating an economy in the budget of fixed expenses of R $ 152 million in relation to 1998, according to Padoveze and Taranto (2009). The concept is that in the elaboration of the budget, the crossing of packages and entities in a matrix is performed - the packages being a set of accounting lines and the entities being the areas responsible for monitoring and controlling certain items. The company now has a horizontal view and a vertical view characterized by an analysis matrix. Thus, all revenues and expenses are classified in the matrix as a line of information and are allocated in relation to those responsible for

their management and departments that appear as column information. In the traditional budget model, column managers are responsible for managing all of their department's revenue and expense accounts. In the matrix model, we have a conceptual novelty when proposing the management of each line of revenue or expense, regardless of the primary responsibility of the person in charge of the column or department. Thus, the column manager is responsible for the budget piece of his department and accounts for his revenues and expenses, while the line manager is designated by the company as a specialist to help the department to budget better and should also respond to the company by the account.

The matrix budget implies double management for all revenues and expenses. Teamwork and the good relationship between the column manager and the line manager are fundamental in this type of budget. The matrix budget unfolds in three complementary tools, according to Vieira (2011):

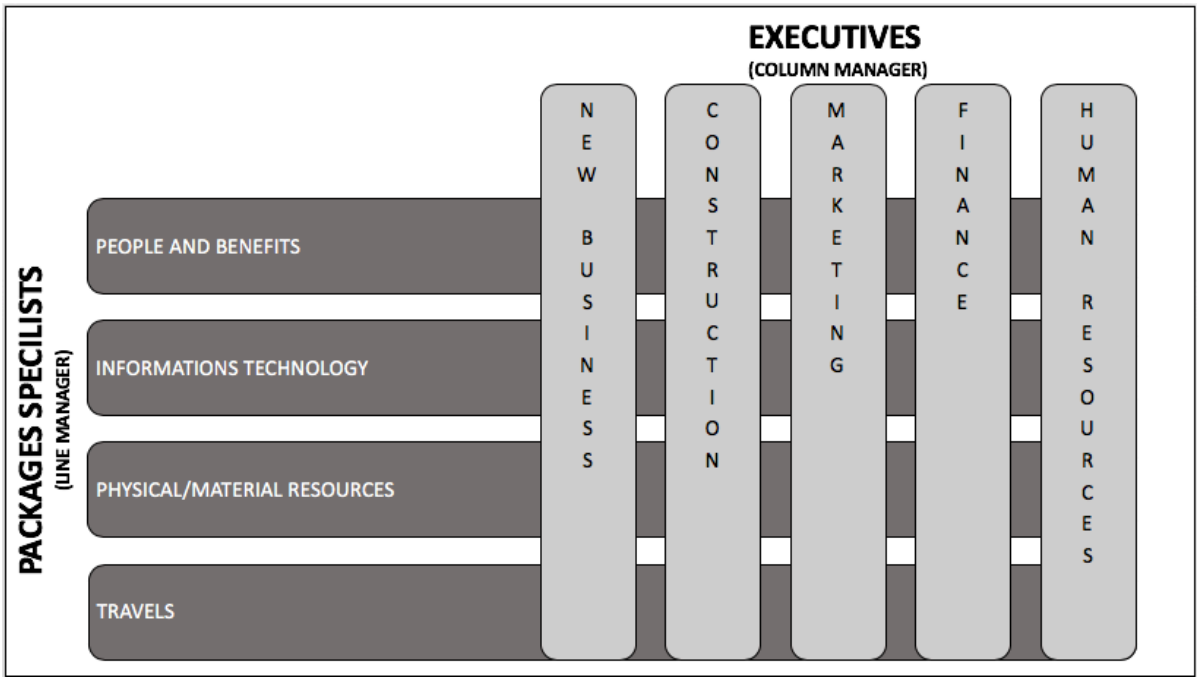
- Matrix expense management - MEM - aimed at reducing expenses.
- Matrix revenue management - MRM - aimed at maximizing results.
- Diagnosis of operational performance - DOP - aimed at reducing operating expenses.

The matrix budget is very important both in budgeting and in controlling it.

One of the most complex areas inside large corporations is budgeting and its control. Aiming to offer some insight that can help to reduce the risk of costs inflation in each area of the construction companies, this session was put forward. As above described, distinct from the traditional budgeting methodologies, the matrix budget proposes a division of expenses responsibilities between the lines' managers and the columns' ones. Therefore, an intersectionality of checks and balances are built up inside the company around of each expense package. Accordingly, while in the traditional budget model your foundation relies heavily on each manager's broad knowledge of their area of responsibility, the matrix budget submits this vast knowledge to the expert review of expense packages. This structure of work and double checks can be represented in the following manner:

Figure 3

Example of a matrix budget structure



Source: Coelho and Pontes (2018).

For the company readiness for the implementation of this type of budgeting method, a previous step must be taken, that is the underlying necessity of malleability in the hierarchy. And it is due to the decomposition of the expenditures through the organization and the liberty that the line manager should enjoy when questioning some kinds of expenditures behaviors (Coelho and Pontes, 2018).

Therefore, as exposed before, it becomes clear that is of utmost importance the alignment of the strategic assumptions with the adopted methodology.

Budgetary basic structure

The literature on the business budget gained relevance in the middle of the twentieth century, around the 1950s and 1960s, when large companies began to use it in their operations. However, it is important to highlight that its design and structure must be adapted to the level of complexity and detail desired to take into account the size, organizational culture, and area of activity of the company. In addition, since budgeting is a managerial tool, each manager can work the way he or she wants without being tied to accounting rules - as long as he or she manages the right information at the right time (Coelho and Pontes, 2018).

Although most of the concepts in this article are in line with what managers, consultants, and teachers practice, there is freedom for each company to tailor budget routines to their realities. What matters, in the end, is: how to direct the company to achieve certain objectives and whether they are being achieved throughout the execution.

The establishment of the business budget presupposes the systematic execution of actions of responsibility of the different sectors. This participation has advantages such as the prior communication of goals and targets to the sectors and the commitment generated among the various stakeholders.

There are several models of the budget process. They vary from company to company, there being no standard model. What is important is that it fulfills the objective of supporting the budget setting where the actions of planning, organizing the resources, coordinating actions and utilizing resources are being carried out in order to achieve the objectives and goals established in the strategic planning.

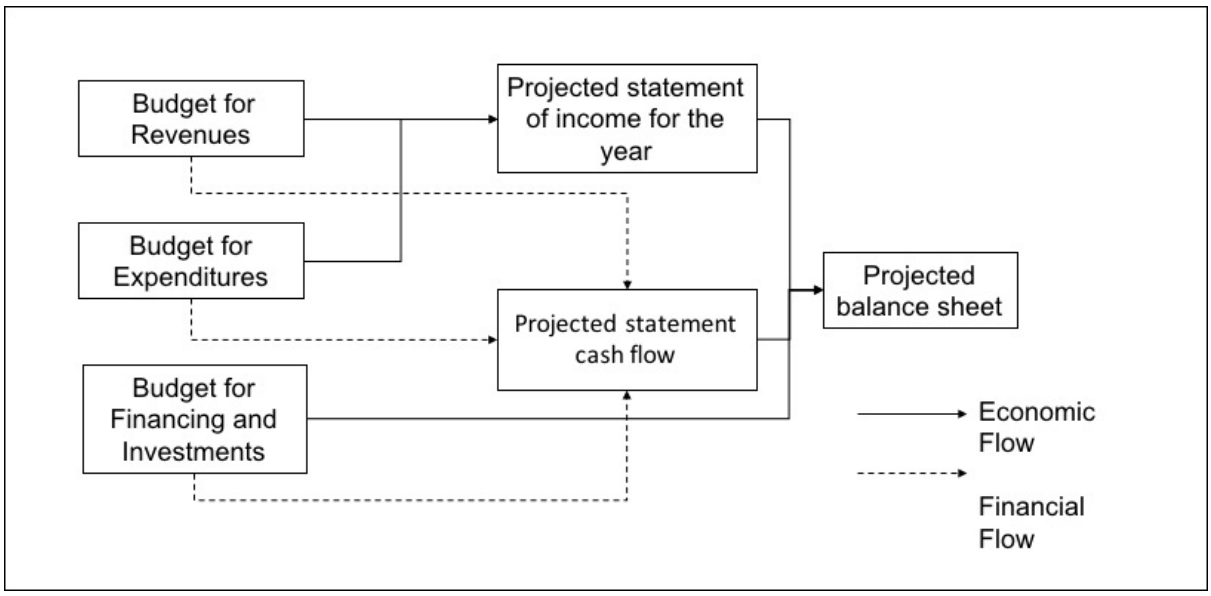
The budget process starts from the premises and objectives established in the strategic planning approved by the board and/or the presidency. This defines the policies and budget targets for the company.

Based on the policies and goals of each unit and/or centre of responsibility defines its strategies and quantifies them in budgets taking into account the individual goals. These budgets from each unit and/or centre of responsibilities are sent to the budget sector to consolidate and simulate the budget of the company as a whole. In this stage, the project budgets are also presented: systems, process mapping, infrastructure, organizational changes, continuous improvement, new products, among others. These project budgets should integrate the company's operating budget to establish the overall budget. If the simulation result meets the goals and targets set by the board and the presidency the budget goes to approval and then be disclosed to the entire organization. If the result of the simulation does not meet the objectives and targets, the budget is submitted to the presidency to establish new targets for the budget of each unit in order to meet the guidelines established in the strategic planning. Once the budget is approved and released, the budget sector begins to follow up

and control. The basic structure of the budget consists of the financial projections of the individual budgets of each unit or centre of responsibilities of the company, consolidating into a global budget piece for a given period. The overall budget is composed of a structure, as can be seen in Figure 4, below.

Figure 4

Business basic budgetary structure



Source: Coelho and Pontes (2018).

The budget consists of almost four parts: the budget for revenues, expenditures, financing, and investments, also known as project budget, and treated as such in this article and cash budget. The Budget of the Projected Statement of Income and Budget of the Projected Balance Sheet are the consequences of the others.

The revenue budget aims at estimating the company's sales, month by month, as well as, if necessary, estimating the nature, qualities, and quantities of the products and services and their respective prices. Its importance lies in the fact that this budget represents a limiter for other budget items (for most companies).

When overestimated, revenues force production budgets that are also overestimated and a whole preparation of resource utilization at a level above the actual needs, causing above-necessary expenses impacting on smaller profits. When underestimated, the company prepares for a production volume below the real needs, losing business opportunities and profits (Lunkes, 2003 and 2010). Thus, revenues must include any type of source, from the main source to the operational, to eventual, such as the sale of fixed assets, dividend income, and financial revenues.

The expenditure budget, comprising costs and expenses, represents the set of estimates of expenses related to revenue - such as sales commission and taxes - with products - as raw material and with the budgets of each different managers.

The budget for projects, also known as investments and financing, consists of estimating the number of investments required, as well as the financing used to carry them out (Padoveze and Taranto, 2009).

Lastly, along with the three budgets already mentioned, the company will survey all revenue collection and payment policies, as well as the inflow and outflow of investments and financing decisions, to measure, month by month, the company's cash flow.

Financial reports

The combination of budget parts produces three key financial reports: Cash Flow Statement projected month by month, the Statement of Income for the Year, and the Balance Sheet.

Demonstration of projected cash flow: The projected cash budget summarizes all estimates of inflows and outflows of financial resources in the enterprise. Accordingly, the quality of flow forecasts depends, in particular, on the degree of reliability of estimated values in the various budgets of the budget process. This budget has three basic objectives, namely:

- Predict the cash balance at the end of each period considered;
- Forecast the cash generation of the budgeted period;
- Determine whether the policies of receipt, payment, and storage are in tune.

Although the cash budget is prepared after the elaboration of the other budgets, due to its dependence on the use of the data elaborated by them, this does not show that this budget is less important than the others. Depending on the amounts determined in cash balances, in each period, it may be necessary to revise some of the previously established budgets, given the degree of impact on the company's cash flow (Churchill and Peter, 2000). It should not be forgotten that the budget process is an instrument for forecasting and coordinating resources for the achievement of the company's mission, and financial resources are among the most important in this process. The preparation of the cash budget presupposes the collection of two categories of data:

- Basic data: normal operating financial data of the company, such as operating revenues, raw material, labour, energy, among others; project data such as revenues and expenses with acquisition and sale of real estate, various equipment, implementation of new systems, among others.
- Complementary data: normal average terms of receipts and disbursements for the company, as well as the average term of storage; receipts or payments of bank interest; allowance for doubtful accounts arising from sales revenues.

Once the average maturity and disbursement deadlines have been defined and approved by the Budgets Committee, the other budgets should be prepared for receipt of revenues and payment of expenses.

- Projected statement of income for the year: The preparation of this statement aims to make it possible to forecast, for the year, the economic results of the company. Based on previous budget items, this statement also enables executives to estimate future results by assembling other budgets considering different cost and expense alternatives (Oliveira, Perez Junior, and Silva, 2002). This statement is important in assessing whether the company is able to achieve the shareholder's desired compensation goal. The data projected in the statement of income for the year are essential for the calculation of future profitability indicators.

An important detail worthy of a dedicated study is that in the business budget, unlike Financial Accounting, the income statement can be projected by the Direct or Variable Costing Method. In this method, there is a total segregation of fixed expenses and variable expenses in order to evaluate the evolution of the Contribution Margin, essential for the budgeting of fixed expenses.

Projected balance sheet: Many companies set their budgets in the budget process. There are several reasons; for example, its assembly helps to confer the assembly of the other budget pieces; enables an economic financial analysis of the company; and provides data for analysis of the company's working capital management.

In the light of all of the above, one can see that the fundamental concepts of the business budget, the budgets that make up the budget process and the main budget reports were presented. Understanding the basic concepts is what makes it possible to understand the various phases of the budget process.

Final considerations

The budget, the subject of this article, is not an isolated document, but it is part of the budget process that consists of planning, controlling, coordinating and, through the financial quantification of resources, motivating the members and respective sectors of an organization. So, succinctly, the budget is a plan that communicates the strategy to all sectors of the organization. From it establishes an agreement between the response of the sectors and direction of the organization, according to which next year, certain activities will be realized and, for that, will be spent monetary values previously agreed.

Budgeting is a fundamental management tool and should not be adopted as a policing mechanism. It is a system that directs the behavior of managers because it establishes a performance pattern in a way that evaluates the activities, results and helps to anticipate corrective actions assertively. We can say that the budget process is the main tool, or main source of information, that helps to reward or reward the people working in the organization.

As it was presented, after the elaboration of the budget, during the execution, one must act in the control. This control is performed, comparing the performance effectively obtained with the planned one, with the purpose of adopting corrective actions, in order to achieve the goals that converge to the planned strategy. Budgeting and control are two distinct but important phases that require collective participation in the process, which is essential for the commitment of all staff, motivating them in the pursuit of the planned goals. If the budget process directs human and financial resources in order to achieve congruent goals, control is a continuity to ensure its achievement.

As there is no possibility of going back to the company's past and promoting changes in the current scenario, what we have at hand is what we can implement in the present, with our eyes on what we estimate for the future, aiming to reach a new end.

Over time, many companies were born and subsist without the use of the budget tool. However, it is noticeable - through the study developed - that its use is essential for the company to map its risks, to control the various variables that affect the result, to allocate resources efficiently, to align budget items with strategic planning, and to evaluate the performance of all involved. Without it, a true development cannot be promoted or measured.

Finally, having achieved the objective of explaining and explaining the introductory contents of the budget, he hopes that this article will contribute to the consolidation of the budget literature and serve as a basis for further studies in the area.

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GRASSROOTS TO GRANDEUR: QUANTITY SURVEYORS AND HERITAGE BUILDING CONSERVATION

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Keywords: Heritage Buildings, Building Information Modelling, Quantity Surveyors, Conservation

Abstract

Heritage buildings are iconic and symbolize the backgrounds of a country in both historical and cultural contexts. It is significant for heritage buildings to be conserved and therefore, quantity surveyors are needed to estimate the costs of the conservation. However, estimation of heritage buildings conservation costs is tedious and different from conventional approach for new buildings. This is due to insufficient amount of data especially the as-built drawings which in most cases are unavailable and even if they are available, they are often outdated. Heritage Building Information Modelling (HBIM) platform with the utilization of 3D laser scanner provides a bridge to this issue. However, previous studies on HBIM focus mainly on the creation of as-built Building Information Modelling (BIM) model and very little is known about its potentials in enhancing the estimation of heritage building conservation works by the quantity surveyors. Therefore, this research seeks to demonstrate the potentials of HBIM with the utilization of 3D laser scanner in enhancing the estimation of heritage building conservation works by the quantity surveyors. To achieve the aim of this research, single case study approach is adopted, and a 150 years old heritage building is chosen as the case study. The findings reveal that HBIM with the utilization of 3D laser scanner can acquire 3D data which can be subsequently processed to create as-built BIM model that can be used for preparation of cost estimation. Essentially, this research corroborates that HBIM with the utilization of 3D laser scanner provides enhanced platform and processes for quantity surveyors in preparing cost estimation for conservation of heritage buildings. In conclusion, the digitalization of processes of cost estimation of conservation of heritage buildings significantly improve the grassroots services of quantity surveyors to grandeur.

INTRODUCTION

Quantity surveyors are one of the main professionals in construction industry. Also, they are often found in many sub-fields collaborating with other professionals (Lee and Lim, 2009). Since the past years, quantity surveyors are highly demanded in heritage building conservation works (Mustapa et al., 2005). Heritage buildings are iconic and symbolize the backgrounds of a country in both historical and cultural contexts. Therefore, it is substantial to conserve heritage buildings for future generations. Mustapa et al. (2005) reported that there are 39000 heritage buildings in Malaysia that are built between 1800 and 1948. Li Woon and Yoke Mui (2010) added that the listing of Malacca and Penang as UNESCO World Heritage Sites has enforced demand for heritage building conservation works. This has drawn more attention from the government and property owners to conserve their properties, and thus, quantity surveyors' expertise and professional practices are highly demanded for heritage building conservation works.

Harun (2011) explained that heritage building conservation works are activities that are carried out to enhance the life span of the building. It is different from construction of new building but quite like refurbishment of existing building (Yoke Mui et al., 2016; Quah, 1992). Typically, it involves small labour, but the operation is extremely intensive as the works are disseminated throughout the building. According to Lim and Ahmad (2015), in Malaysia, heritage building conservation works follow the traditional procured approach, by means of Bills of Quantities (Cunningham, 2016). The traditional procured approach is the most appropriate to select an expert contractor with competitive price (Lim and Ahmad, 2015). Regarding this, an accurate cost estimation is highly essential to provide the basis

for establishing the likely cost of resource elements of the tender price for conservation work (Li Woon and Yoke Mui., 2010). Accurate cost estimation is doable only with sufficient and accurate as-built drawings and information that quantity surveyors could use to perform quantity take-off in determining the amount of work required for heritage building conservation works (Lee and Lim, 2009; Skitmore and Wilcock, 1994; Chandler, 1991).

However, preparation of cost estimation for heritage building conservation works is complex as it is of different approach from preparation of cost estimation for new building work. Unlike new building work, heritage building conservation work might be impacted with insufficient as-built drawings and information. Sometimes, even if the as-built drawings and information are available, they might be outdated (Amano and Lou, 2016; Pawlowicz and Szafranko, 2015; Lim and Ahmad, 2015; Highfield and Gorse, 2009). Klein et al. (2012) added that there is also possibility that even if the as-built drawings and information are available, it might not be useful because it does not represent the current condition of the building (Amano and Lou, 2016; Shamkhi and Al-hajj, 2014; Highfield and Gorse, 2009; Ramsey, 2007). According to Ramsey (2007), as-built drawings and information of heritage building might not be accurate due to the improper maintenance of the building, building defects and changes that may have occurred to the building or its structure without proper documentation. Consequently, there is an essential need to reproduce as-built drawings and information by means of re-measurement to clarify any discrepancies between the as-built drawings and information and the current condition of the heritage buildings (Lee and Lim, 2009).

Re-measurement involves tedious processes of detailed investigation of building, measurement recording, photograph taking as well as on-site observation (Lee and Lim, 2009). Barbosa et al., (2016), Megahed, (2015) and Jung et al., (2014) further explained that the use of traditional tools for on-site measurement include total station, laser distance meters, digital cameras and measuring tapes. In these ways, all the dimensions of all building elements are manually measured and documented. However, conventional re-measurement process is laborious, prone to errors and time-consuming (Baik, 2017; Megahed, 2015; Jung et al., 2014; Arayici and Hamilton, 2005). Also, it is associated to various issues including health and safety, accessibility and physical contact with the building fabrics might cause alteration (Beckmann and Bowles, 2012; Woodly, 2006).

In response to the need for more efficient and less time-consuming reproduction of as-built drawings and information, Heritage Building Information Modelling (HBIM) with the utilization of 3D laser scanner have been introduced to substitute the conventional re-measurement (Baik, 2017; Cheng et al., 2015). 3D laser scanner is gaining rapid attention and usage in the architecture, engineering and construction (AEC) industry in heritage building conservation works due to its significant benefits (Bassier et al. 2017; Jung et al., 2014). Djuricica et al. (2016) added that 3D laser scanner can produce valuable and accurate measurement in a non-destructive manner.

Previous studies on HBIM focus mainly on the creation of as-built Building Information Modelling (BIM) model and very little is known about its potentials in enhancing the estimation of heritage building conservation works by the quantity surveyors. Frei (2010) highlighted quantity surveyors need to adapt to changes to their professional practices to remain relevant and successful. Hence, this research aims to demonstrate the potentials of HBIM with the utilization of 3D laser scanner in enhancing the estimation of heritage building conservation works by the quantity surveyors.

LITERATURE REVIEW

Heritage Building Conservation Works

A report “Convention Concerning the Protection of the World Cultural and Natural Heritage (1972)” published by the United Nations Educational, Scientific and Cultural Organization (UNESCO) defined

heritage buildings as a group of separate or connected buildings which, due to their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science. While, in Malaysia, the National Heritage Act 2005 defined the heritage buildings as tangible heritage and they are nine criteria required to be fulfilled in order for a potential heritage building can be considered on the declaration of national heritage property: (1) historically important; (2) offer architectural value; (3) scientifically or technically innovative; (4) possess social or cultural value; (5) potentially to be studied in term of Malaysian cultural heritage; (6) offer unusual or unique characteristics; (7) offer unique natural heritage; (8) capable of representing the nature of a site or object as part of a class or type of a site or object; and (9) capable of defining cultural heritage.

According to Harun (2011), in Malaysia, heritage building conservation works are initiated by the government as well as the private sectors. Heritage building conservation works involve activities such as preservation, rehabilitation, maintenance, refurbishment, restoration and others (Yoke Mui et al., 2016; Dann and Wood, 2004). Harun (2005) provided that to summarize, there are two main activities involve in heritage building conservation works which are to care and provide conservation to the buildings. However, the activities must not have destroyed or changed the buildings in any way. As mentioned earlier, there are many heritage buildings in Malaysia, hence, it is extremely significant for the building to be conserved for future generations to appreciate and value their valuable characteristics.

Issues of Heritage Building Conservation Works

According to Yoke Mui et al. (2016), compared to new building works, heritage building conservation works are different as they follow top down approach whereby works usually start from the highest level which is the roof before proceeding to the other levels. Moreover, heritage building conservation works do not include structural works (Lim and Ahmad, 2015). Hence, heritage building conservation works are smaller than new building works but often, they are laborious. Harun (2011) and Lim and Ahmad (2015) explained that heritage building conversation works are laborious because of the absence of as-built drawings and information which render difficulties and uncertainties. Typically, heritage building conservation works are carried out in a poor and challenging site condition (Lee and Ebu, 2006).

Additionally, it is also found by Pawlowicz and Szafranko (2015) that usually, as-built drawings and information of heritage buildings are missing. Amano and Lou (2016) and Highfield and Gorse (2009) agreed that heritage buildings are often lacking as-built drawings and information compared to new building works where most of the drawings and information are readily available and accessible. Sometimes, even if the as-built drawings and information of heritage buildings are available and accessible, but they might be not useful because they are usually outdated (Amano and Lou, 2016; Shamkhi and Al-hajj, 2014; Klein et al., 2012; Highfield and Gorse, 2009) and do not represent the current condition of the buildings (Ramsey, 2007). Therefore, it is challenging for quantity surveyors to visualize and quantify the amount of works required for heritage building conservation works. In response to that, there is a necessity to create or reproduce the as-built drawings and information.

Creation of reproduction of as-built drawings and information is known as re-measurement. Re-measurement is carried out to lessen the discrepancies between the as-built drawings and the actual condition of the buildings (Lee and Lim, 2009). It is believed that re-measurement can produce accurate as-built drawings and information which subsequently can be used for accurate cost estimation. Conventionally, re-measurement involves in-depth and detailed dilapidation survey and building investigation (Harun, 2011). It is conducted by using written and descriptive analysis, photos, sketches and drawings, and manual surveys (Barbosa et al., 2016; Megahed, 2015; Jung et al., 2014). However, the creation or reproduction of as-built drawings and information is not that simple and often it is extremely laborious and time-consuming as well as prone to errors (Jung et al., 2014; Klein

et al., 2012; Anil et al., 2011). It is challenging to conduct re-measurement and Woolley (2006) identified some of the common challenges that are associated to re-measurement of heritage buildings:

(1) Accessibility: Lim and Ahmad (2005) pointed out that sometimes, heritage building conservation works are conducted in confined spaces of the building. The condition of the building is very old and usually, unstable in term of structural and there are lots of associated issues, for instance, the absence of safe access (Woolley, 2006). Moreover, re-measurement is challenging when elements such as columns, beams or windows are in distant height and can be only be seen somewhat implicitly from ground. Additionally, to protect the authenticity of the architecture of heritage building, the measurement works has to be performed following strict conservation principles and guidelines (Lim and Ahmad., 2015). The quantity surveyors need to be extra careful to ensure that there is minimum contact and alteration done to the historic fabrics when doing measurement to ensure there is no harm to be done to the heritage significance which cause altered appearance and loss of features.

(2) Health and safety concerns: According to Beckmann and Bowles (2012), re-measurement is associated to various risks. For instance, there are risks associated to falling, trapped in confined spaces and others. Also, as heritage buildings are usually deteriorating and old, there are also risks in relation to poor indoor air quality and growth of fungus that can affect humans' health. Furthermore, quantity surveyors also face health and safety issues where hazardous materials (Amano and Lou., 2016) such as asbestos as they are commonly found in the heritage buildings (Woolley, 2006);

(3) Timescale: Re-measurement consumes significant amount of time and lots of detailing works need to be done to produce accurate measurement that can be used for other purposes. Therefore, adequate time should be provided to allow for information to be compiled and gathered.

(4) Experience: Woolley (2006) emphasized that quantity surveyors need to be historically well versed to prepare cost estimation for heritage building conservation works. However, heritage building conservation works are relatively new in Malaysia as compared to other countries (Wee Li and Yoke Mui, 2010; Kamal et. al., 2007). Wee Li and Yoke Mui (2010) added that similarly, research in heritage building conservation works is limited in Malaysia. Hence, quantity surveyors are lacking knowledge and understanding in the area of heritage building conservations works.

Building Information Modelling for Heritage Building Conservation Works

Optimization of heritage building conservation works requires collaboration among professionals based on digital platform known as Building Information Modelling (BIM) (Amano and Lou., 2016; Bryde et al., 2013). BIM can be defined as an innovative approach of building design, construction as well as management (Raphael and Priyanka, 2014; Bryde et al., 2013). Since many years ago, BIM has been introduced in the Malaysian construction industry and appreciated by professionals in the Architecture, Engineering, Construction and Facility Management communities (Kulasekara et al., 2013). Conventionally, BIM is intended for new building works, but the trend of adopting BIM for heritage building conservation works is rising and is typically known as Heritage Building Information Modelling (HBIM). HBIM provides the platform for conservation and management of heritage buildings (Baik, 2017; Bassier et al., 2017; Cheng et al., 2015; Megahed, 2015; Volk et al., 2014; Fai and Rafeiro, 2014). In relation to that, the utilization of 3D laser scanner for HBIM is increasing particularly for documenting purposes (Bassier et al., 2017). Cheng et al. (2015) and Eastman et al. (2011) explained that usually, the processes involve in documenting heritage building are: (1) obtain data; (2) manage data; (3) integrate data into a single HBIM platform. Cheng et al. (2015) added that to obtain data, it is common and a trend to use 3D laser scanner technology which offer effective process of acquiring 3D data for HBIM. The 3D data acquisition process indicates the creation of HBIM objects

that represent the information of the building including its sections, details, orthographic projections and schedules (Megahed, 2015; Rua and Gil, 2014; Murphy et al., 2013).
Prior knowledge related to the potential of HBIM achieved by 3D laser scanner has been considered for the creation of as-built BIM for heritage building conservation works. This knowledge is crucial for quantity surveyors to build an as-built 3D model of the heritage building and subsequently, to prepare cost estimation of works required for the necessary conservation works. Apparently, based on the extensive literature review on similar researches that have been conducted in heritage building conservation works, it is found that most of the studies focused mainly on the creation of as-built BIM model instead of the preparation of cost estimation. Also, very little is known about the potential for quantity surveyors to enhance their professional practices and services for heritage building conservation works through HBIM platform. Essentially, there is a need to investigate and demonstrate the potential quantity surveying professional practices in heritage building conservation works on HBIM platform and through the utilization of 3D laser scanner.

RESEARCH METHODOLOGY

Case Study Approach

Case study approach is adopted in this research to demonstrate the potentials of HBIM with the utilization of 3D laser scanner in enhancing the estimation of heritage building conservation works by the quantity surveyors. According to Yin (2003), case study can be defined as an approach that explores current phenomenon within its actual context. Case study approach can be conducted by means of single case study or multiple case studies. Johnson et al. (1999) explained that effective case study must comprise of the followings: (1) begin with an assumption based on theoretical findings; (2) must be systematic and logic; and (3) must be evaluated individually.

Single Case Study Approach

As mentioned earlier, case study approach can be conducted by means of single case study or multiple case studies. In this research, single case study approach is selected as it can achieve the aim of the research effectively. However, heritage buildings are unique in nature and have different features and characteristics as well as require diverse conservation works, hence, no generalisation will be made to other similar case studies. Still, it is believed that the principle and approach of this research is applicable to be tested on other similar case studies. Amaratunga et al. (2002) supported this statement and stated that instead of the data, the main feature of case study is the understanding of the processes. Case study approach is appropriate to be used for this research because Yin (2003) asserted that case study approach should be adopted whenever a phenomenon under study is poorly defined. Evidently, there is limited research that has been carried out in this research. Also, it is worth noting that many researchers have successfully adopted single case study approach in their research, for instance, Angelini et al. (2017) adopted single case study approach to conduct the 3D reconstruction of Papal Basilica of Saint Francis and Baik (2017) created the as-built of Nasif Historical House in Jeddah in his research by adopting single case approach. Similarly, Oreni et al. (2013) adopted single case study approach to develop as-built model of Filarete's Ospedale Maggiore ice house.

Selected Case Study

A 150 years old heritage building which is in Johor is selected as the case study for this research. The building was completed in 1858 and was used as temporary palace for royal ceremonies such as the inauguration of the sultan and royal weddings. The building is now abandoned and located inside the area of Muzium Diraja Abu Bakar and Istana Besar Johor. Furthermore, it is under the protection of Yayasan Warisan Johor, Istana Besar Johor and Muzium Diraja Abu Bakar.

Research Flow

FARO Focus 3D X 130 3D laser scanner is used to 3D laser scan the selected case study. Prior to 3D laser scanning, the scan-stations are determined, and reference spheres are used as guidance of coordinate. The determined scan-stations are ensured to be appropriate or in other words, allows the 3D laser scanner to scan the widest view and angles of the building. The scanned data is then manipulated using SCENE software for automatic registration in point cloud form before it is converted and imported to Autodesk REVIT. In Autodesk REVIT, the imported point cloud data is used for 3D modelling process and finally, to create the completed 3D model of the selected case study. Using the completed 3D model, automation of quantity take-off is carried out in term of their number, area, volume and length. The quantities then are used for further cost estimation of the building.

FINDINGS AND DISCUSSION

Based on the analysis of the scanned data, the followings reveal the findings and discussion of this research:

Conventional Re-measurement versus 3D Laser Scanning

(1) Accessibility: The case study is more than 150 years old and has been abandoned for many years. Thus, there is no safe access to the building especially to the upper floor as the staircase and timber upper floor are defective due to aging factor and vandalism. Regarding that, it is almost impossible to carry out conventional re-measurement. Also, to protect the authenticity of the building, physical contact should be avoided. Fortunately, with the utilization of 3D laser scanner, the entire view and different angles can be effortlessly captured without the need to access to the unsafe parts of the building and with no physical contact with the building.

(2) Health and safety: Accessibility is also associated to health and safety concerns as to perform conventional re-measurement; some personnel must access to the different parts of the building regardless its condition. As mentioned earlier, the upper floor is inaccessible and even if it is accessible, there are associated risks particularly risk of falling and slipping. Additionally, conventional re-measurement at the ground floor may also impose risk to some personnel, for instance, being hit by objects such as timber boards. There is fungus growth in the building and they may affect a personnel's health as well. The utilization of 3D laser scanner can reduce the potential risks as the laser scanner is set up on a tripod without the need of a personnel's manual control to capture the entire view and angles of the building.

(3) Timescale: Conventional re-measurement takes longer time as compared to the utilization of 3D laser scanner. Also, it is prone to human error (Jung et al., 2014; Klein et al., 2012; Anil et al., 2011). The entire building is managed to be scanned in a few hours by means of 40 points of scanning. This supported Jung et al. (2014) findings that 3D laser scanner is capable of capturing data 10 times faster than the conventional re-measurement. On top of that, the captured data is also accurate and enhanced in term of its visibility.

(4) Experience: 3D laser scanning is an easy process and the captured data can be analysed off-site accordingly. Hence, there is no need for expertise in handling the process as well as to analyse the captured data. The captured data in the form of point clouds can easily be manipulated and converted into a 3D model that can be used to prepare cost estimation.

3D Laser Scanning of the Case Study

Prior to 3D laser scanning by means of FARO Focus 3D X 130 3D laser scanner, walkthrough survey is carried out to sketch the plan layout of the building as well as to determine appropriate scan-stations that allow the scanner to capture the widest angle of a specific part of the building. Regarding that, the scan-stations are determined to be in sequence so that overlapping of scanned data is feasible. This is critical to avoid any missing of data or gap in between of the scanned data. The laser scanner is

set on a levelled tripod and reference spheres are used to guide the 3D laser scanning. Without the reference spheres, it would be difficult to determine the coordinate of the scanned data. Typically, a single scanning requires approximately 6 minutes and upon completion, the 3D laser scanner is shifted to another scan-station for subsequent scanning. In total, 3D laser scanning is performed at 40 different scan-stations to receive the entire view and angles of the building externally and internally.

Scanned data is processed to generate geometric drawing, and for that, scanned data is combined into a single point cloud based on a common coordinate. Therefore, it is important to recognize the 3D relationship through a registration process. This supports the analysis discussed by Tang et al. (2010). Registration process is conducted by using FARO SCENE whereby the scanned data in the form of point cloud is imported and automatic registration is carried out. As mentioned earlier, reference spheres are used to determine the coordinate of the scanned data. Hence, during the automatic registration, the reference spheres are used as targets and figure 1 shows the output after the 40 scanned point cloud data are successfully merged based on a common coordinate.

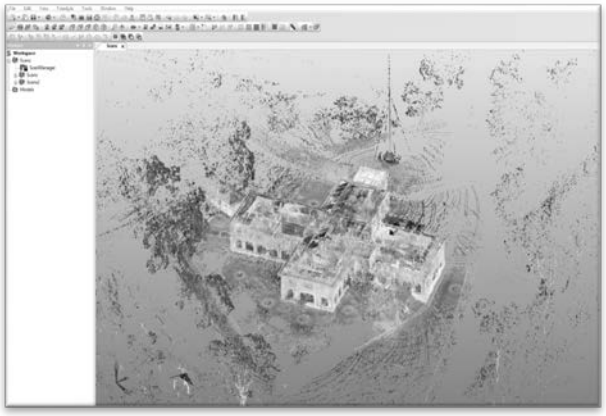

Figure 1: Output of merged point cloud data

Subsequently, the noise or the point cloud data scanned outside of the building is removed by means of polygon selector in FARO SCENE. Basically, this is to ease the import process of merged point cloud data into Autodesk REVIT later and to ensure better quality of as-built BIM model. Figure 2 displays the merged point cloud data after noise removal and colourisation.

Figure 2: Merged point cloud data after noise removal and colourisation

3D Modelling of the Case Study

There are three steps involved in 3D modelling of the building: (1) preparation of the project; (2) preparation of the point cloud data; and (3) creation of as-built BIM model. To import the merged point cloud data into Autodesk REVIT, the data is converted into ReCap format. Autodesk REVIT allows easy modelling based on the merged point cloud data, but PointSense for Autodesk REVIT added advantage in creation and customisation of point cloud data. Basically, after the determination of floor levels as shown in figure 3, PointSense is used to create point cloud images on the floor levels.

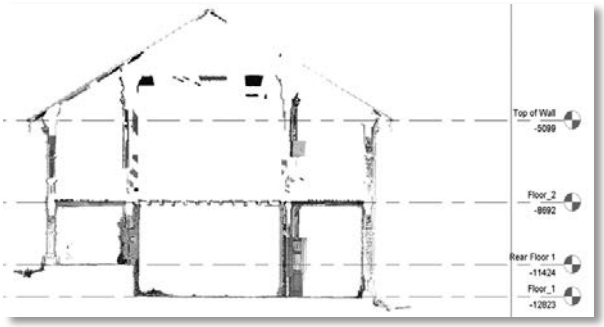

Figure 3: Determination of floor levels in Autodesk REVIT

Next, the as-built BIM creation is carried out starting from basic elements of the building, like, walls, floors and columns. However, due to the extremely defective condition of the building, remodelling in Autodesk REVIT is required to ease the preparation of cost estimation later. The remodelling requires adjustments of openings for doors and windows. Figure 4 reveals the final output of the remodelling of the building.

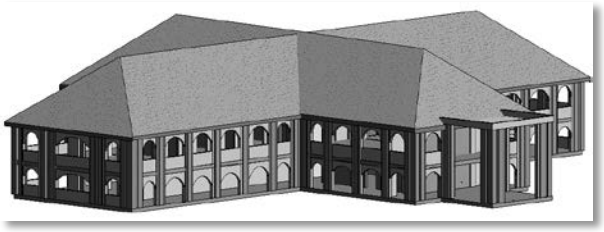

Figure 4: Final output of the as-built BIM model of the case study

Cost Estimation of the Case Study

To estimate the cost of the case study, quantity take-off is easily performed with the availability of the as-built BIM model. Basically, using Autodesk REVIT, scheduling is used and each of the elements of the building is automatically extracted to derive the total quantities as shown in Figure 5.

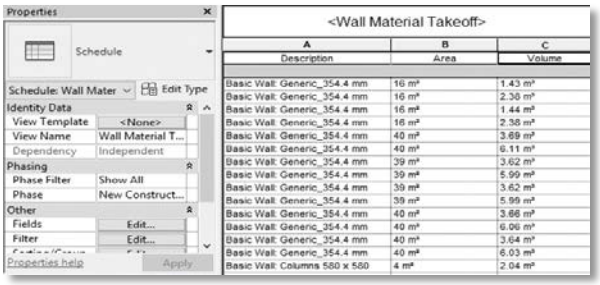

Figure 5: Scheduling of quantities in Autodesk REVIT

Table 1 below reveals the extracted quantities of each of the elements of the building.

Table 1: Extracted quantities of each of the elements of the building

Element	Quantity
External wall	671 m^2
Internal wall	167 m^2
Column 580mm thick	337 m^2
Column 360mm thick	212 m^2
Column 900mm thick	358 m^2
Roof	2192 m^2
Doors	
4904 Width x 4338 High	1 item
1441 Width x 3175 High	47 items
1422 Width x 2438 High	32 items
Windows	
1965 Width x 1886 High	20 items
Flooring	2974 m^2
External wall finishes	1342 m^2
Internal wall finishes	3344 m^2
Floor finishes	2974 m^2
Ceiling finishes	2974 m^2

Further detail quantity take-off can be carried out based on the as-built BIM model. Also, the quantities can then be multiplied with costs to produce the overall costs of the conservation of the building. Obviously, after the creation of as-built BIM model, quantity take-off can easily be performed. Also, accurate quantities can be obtained, and this would enhance the capabilities of quantity surveyors in meeting the needs of the clients. Conventional cost estimation is laborious, time-consuming and complex. It is also prone to human errors and therefore, often, it jeopardizes the professional practices and services of quantity surveyors. Therefore, the findings of the research corroborate that HBIM with the utilization of 3D laser scanner provides enhanced platform and processes for quantity surveyors in preparing cost estimation for conservation of heritage buildings.

CONCLUSION

In conclusion, the digitalization of processes of cost estimation of conservation of heritage buildings significantly improve the grassroots services of quantity surveyors to grandeur. Also, apart from the cost estimation, this research recommends that further research could be carried out by using similar as-built BIM model to explore the quantity surveyors' professional practices and services in context of variation in design decisions by the clients as well as to utilize virtual reality (VR) and augmented reality (AR) for better visualization of the current condition of the building. Moreover, as mentioned in research methodology, the findings of this research should not be generalized to other case studies but the principles and methodologies of the research could be used to other case studies in order to conduct similar researches particularly in the creation of as-built BIM model and cost estimation of the conservation works required.

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GROWTH OF SOUTH AFRICAN GREEN BUILDING: STAKEHOLDER PERSPECTIVES ON PROFESSIONAL SKILLS REQUIRED

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ABSTRACT

The South African Green Building industry faces many challenges. This paper investigated if the professional skills required from consultants may be hampering the growth of green building. Data was obtained from questionnaires completed by 69 architects, quantity surveyors and developers from the Gauteng Province of South Africa.

The participants believed that they require a broader skill set to achieve green building ratings. Stakeholders were often unsure of the benefits of green building, of the process is to achieve a green star rating and they believed that the GBCSA should do more to market green building benefits. The cumbersome and complicated application process is another big constraint to green building progress.

This study highlighted stakeholders opinion on skills required by green building and on the GBCSA role to facilitate the process.

Future research should expand the study to other provinces, should compare findings with international studies, discuss specific skills required in more in depth and should also include the opinion of other stakeholders such as project managers, engineers and construction managers.

KEYWORDS: Green building, Growth, Skills, South Africa, Stakeholders.

INTRODUCTION

Global warming is a key issue in the 21st century. The carbon dioxide emissions produced by the economic and lifestyle activities of our generation are a main contributor to global warming (NASA, 2016). April of 2016 was the hottest month recorded in 135 years with the average temperature 1,1°C above the 20th century average. The 12 months since April 2015 were the hottest months ever recorded (Tempelhoff, 2016:3).

Global warming has various negative effects such as the melting of the polar ice-caps and rising sea levels, as well as increasing droughts and heat waves in areas such as the western United States, Australia and South Africa. This in turn effects the supply of food and fresh water and may lead to the extinction of certain species (CEF, 2016).

The construction industry is a major consumer of natural resources - more than 40% of energy consumption, 12% of fresh water consumption, 40% of solid waste generation and one third of greenhouse gas emissions worldwide can comes from this industry (GBCSA, 2016a; Makwarela, 2010; WGBC, 2016a; Kruse, 2004; Toller et al, 2011). The scenario in South Africa is no different (Milne, 2012). An estimate of the contribution by construction to global pollution is detailed in Table 1.

Producing electricity, which the construction industry severely depends on, is the largest source of CO_2 radiation contributing to the greenhouse effect. Continuous growth of these emissions are evident, as clearly displayed by the AAGR (Average Annual Growth Rate) calculated at 2% during the period 1990-2000 and 3,2% during 2000-2010 respectively (De la Rue du Can et al, 2012)

The creation of the green building industry originated from the realization that the exploitation of the earth's resources is unsustainable (The Economist, 2004). Green building is based on the principle of sustainability - not to compromise the capacity of future generations to provide for their future needs. Construction must embrace energy and resource efficient methodologies and exercise environmental responsibility (GBCSA, 2016b; Kerswill, 2007).

Table 1 The effect of buildings on global pollution (Dixon, 2010)

Pollution	**(%)**
Air qualities (Cities)	23
Climate change gasses	50
Drinking water pollution	40
Landfill waste	50
Ozone depletion	50

The wide spread implementation of green building practices can significantly reduce the carbon footprint of the construction industry and can reduce energy consumption by as much as 80% if sustainable practises can be applied through-out the industry (Pekka, 2009; Lafarge, 2015). The benefits of applying green building can also have direct, positive financial outcomes. A study by Chekut, et al (2012) on London properties from 2000–2009 reported a 21% premium on transaction prices and an 18% premium on rents achieved by green buildings.

The above insights and recognition resulted in new green building structures and organisations being established across the globe. Various green building councils were formed and they launched rating tools for green buildings to provide structure and context to this infant industry. The Building Research Establishment Environmental Assessment Method (BREEAM) (1990) in the United Kingdom, Leadership in Energy and Environmental Design (LEED) of the United States Green Building Council (USGBC) (2000) and the Green Star system of the Australian Green Building Council (GBCA) (2003) are well-known tools in this regard (GBCA, 2016). The Green Building Council of South Africa (GBCSA) was established in 2008 and launching the South African Green Star SA rating tool in 2009. The tool is based on the Australian Green Star tool and is customised to suit local conditions (GBCSA, 2016c). The GBCSA recently certified the 250th Green Star SA certified buildings in the 10th year of its existence (GBCSA, 2018).

The relatively young South African green building industry requires contributions and support from all local stakeholders as it faces many challenges. This paper investigated if the professional skills required from consultants may be hampering the growth of green building. In this context it is therefore important to know and understand the roles and functions, opinions and skill levels of the South African green building stakeholders. This study strives to add insight into the opinions of different primary stakeholders on skill levels that may constrain the growth of the South African Green Building industry.

GREEN BUILDING CHALLENGES

Professional skills and lack of information

According to Seah (2009) built environment consultants will have develop new skills to be able to support clients with green building development. This study will be able to add comment on this opinion. In 2012 Milne (2012) noted that the quantification of green building benefits such as lower lifecycle costs and increased green rentals will remain a challenge in South Africa for some time due to lack sufficient data on due to the age of the industry. Montoya (2011).pointed out that such lack of data may result in developers declining green design alternatives.

A Dodge Data & Analytics report (2016) confirmed positive advances for green building in South Africa. The study did however indicate that South Africa has challenges to produce and find green professionals with the proper skills and education, that there is not enough public awareness and that the government doesn't provide enough incentives for the development of green buildings. South Africans expect that the biggest growth in the sectors are the upgrading to green buildings of existing buildings followed by commercial developments and low-rise buildings.

Jane Henley, chief executive officer of the WGBC acknowledged that skills and knowledge may be a world-wide concern. Stakeholders and organisations should start to share information much more readily and build partnerships. Together, they can be much more than merely the sum of their parts. Green Building Councils should form partnerships with other industry organizations– architects, planners, engineers, consultants, environmental groups, economists – to pursue their common objectives" (Henley, 2015).

Green cost premium

Several studies confirm the existence of wide spread perceptions amongst industry stakeholders that green building carries a significant cost premium compared to conventional construction (Morris, 2007; Bond and Perrett, 2012 and Fitch and Laquidara-Carr, 2013; Dwaikat and Kherun, 2016). Seah (2009) however argues that social, environmental and operational benefits may offset the initial cost premium of a green building. South African has a very young green building industry compared to some more mature green industries and may therefore experience an elevated cost premium (GBCSA, 2016c).

A 2017 study on South African green building costs and trends found an average green building cost premium of only 5% for Green Star SA certified office buildings (ASAQS, 2017).

Professional consultants

Various studies have confirmed that green building will challenge consultants. A 2014 study amongst South African architects found that although all respondents were positive to embrace green building, as much as 47% indicated that South African built environment professionals were not sufficiently aware of green building requirements. A total of 84% stated that more education and training is necessary to address the situation (Hoffman & Cloete, 2014). Gardiner & Theobald, the well known international quantity surveying firm agreed that green building is challenging quantity surveyors to find the balance between financial viability and sustainability - to achieve green, but within budget of clients and developers (2012). According to X.L. Zhao green building requires engineers to overcome the specific focus on conventional designs by collaborating with architects and members of the design team in order to achieve innovative sustainable solutions (Zhao, et al., 2014).

Czerwinska (2015) agrees that green building sets pressure on older professionals to adapt and learn various new green techniques and sustainable alternatives in order to keep up with new

developments. These older professionals must make use of the various available courses provided by green building councils and higher education institutions.

PROBLEM

The study will evaluate professional skills required by green building as a potential constraint that may be hampering the growth South African green building industry.

ASSUMPTIONSAND LIMITATIONS

The study is limited to South African green buildings and only the opinions of architects, quantity surveyors and developers as stakeholders from Gauteng Province were included. Other stakeholders in the building industry such as engineers or environmental consultants have not been included.

RESEARCH DESIGN AND METHODOLOGY

The target group of respondents consisted of randomly selected professional firms from three built environment disciplines who are all directly involved as stakeholders in the construction industry - namely architects, quantity surveyors and developers. All green building projects make use of the services of these three professions. The respondents were all located in the Gauteng Province of South Africa which contributes approximately 33.9% to the GDP of South Africa (Gauteng Online, 2016).

The study sample consisted of 69 respondents who returned the questionnaires - 19 architects, 29 quantity surveyors and 21 developers.

The research questionnaire consisted of Likert scale based statements. Respondents had to respond with “Absolutely Disagree, Disagree, Agree or Absolutely Agree”. This study will consider the aspect of skills required by green building and the green building process. Another parallel running study will describe cost and economic constraints.

The data from the returned questionnaires was captured, categorized, described and statistical analysis as required by the problems. The captured and categorized data and the analysis thereof was used to propose underlying motivation, philosophies and traits that may explain or motivate any identified trends.

THE DATA

The data confirmed that more than 75% of firms responding have been in practise for more than 10 years. The majority of the respondents firms can therefore be regarded as experienced and well established. The respondents were then asked to respond to the statement that their firm supports the potential and the need for Green Buildings (see Figure 1). A total of 82% of respondents agreed or strongly agreed with the statement. The response was not similar between the three disciplines. All the architects agreed with the statement, but 35% of quantity surveyors did not agree. This was an early indicator of dissimilar views on green building.

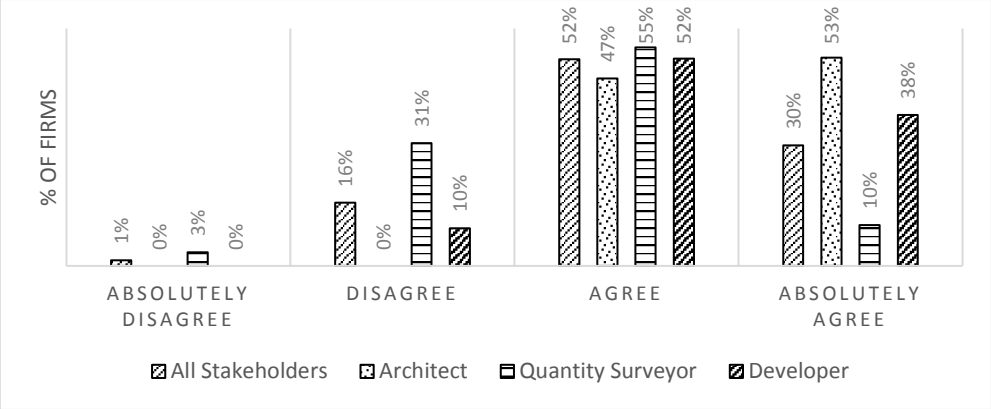

Figure 1 The company believes in the potential and the need for Green Buildings

Most (87%) of the stakeholders agreed that there is a growing trend in the industry for designers and developers to pursue the development of green buildings. However 10% of the quantity surveyors and 24% of the developers did not share this opinion (see Figure 2).

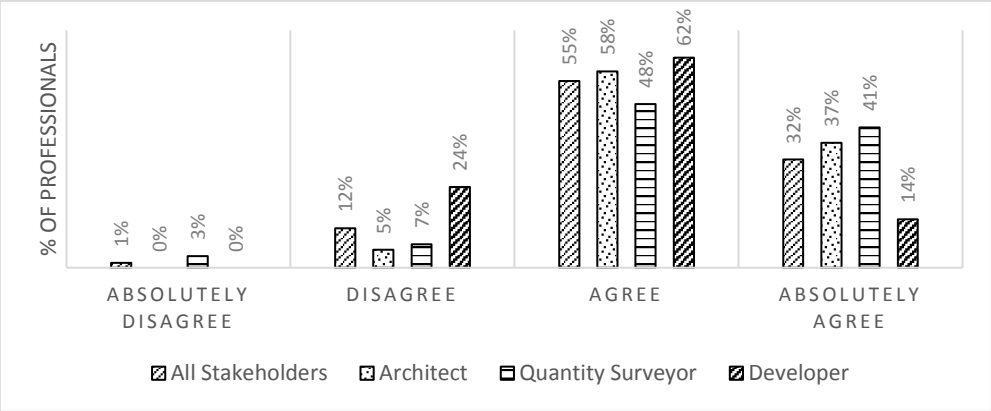

Figure 2 There is a growing trend in the industry for designers and developers to pursue the development of green buildings

The questionnaire than explored the important aspect to evaluate the previous involvement with green building of the respondents. Figure 3 portrays that a significant majority (64%) of the respondent's firms have been actively involved in green-building development. As the majority of firms are older, well-established firms this may indicate that such firms are more likely to be engaged in green building developments.

The finding also corresponds with and confirms the Dodge Data & Analytics report of 2016 that indicated a growing involvement in green building by South African consultancy firms. However, 48% of the quantity surveyors are not yet involved in the development of green buildings. By comparison the respective non-participation levels of architects (36%) and developers (29%) are much lower. This finding indicates that there may be potential for professionals and especially with the quantity surveyors to gain share in green building and for the GBCSA to market green building more aggressively amongst quantity surveyors.

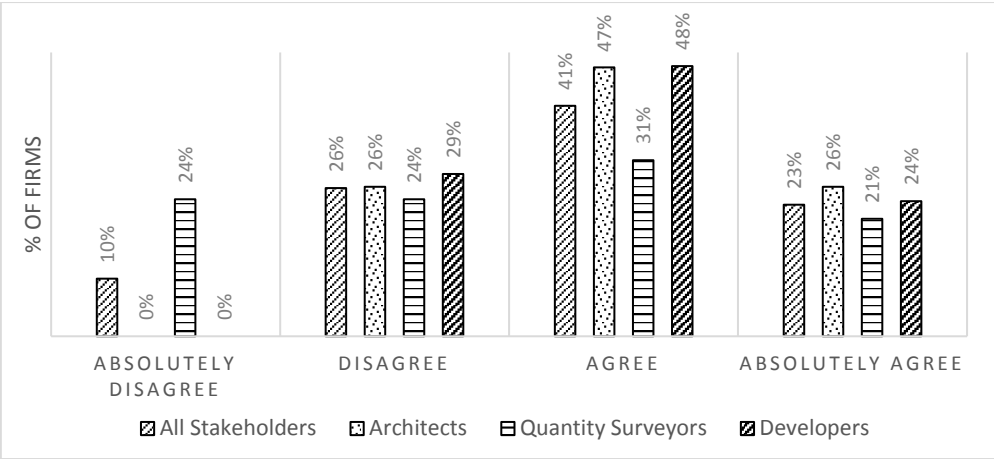

Figure 3 Your firm has been actively involved in green building

Figure 4 indicates that a total of 63% of the professionals agree that the driving force of implementing green buildings come from the owner. There is however an indication that 37% of professionals are starting to believe that the suggestion to implement green building does not have to come from the owner. This finding may indicate that some consultants believe that they can also take the lead in green building developments and that they may in fact be doing so already. Figure 1 confirmed that 100% of architects and 90% of developers have a positive opinion towards green building. These stakeholders can typically be expected to act pro-actively towards green building developments. Only 53% of architects agreed that the owner should drive green building. As with Figure 1 quantity surveyors again differs from architects with 73% agreeing that they will tend to wait for the owner to take the leed in green building.

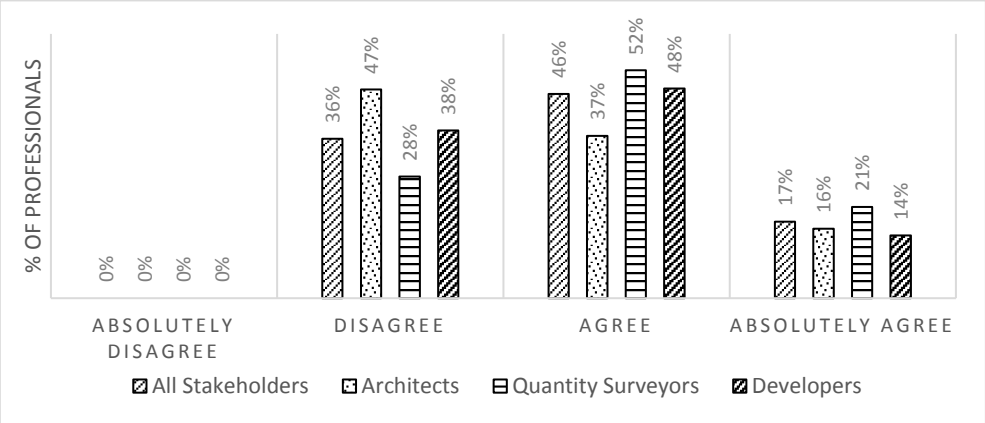

Figure 4 The owner is the driving force behind green building

The study then progress to the consideration of green building skills. The respondents were first asked to respond to the statement "Most professionals are aware of the necessary requirements of the GBCSA to obtain a green star rating". Figure 5 indicates that on average only 45% of respondents agreed with the statement. A total of 55% of architects and 66% of quantity surveyors disagreed with the statement. This may indicate that they are of the opinion that professionals are in need support and training to increase their levels of competence and confidence in the requirements of green building.

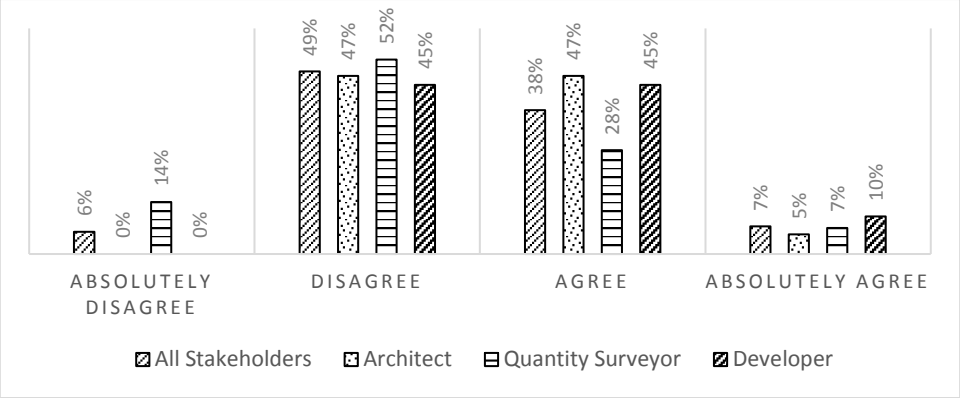

Figure 5 Most professionals are aware of the necessary requirements of the GBCSA to obtain a green star rating

To confirm the above finding the respondents then had to answer to the statement "Professionals need a broader skill set to work on green buildings compared to skills required by conventional buildings". Figure 6 indicates that on average 90% of the respondents agreed with the statement. This finding support the earlier suggestion that more training and support of professional consultants may be required to reinforce the consultants' ability to support green building development.

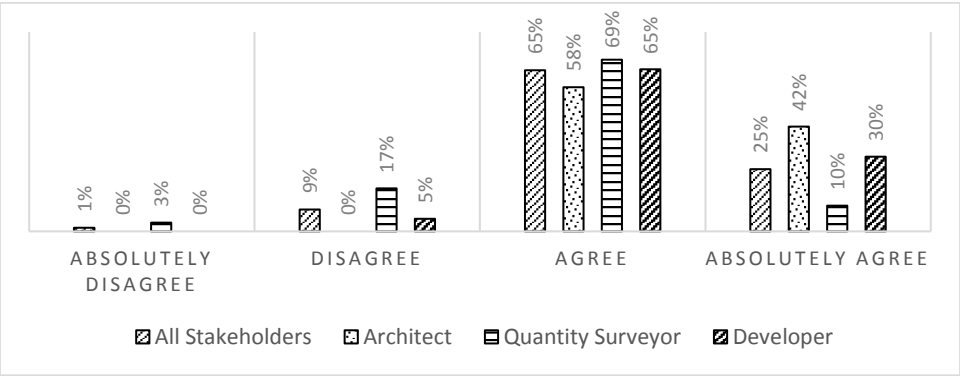

Figure 6 Professionals need a broader skill set for green buildings than for conventional buildings

The respondents were then tested about the green building certification process with the statement "The process to achieve green star rating is cumbersome and complicated". An average total of 65% of respondents agreed with the statement (see Figure 7). The GBCSA should take note of this finding to ensure that the certification process is as uncomplicated and rational as possible. Training and education of industry stakeholders can also assist to remove challenges to the green building certification process.

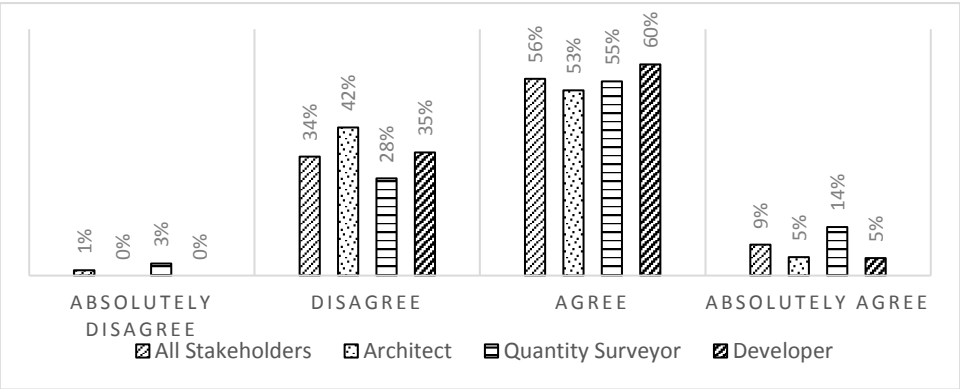

Figure 7 The process to achieve green star rating is cumbersome and complicated

Notice should also be taken of the 28% - 42% of respondents that did not find the green star rating process challenging. These are most probably the firms with a well-established history of regular and successful green building projects. If more firms can join the ranks of those regularly participating in green building development, the rating process will seem less complicated and cumbersome.

Following the evaluation of the green building rating process, the study then concluded by focussed on the information and educational role of the GBCSA in addressing problems experienced by stakeholders. In response to the statement "The GBCSA can do more to make professionals aware of the process to obtain green ratings". An average total of 87% respondents agreed with the statement. Every individual discipline was also in agreement with responses varying between 84% for architects to 90% for quantity surveyors (see Figure 8). This was a strong and clear finding and provided clear confirmation that there may exist a gap between the nature and the level of information and training provided by the GBCSA and how this offering is perceived by the industry stakeholders.

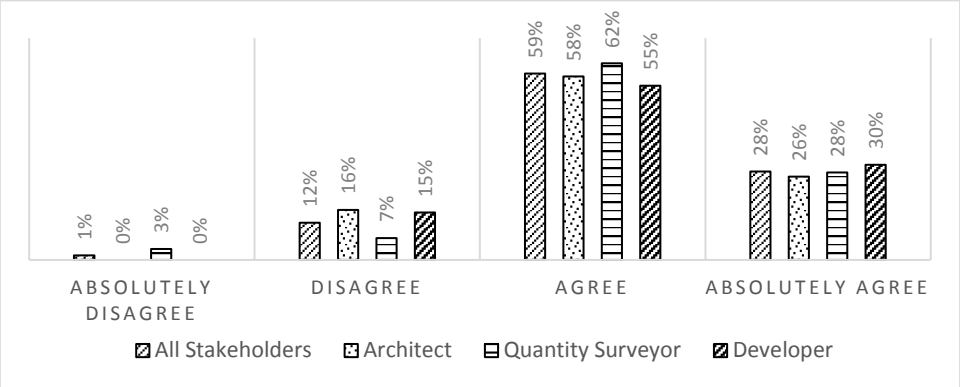

Figure 8 GBCSA can do more to make professionals aware of the process to obtain green ratings

CONCLUSIONS

This study evaluated the opinions of stakeholders in the South African green industry on the skills required from consultants by green building. The study found that 82% of respondents support green building, At support levels of only 65% quantity surveyors were less positive about green building. Most (87%) of the stakeholders agreed that the South African green industry is growing. A significant majority of 64% of the respondent's firms have been actively involved in green-building development to date. This finding confirms the Dodge Data & Analytics report of 2016 that indicated a growing involvement in green building by South African consultancy firms.

Respondents differed on their opinion that the owner should initiate green building development. 73% of quantity surveyors agreed for the owner to lead the process while 53% of architects did not agree. A total of 55% of respondents disagreed that most professionals are aware of the necessary requirements of the GBCSA to obtain a green star rating. Many professional consultants may indeed require support and training to increase their levels of competence and confidence in the requirements of green building.

Almost all (90%) of respondents agreed that green buildings require a broader skill set from professional consultants compared to skills required by conventional buildings. This finding support the earlier indication that more training and support of professional consultants may be required to reinforce the consultants' ability to support green building development.

The challenges presented by green building was confirmed by the finding that 65% of respondents agreed that they found the green building certification process cumbersome and complicated. The GBCSA should ensure that the certification process is kept as simple and rational as possible. Training and education of industry stakeholders can also assist to remove challenges to the green building certification process.

The study concluded by considering the information and educational role of the GBCSA in addressing problems experienced by stakeholders. An average total of 87% of respondents agreed that the GBCSA can do more to make professionals aware of the process to obtain green ratings. This was a strong and clear finding and provided clear confirmation that there may exist a gap between the nature and the level of information and training provided by the GBCSA and how this offering is perceived by the industry stakeholders.

RECOMMENDATIONS

Some recommendations for future research is to:

- Repeat the study but with a larger sample that include respondents from other provinces;
- Include other industry stakeholders such as engineers, owners, environmental consultants and contractors in the study;
- compare the findings with similar international studies; and
- evaluate the green building information and training provided to educate the industry and the perceived gaps in this offering.

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Keywords: Certification Systems; Facilitator; International; Training; Value Management.

IDENTIFYING VM TRAINING AND CERTIFICATION COMPONENTS FOR INTERNATIONAL FACILITATORS AND CO-FACILITATORS

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ABSTRACT

Value management (VM) is a multidisciplinary, function-oriented, innovative team approach that uses a systematic approach to ensure the best value. VM facilitators play a key role designing, managing, controlling, and leading a VM study throughout the whole process. Hence, adequate VM training is necessary for VM facilitators. This study aims to separately identify the required training and certification components for VM facilitators and co-facilitators. An international questionnaire survey was adopted and 87 samples were collected from international VM experts and participants. The empirical findings identified ten VM training components and eight VM certification components for facilitators/co-facilitators. All training and certification components for facilitators scored higher than the mid-point (i.e., 0.5 out of 1). However, VM co-facilitators only rated five training components and four certification components higher than the mid-point. In general, expectations of the training and certification requirements for the facilitators were higher than for the co-facilitators. Hence, it is suggested that all VM training and certification components are adopted by facilitators, while only fundamental VM knowledge (basic cost analysis) and a few soft VM skills (people topics) are adopted by co-facilitators. Simple VM exercises for different techniques and phases could be applied for co-facilitators, but training for VM facilitators should consist of a real project throughout the VM process. This paper contributes to identifying key components in the VM training and certification systems for both VM facilitators and co-facilitators internationally.

INTRODUCTION

The concept of value management (VM) was first developed in 1947 by Lawrence Miles, who was a purchase engineer with the General Electric Company in the US (Park, 2017; McGill, 2011). In light of its contributions to cost-saving and value enhancement, successful applications of VM have been observed in a number of countries around the world, such as the USA, the UK, Australia, China, Malaysia, South Africa, and Hong Kong (Bowen, 2011; Leung, 2013; Mohammad, 2014; Philips, 2015). VM is defined as "a structured, systematic and analytical process which seeks to achieve value for money by providing all the necessary functions at the lowest total cost consistent with the required levels of quality and performance" (Standards Australia, 2007), while the Society of American Value Engineers (SAVE international) defines value management as "the application of the value methodology by an organization to achieve strategic value improvement" (SAVE International, 2017).

VM was first introduced in Hong Kong in the 1980s and the Hong Kong Institute of Value Management (HKIVM) was formally established in 1995 (HKIVM, 2018). The HKIVM has introduced a List of Facilitators, recognizing competent VM facilitators who have certifications under other recognized national VM institutes (HKIVM, 2015). However, it still very much relies on foreign qualification systems. Hence, it is vital to investigate a proper VM training and qualification system to enhance the performance of VM applications. Finally, it not only helps the industry to improve in regard to the application of VM, but also enhances its further development within the territory and further benefits our construction industry as a whole. This paper accordingly aims to identify the key components required for VM training and certification systems for both VM facilitators and co-facilitators, in order to improve VM practice professionally.

VM TRAINING AND CERTIFICATION SYSTEMS

VM Training in Different Countries

The main objective of VM training is to nurture competent VM professionals. Therefore, facilitators are required to train in all important areas of VM (Oke, 2017). However, international formal training varies from country to country both in terms of the contents of the training and the different levels involved. Accredited training programs in Australia accept individual modules with VM knowledge and facilitation skills (IVMA, 2018), while the SAVE International in the USA has made significant changes to its training courses since they were established, such as adopting Value Methodology Fundamentals 1 (VMF 1) to replace the original Module I and using Value Methodology Fundamentals 2 (VMF 2) to replace the existing Module II (SAVE, 2018). In the UK, IVM adopts three levels of training courses (Foundation, Advanced 1, and Advanced 2 courses), plus a "train the trainer" course, so these practitioners can effectively cultivate standard training courses in practice (IVM, 2018). The train the trainer course required by the IVM in the UK is totally unique from all other international institutions. The formal qualification system in Hong Kong has just started a 12-hour registered VM program for VM beginners, though VM courses have been taught at universities since 1995 (Leung, 2006).

VM Certification Systems in Different Countries

The primary purpose of VM certification systems is to assess the competency of VM facilitators by establishing a series of VM standards (Sari, 2017). The SAVE international has adopted a two-level certification system for different levels of practitioners: Value Methodology Associates (VMAs) and Certified Value Specialists (CVSs). Unlike in the past, the new examination can be taken through an online portal (SAVE, 2018). There are three levels of certification for VM practitioners in the UK, including Qualified Value Associate (QVA), Professional in Value Management (PVM), and Trainer in Value Management (TVM) (IVMA, 2018). In Australia, in the past, there has been only one qualification and the accreditation was proposed for the recognition of VM facilitators only. However, it has been recently revised and recognized across three accreditation levels (i.e., Value Analyst, Value Facilitator, and Value Trainer) (IVMA, 2018). Unfortunately, there is no formal certification system for VM professionals in Hong Kong. Facilitators are generally recognized across two levels (List A and List B facilitators). In summary, the requirements for certification in the UK and Australia are relatively similar as compare to the US system.

A standard helps us to agree on the terminology, definitions, processes, techniques, tools, skills, and best practices in the industry (Male 2006). As practices differ across various countries, the international VM standards in the US, Europe, and Australia involve different main points. Hence, the required training and certification for VM facilitators and co-facilitators vary across different countries. Based on the extensive literature on VM training and certification systems, ten VM training components (i.e., Basic VM knowledge, Basic cost analysis, Simple VM exercises for different techniques/phases, A real project for the whole VM process, Detailed VM techniques, Strategic level for VM application in an organization /a project, Financial, People topics, Participant-led workshops, and Value culture) and eight certification components (Fundamental VM knowledge, Function analysis, Strategic organizational level, Team-building techniques, Facilitation skill and team leading, Financial techniques, VM promotion, and Certification system) for facilitators and co-facilitators are identified.

In order to enhance the overall VM performance, this study aims to identify the key components in VM training and certification systems for both facilitators and co-facilitators in the real world.

RESEARCH METHODOLOGY

Measurement and Sample

To identify the key training and certification components for VM facilitators and co-facilitators, a descriptive study with a questionnaire was designed to measure the relevant components

through a review of the literature and related studies (Sucuoglu, 2018). The data collection process consists of three parts: Part I for respondents' demographical information; Part II for training components; and Part III for certification components. In the last two parts of the survey, closed-ended questions with "yes or no" answers were adopted for the required components (Abed, 2018). This quantitative survey was conducted among international VM facilitators and participants in Australia, Hong Kong, the UK, and the USA. Respondents were invited to indicate the importance of the listed training and certification components for VM facilitators and co-facilitators separately. The data were collected via an international questionnaire survey distributed to both VM facilitators and participants. A total of around 100 questionnaires were returned, in which some data were missing, and only valid responses were used. The 87 valid responses are mainly from Hong Kong, the USA, Australia, and the UK. The majority of respondents worked in consultant firms and the government. Respondents' whose ages were above 40 and 50 years were dominant, constituting 35% and 43% of the sample, respectively, as compared to younger participants.

Methodology

To determine the relative rankings of the key training and certification components of international VM facilitators and co-facilitators, the data were analyzed using descriptive statistics; both frequencies and percentages were employed (Abed, 2018; Kaimal and Sreedevi, 2018; Quadri, 2018). The respondents were asked to indicate the important training and certification components for VM facilitators and co-facilitators separately. They were allowed to select more than one component from the list. In connection with the expectations of respondents, the training and certifications components were ranked first by the highest percentage of frequency (Rahmani, 2018). Both frequencies and percentages were calculated using the SPSS descriptive analysis, while the ranking sequence was established according to the frequencies and percentages found.

RESULTS

To identify the key components in the training and certification systems for VM facilitators and co-facilitators, both frequencies and percentages were adopted in this study.

VM Training and Certification

Based on the hypothetical competences of facilitators and co-facilitators, the results from the respondents regarding agreement within training and certification systems for VM facilitators and co-facilitators are listed in Table 1.

Table 1 Recommended Training and Certification Components for Co-Facilitators and Facilitators

		Facilitators			Co-Facilitators		
		Freq.	%	Rank	Freq.	%	Rank
	Training Components						
TC1:	**Basic VM knowledge**	85	**0.98**	**1**	76	**0.87**	**1**
TC10:	*Value culture*	85	**0.98**	**1**	18	*0.21*	*10*
TC2:	**Basic cost analysis**	84	**0.97**	**3**	73	**0.84**	**2**
TC9:	**Participant-led workshops (participants as a VM facilitator)**	82	**0.94**	**4**	54	**0.62**	**4**
TC4:	*A real project throughout the whole VM process*	82	**0.94**	**4**	36	0.41	7
TC3:	*Simple VM exercises for different techniques/phases*	81	0.93	6	65	**0.75**	**3**
TC8:	*People topics (e.g., team building, leadership, motivation, communication, etc.)*	77	0.89	8	50	**0.57**	**5**

TC5:	Detailed VM techniques (e.g., value analysis, creativity, evaluation, and implementation strategies, etc.)	79	0.91	7	22	0.25	9
TC7:	Financial	76	0.87	9	31	0.36	8
TC6:	Strategic level for the application of VM in an organization/a project	71	0.82	10	38	0.44	6
	Certification Components						
AC1:	**Fundamental VM knowledge**	84	**0.97**	**1**	73	**0.84**	**1**
AC6:	**Financial techniques**	84	**0.97**	**1**	45	**0.52**	**3**
AC4:	**Team-building techniques**	83	**0.95**	**3**	45	**0.52**	**3**
AC2:	**Function analysis**	77	**0.89**	**4**	51	**0.59**	**2**
AC5:	Facilitation skill and team leading	68	0.78	6	19	0.22	7
AC7:	Ability to promote VM	73	0.84	5	25	0.29	5
AC3:	Strategic organization/project level	68	0.78	6	23	0.26	6
AC8:	Certification system	68	0.78	6	13	0.15	8

The results reveal that the percentages and frequencies of both VM training components and certification components for VM facilitators were all higher than the 0.5 mid-point (i.e., between 0.82 and 0.98 and between 0.78 and 0.97, respectively). However, VM co-facilitators only rated five training components and four qualification certification components higher than the mid-point (i.e., between 0.57 and 0.87 and between 0.52 and 0.84, respectively). VM studies are usually used to seek alternative solutions to cost-saving (Barton 2000).

Among the 10 hypothetical training components, four top components include basic VM knowledge (TC1), basic cost analysis (TC2), participant-led workshops (TC9), and simple VM exercises for different techniques/phases (TC3) for VM facilitators (with percentages of 0.98%, 0.97%, 0.94%, and 0.93%, respectively) and for VM co-facilitators (0.87%, 0.84%, 0.62%, and 0.75% respectively). It is interesting to note that value culture (TC10) and a real project throughout the whole VM process (TC4) were ranked as essential components (first and fourth, respectively) for VM facilitators but as the least important components (tenth and seventh, respectively) for VM co-facilitators. On the other hand, simple VM exercises for different techniques and people topics were ranked as the third most essential component for co-facilitators, but only as the sixth and eighth important components, respectively, in VM training for facilitators.

Although the percentages of the eight qualification certification components for co-facilitators are generally lower than those for facilitators, the top four VM certification components for both parties are identical, including fundamental VM knowledge (AC1), function analysis (AC2), team-building techniques (AC4), and financial techniques (AC6) (0.97%, 0.97%, 0.95%, and 0.89%, respectively, for facilitators; 0.84, 0.52%, 0.52%, and 0.59%, respectively, for co-facilitators).

RECOMMENDATIONS

A standard can help to define a skill base for agreed practices and formal training (Male, 2006). VM training and certification systems are essential in nurturing qualified, competent VM professionals. This study identified key components for international VM training and certification systems for VM facilitators and co-facilitators.

Due to the high scores across all training and certification components for VM facilitators, the results clearly indicate that the expected requirements for VM facilitators are much higher than for co-facilitators. All VM training components should be adopted for VM facilitators, while only basic VM

knowledge, basic cost analysis, and a few soft VM skills (people topics and participant-led workshops) are necessary for the training of co-facilitators. Simple VM exercises for different techniques/phases are sufficient for co-facilitators' training, but a real project throughout the whole VM process plays an important role for facilitators. Moreover, facilitators have the need for value culture in their formal training.

Although the study found various VM training components for facilitators and co-facilitators, the qualification certification components are similar. Both parties considered fundamental VM knowledge, function analysis, team-building techniques, and financial techniques to be important in the certification system, while the remaining certification components, including VM promotion, facilitation skill, and strategic organization, should also be involved in the certification system for facilitators.

This study was conducted among international VM experts and participants, including those in Australia, Hong Kong, the USA, and the UK. In recent years, the one-belt-one-road scheme has been proposed in mainland China. It is strongly recommended that a study is conducted, particularly in regard to team building and value culture, in the regions affected by the one-belt-one-road scheme. It is expected that the implementation of VM in developing countries may be different to that in developed countries.

CONCLUSION

This study identified important training and certification components for both VM facilitators and VM co-facilitators on the basis of valid responses collected through an international questionnaire survey, using frequencies and percentages to rank the listed components. The findings revealed that training for VM co-facilitators should involve basic VM knowledge and basic cost analysis, with simple VM exercises for different techniques/phases in participant-led workshops, while fundamental VM knowledge, function analysis, team-building techniques, and financial techniques are recommended to be included in VM qualification certification assessments for co-facilitators.

On the other hand, VM facilitators should cover all VM training components and VM certification components in a deeply comprehensive way. Apart from the four aforementioned VM training components for co-facilitators, value culture and a real project throughout the whole VM process are also particularly important for VM facilitators. In addition to the four basic VM certification components for VM co-facilitators, facilitation skills, VM promotion, strategic organizational levels, and certification systems should also be included in qualification assessments for VM facilitators.

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IMPLEMENTATION AND UTILIZATION OF VALUE MANAGEMENT PRACTICE IN CONSTRUCTION COST MANAGEMENT PRACTICE IN NIGERIA

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ABSTRACT:
Construction project cost is one of the main key parameters that is used in assessing the success performance of any project. In Nigeria, the construction industry is facing the challenges of high cost of construction projects as a result of poor planning and management that sometimes led to project abandonment. The Nigerian Institute of Quantity Surveyors (NIQS) in collaboration with the Quantity Surveyors Registration Board of Nigeria (QSRBN) have jointly come up with different approaches and strategies to overcome the challenges. How well have these worked in addressing the challenges of high construction cost? What can be done to overcome these challenges in the country? These questions have postulated the need to examine the implementation and utilization of value management practice as a means of reducing the high construction cost in Nigeria. Value Management (VM) is a systematic approach in achieving the necessary functions of a project at the lowest resulting cost and optimum value for money. The survey used existing literature and obtained data from various studies on the challenges being experienced in the construction cost management practice to examine the implementation and utilization of value management as an alternative approach not only on cost but function and optimum value for money. Findings of the study have identified the key roles of the value management practice: achieving better value and cost; proving most effective design; promote sustainable and effective project delivery; clients achieve value for money; and improved communication and team working. It is evident from the findings that value management is a problem solving system aimed at reducing cost whilst maintaining or increasing performance and this can be achieved in the procurement process of construction projects delivery. Therefore, it is concluded that the use of value management practice in construction cost estimating procedure especially on projects that attract high capital outlay should be encouraged. This will greatly help in suggesting significant changes to the practice of cost management in the construction industry towards improving value and reducing cost of construction projects in Nigeria.
Keywords: Construction industry, Cost management, Value management, Implementation, Utilization.

INTRODUCTION

Construction projects plans are drawn to ensure that work is carried out to the desired quality within the stipulated time and cost (Austin and Thomson, 1999; Vasista, 2017a). Cost is one of the main considerations throughout a project life cycle and thereby regarded as a significant factor of a project and also a driving force of project achievement (Vasista, 2017a). Despite its proven significance, it is a common practice in Nigeria to observe a construction project failing to accomplish its objectives within the specified estimated cost (Mac-Barango, 2017). Studies have shown that cost of construction projects in Nigeria is one of the highest in the world (Dikko, 2015; Dahiru, 2015; Kasimu, 2015; Ogbili, 2015). It is also observed that there is total absence of value for money in the project's development matrix and most projects are left abandoned and uncompleted (Dikko, 2015). Ibrahim (2011) in Ofide (2015) identified inadequate planning as among the major factors responsible for high cost of these projects. Most of these challenges emerged as a result of poor project planning and management that usually resulted to dispute,

claims, fluctuation, cash flow problems and variation (Okpala & Aniekwu, 1988; Dikko, 2015; Kasimu, 2015).

However, it is against these practices that the Nigerian Institute of Quantity Surveyors (NIQS) in collaboration with the Quantity Surveyors Registration Board of Nigeria (QSRBN) have jointly developed efforts to overcome these challenges in different approaches and strategies. The NIQS & QSRBN were set up to regulate the Quantity Surveying profession by setting standard and providing support for continuing professional development through learning opportunities, networks for professionals to meet and discuss issues surrounding Quantity Surveying field of expertise and issuance of a code of conduct to guide professional behaviour, and provide career support and opportunities for students, graduates and the working professionals, etc. These two bodies (QSRBN & NIQS) were making efforts in spreading and disseminating the knowledge, understanding and facilitating collaborative work required to resolve current industry inadequacies through talks, workshops, seminars, and conferences. Such workshops, seminars and conferences include: Project Cost Reduction Summit (PCRS); Building & Construction Economic Round Table (BCERT); Registered Quantity Surveyors Assembly (RQSA); Professional Clinic (PC); and Annual Research Conference (ReCon). Each of these events is usually held every year to curtail the menace of the construction sector by devising a means of improving the sector through collaborative efforts of the stakeholders. Furthermore, the Bureau of Public Procurement (BPP) in a joint effort with professional bodies such as NIQS, QSRBN, and COREN have saved the federal government expenditure of over N216 billion (USD$1.44) in 2010 and N78 billion (USD$0.52) in 2011 (Ofide, 2015).

In an effort to improve value and minimize the cost of construction project, Ibrahim (2011) in Ofide (2015) had emphasized the need for the introduction of Value Management (VM) concept especially at the design stage of project development. Ofide (2015) had further noted that VM is one of the specialization of Quantity Surveyors recommended by the NIQS since 2008. Implementation and utilization of VM will reduce unnecessary project cost through a systematic process and such cost can be eliminated through creative thinking without compromising the functionality and performance of the project. VM is not just concerned about cost, but also about the relationship between function, value, quality and cost, with functional analysis as its principal components (Akram *et al.*, 2011). It is evident that promoting VM application in Nigeria requires continuous government support and other relevant stakeholders besides the establishment of a set guideline of its implementation in the country (Oke & Ogunsemi, 2009).

Therefore, it is on the basis of promoting cost management practice that this study is been conducted with the aim of examining the significant impact of value management implementation and utilization on construction project delivery. To accomplish this aim, the following objectives were drawn: the role of value management, its implementation process and utilization for effective project cost management in the Nigerian construction industry.

CONSTRUCTION PROJECT COST MANAGEMENT PRACTICE

The main project participants in a typical construction project are the client and his team of professional advisers (consultants) on the one hand and the main contractor, subcontractors and suppliers on the other (Vasista, 2017b). Clients, consultants and contractors are the principal actors to the development of construction projects delivery (Mac-Barango, 2017). Client is the initiator and financier and his contribution in specifying his needs is significant prior to the preparation of the design (Anyanwu, 2013). Consultants form part of the design team responsible in designing the project within the client's budget

and cost forecasts to ensure that accurate cost analysis and control is being put in place (Vasista, 2017a). The design team is traditionally made up of architects, engineers and quantity surveyors responsible for producing the documents/information (drawings, bills of quantities, specifications, equipment schedule, etc.) required by all the project participants (Vasista, 2017b). Contractors are virtually responsible in assembling and allocating the resources of labour, equipment and materials to the project in order to achieve completion at maximum efficiency in terms of cost, time and quality (Yismalet & Patel, 2018).

In Nigeria, one of the greatest challenges facing construction industry is to manage the risk of cost overruns due to poor cost management practice (Okpala & Aniekwu, 1988; Dahiru, 2015; Ikechukwu & Akiohnbare, 2017). In the quest to address this problem, the opinions of clients, consultants and contractors were sampled. It was discovered that factors attributable to construction cost overruns in Nigeria (Elinwa and Buba, 1993; Anyanwu, 2013; Dahiru, 2015; Ogbiti, 2015) are poor project planning, design and contract management as the most influential factors. Others include: errors, defects and omissions in contract documents, under/or overestimating the real cost of the project in the beginning. Inconsistencies between contract drawings and bill of quantities is another problem in construction contract and contribute negatively to the overall project cost management.

Project cost management refers to the processes of resource planning, cost estimating, cost budgeting and cost control required to ensure that the project is completed within the approved budget (Potts, 2010; Anyanwu, 2013; Mac-Barango, 2017). In an effort to promote an effective cost management practice, Potts (2010) emphasized the need to: recognize cost as a design factor; design to a cost target; develop a realistic first estimate based on stringent government cost limits; develop the cost plan based on an elemental cost analysis approach, cost check throughout the design process; the architect and quantity surveyor should work together as a team (preferably in the same office) with the close involvement of the building services consultant; use value management/value engineering techniques on the project; among others. Effective project cost management is an extremely complex process that begins very early during a project life cycle, and long before its actual start (Mac-Barango, 2017). Among the factors that influence success is a reasonable and accurate system for estimating costs (Ikechukwu & Akiohnbare, 2017). Dahiru (2015) noted that effective cost management practice is heavily dependent upon the level of professional expertise and extent of the use of value management technique among other things.

FRAMEWORK OF VALUE MANAGEMENT

Value Management (VM) is an integral part of management technology as well as an effective method of reducing cost and improving resource efficiency (Oke & Ogunsemi, 2011; Akram et al., 2011). VM is regarded as a structured and analytical process aimed at achieving value for money by providing necessary functions in projects at the lowest cost consistent with required standards of quality and functionality (Karim, 2016). Perera *et al.*, (2003) noted that the concept is unlike traditional Value Engineering (VE) which focuses only on design and construction. VM is a comprehensive evaluation of all aspects of the project from the project feasibility study, the financing plan and costs, project design & construction and through project operation (Perera *et al.*, 2003). Therefore VM include the whole range of value techniques available and can illustrate as the generic process (Perera *et al.*, 2003) that includes: Value Planning (VP) example, apply VM during the concept or planning phases of the project; Value Engineering (VE) apply VM during the design or engineering phases of the project; Value Analysis (VA) or Value Reviewing (VR) apply retrospectively to completed projects to analyze or to audit the project's performance, and to

compare a completed, nearly completed, design or project against predetermined expectations (Moon *et al.*, 2016).

VM serves as a systematic approach for analyzing the functional requirements of the project capable of obtaining the essential functions at the lowest total cost (Moon *et al.*, 2016). In fact, it aims to reduce overall project costs through identifying and eliminating unnecessary costs. According to Ajator (2004), the successful implementation of a VM practice can result in update of standards and policies, and quality improvement of projects. Contemporary perspectives, however, suggest a wider role for VM in the process of identifying, clarifying and confirming client (project proponent) requirements and objectives at an early stage in the project procurement phase (Ramly *et al*., 2015).

Figure 1 illustrates how VM framework employs to maximize the functional value of a project by managing its evolution and development from concept to completion, through the comparison and audit of all decisions against a value system determined by the client. The technique has long been regarded as an effective means of eliminating unnecessary cost at different stages of project development. However, in Nigeria many professionals in the construction industry are familiar with the underlying theory, but its use locally is perceived to be less widespread. This is due to the fact that little is known about the management of opportunities in infrastructure projects delivery. It is expected that a better understanding of the management of opportunities can support the design team at the pre-construction stage in exceeding their project objectives and thereby creating short and long term added value for the client. VM helps clients ensure that their investment in construction produces valuable assets which are cost effective to construct, use and maintain (Tang & Bittner, 2014). It is a structured approach to defining what value means to a client when meeting a perceived need, and to delivering that value via the design and construction process. It does this by clearly defining and agreeing project objectives and the means of achieving them (Perera *et al.*, 2003). The decision to build is a major one, with far reaching consequences. It involves a substantial investment of time, effort and money, and produces valuable assets which affect the lives and businesses of those who own and use them. The concept is attracting considerable interest in the Nigerian construction industry as a means of improving the overall value and performance of construction projects (Oke & Ogunsemi, 2011). VM study used to: identify and evaluate the need for construction before making a major financial commitment; identify and prioritize key project objectives; ensure all aspects of the project design are the most effective for their purpose in terms of cost, quality and satisfaction of the client's long term needs; improve team building; and eliminate unnecessary cost. Akram *et al.*, (2011) observed that there are a number of techniques which are commonly used in the conduct of VM studies. Some of these techniques are: Function analysis; Function analysis system technique (FAST); Cost/worth; SMART methodology; Value drivers; Value benchmarking (or value profiling); Options selection; Weighting techniques; Creative techniques; Evaluation techniques; Scenarios technique; Target costing; Function performance specification (FPS).

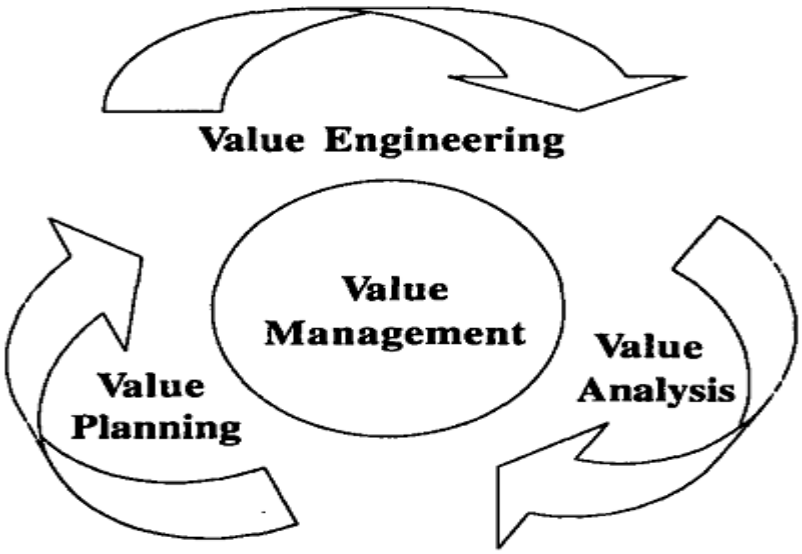

Figure 1: Generic Process of VM (source: Perera *et al.*, 2003)

THE ROLES OF VALUE MANAGEMENT PRACTICE

Value, in its broadest sense, is the benefit to the client – or the wider country, for many projects delivered by the public sector. Kelly & Male (2005) noted that VM confirms the project is worth doing and quantifies the evidence of this in business terms (though not necessarily in financial terms), e.g. creating a better working environment or improving the experience of patients during treatment. In this study, managing value means making the right choices to obtain the optimum balance of benefit in relation to cost. Value management provides a structured approach to the assessment and development of a project, to increase the likelihood of achieving these requirements with optimum whole-of-life value for money (Tang & Bittner, 2014).

Value Management is a Continuous Process

As a continuous process, consensus and mutual understanding between stakeholders, clear objectives, reduced risk of changes in scope and improved communications will help ensure that the project meets the objectives of the client and is delivered within the relevant parameters. Value Management is a continuous process throughout the project lifecycle and its activities inform key decision points (Tang & Bittner, 2014). In fact, all the components and processes involved in construction are critically appraised to determine whether better value alternatives or solutions are available (Oke & Ogunsemi, 2011). It help reduce wasteful processes and inefficiency in specific aspects of the design, construction, maintenance and operation. Value management is also important because it enables stakeholders to define and achieve their needs, through facilitated workshops that encourage participation, team-working and end-user buy-in. It enhances quality performance of construction projects and eliminates unnecessary design. VM is a basis for ensuring the project is the most effective way of delivering business benefits and satisfying business needs. As part of these roles, Hayatu (2015) emphasized the need for the government to adopt value management as part of the procurement process as designed by the Bureau for Public Procurement in Nigeria.

Achieve better value and cost

Value management can be a very low-cost, high-benefit exercise (Kelly & Male, 2005; Mesbah, 2014). When integrated into the project management methodology early in the project life cycle, the cost may become almost negligible because of the reduced need for subsequent reviews and opportunities for substituting value management for some of the routine appraisals and quality audits that are always necessary. VM is able to achieve the essential functions at a cost that fits with the needed purpose, performance, reliability and maintainability. Oke & Aigbavboa (2017) identified that VM provide the best option and remove components as well as costs that do not contribute to the value of the projects, programs, facilities and systems without compromising the objectives and functions defined. VM is a systematic multidisciplinary approach and innovative in order to study the function of a program requirements, design, products, services, projects, facilities and systems to achieve better value and cost optimization without compromising the performance of the projects, programs, facilities and systems (Kelly & Male, 2005). VM focus on function and value for money over the whole of the life of the project, rather than on reducing cost. Eliminates unnecessary design and improves functional space quality of projects, reduce cost and improve value (Oke & Ogunsemi, 2009). The practice of VM promotes economic investment, reduce cost and improve value (Tang & Bittner, 2014).

Provides most effective design

The design stage of the project development is the most effective time to introduce value management as it has more potential to provide significant cost reductions as more appropriate solutions are developed based on a consideration of all major stakeholder issues and concerns (Tashir *et al.*, 2016). It is apparent that greater collaboration between the design team is required if construction projects are to be delivered more effectively (Austin and Thomson, 1999). To achieve this, the VM concept must be applied to facilitate the identification of design expertise distribution within the design team members. VM promotes collaborative and mutually beneficial working methods to reduce design process inefficiency by incorporating the design expertise of the design team members into the continuous project design function. It is anticipated that this will cause the design of each project element to be undertaken by the most capable design team members, causing design efficiency to be improved as initial design process. These can then be specifically addressed to minimize inefficiency and ensure client satisfaction. Kelly and Male (2005) had identified and report 7 benefits of VM in construction project delivery and the top among the factors is to provide most effective design. This is followed by lowering project cost; improves the project schedule; cost and quality improvements for the client and contractor. Others include improved value and technical specification; improves the management of a project; and peace of mind for the client.

Promote sustainable and effective project delivery

Sustainable and effective project delivery was proved to be the key benefits of VM practice in construction project delivery (Potts, 2010). Others include better business decisions by providing decision makers a sound basis for their choice; improved products and services to external customers by clearly understanding and giving due priority to their real needs; enhanced competitiveness by facilitating technical and organizational innovation; a common value culture, thus enhancing every member's understanding of the organisation's goals; improved internal communication and common knowledge of the main success factors for the organization. Simultaneously enhanced communication and efficiency by developing multidisciplinary and multitask team work and decisions which can be supported by the stakeholders.

Clients achieve value for money

VM helps clients to understand what value management involves and what resources and other support are needed to exploit fully its potential benefits (Potts, 2010). Its application helps clients to achieve value for money from their construction projects by ensuring that the need for projects is always verified and supported by data and project objectives are openly discussed and clearly identified. Mesbah (2014) observed that in VM practice, the key decisions are rational, explicit and accountable and the design evolves within an agreed framework of project objectives. By applying the concept, alternatives options are always considered and outline design proposals are carefully evaluated and selected on the basis of defined performance criteria. Using VM techniques promote the adoption of new construction techniques or innovation that enhance good quality of work capable of achieving client's satisfaction (Oke & Ogunsemi, 2009). VM promotes adaptability and flexibility that gives the true worth or value of money to client. Effective delivery system capable of meeting project completion period is essential to the application of VM in construction project delivery.

Improved communication and team working

VM is a functional basis for design development and management, through improved communications, mutual learning and enhanced collaborative working, leading to better technical solutions with enhanced performance and quality, often through innovative solutions. A basis for creating a clear project brief that reflects the project sponsor's priorities and expectations, expressed on the basis of value and function. This improves communication between all the stakeholders so that each can understand and respect the other's constraints, expectations and requirements. Tang and Bittner (2014) advocates that VM improved communication and team working. A shared understanding among key participants will amount to better quality project definition that increased innovation and the elimination of unnecessary cost. VM practice provides a better understanding of the business needs, including the flexibility required to meet future needs and the clear definition of specific stakeholder needs. Consideration of all options, alternatives and innovative ideas and the achievement of optimum value for money while satisfying the range of user requirements are found to be the key elements of VM. Tashir *et al.*, (2016) recognized that value management prevent unnecessary expenditure through reducing waste and inefficiency and improved team-working with joint ownership of solutions as a result of effective communication and team work. VM improves construction professionals to work as a team and give room for motivation and high technical advancement through effective communication and team work (Kelly & Male, 2005). Through effective communication and team work, VM promotes mutual relationship and confidence among project team which will ensure standard delivery of the project.

IMPLEMENTATION

The main reason for undertaking VM is to achieve the essential functions at the lowest cost according to the clients' needs and requirements in terms of performance, reliability and maintainability. VM and its structured process with effective tools and techniques ensure the need to solve problems in the project. VM is a methodology that enhance the work relationship among the team and in the meantime able to achieve better value for money and imperative idea to be executed in the construction industry particularly in the public projects. Value management has not been fully embraced in the Nigerian construction industry (Oke & Ogunsemi, 2009). Perhaps, various studies have revealed that professionals have a good understanding of value management and the barriers to implement it are more prevalent than the facilitators of adopting it in the country (Kolo & Ibrahim, 2010; Dahiru, 2015; Hayatu, 2015). VM techniques such as: Value Analysis (VA); Risk Management (RM); Function Analysis System Technique

(FAST); Cost Benefit Analysis (CBA); and Strength, Weakness, Opportunity and Thread (SWOT) analyses were identified as the few techniques sometimes adopted in Nigeria (Leje et al., 2017). Kolo and Ibrahim (2010) have long realized the requirements of value management implementation and were categorised into environment, people, process, issues and information. On the other hand, Hayatu (2015) identified the key barriers existent to the implementation of VM in the Nigerian construction industry as: lack of government commitment to support the system application; lack of value management qualified practitioners; lack of time due to rushed designs and difficulties in the involvement of all key stakeholders in project processes. To bridge this gap, this study examine the key benefits and implementation strategies of VM practice in the Nigerian construction industry as a way of reducing the high cost of construction projects in the country.

VM becomes the favoured control tool of the design team in the planning and development phases where you need a proactive and creative problem solving method while all options are still open. Other control techniques can be used only when all parameters are set. The technique will explicitly state the client's value system, covering all aspects of the project. The design team under the leadership of the project manager will rely on the analytical aspect of functional analysis and value analysis in the first two phases and on the overall concept of value throughout the entire project in order to cover each project management core and supporting function.

In an effort to promote the application of VM in the built environment, Tang and Bittner (2014) have determined seven steps formalized into systematic decision-making procedures of VM implementation. These are:

- Gather information – collect information about a project and the specific problem to be solved,
- Analyze functions – analyze the project and problem to understand functions required by the project and the problem resolution process,
- Generate solutions – identify solutions that can provide or accomplish the required functions,
- Evaluate solutions - use predefined performance metrics to evaluate the generated solutions,
- Select and prepare solutions – select one or more promising solutions, and further analyze the technical and economical feasibilities of carrying out these selected solutions with the required performance of construction operations;
- Present solutions and its expected value and submit that to the owner and decision makers for approval; and
- Monitor the solution execution process once it is approved, managers can implement the solution and execute the plan to carry it out. During that process, managers need to follow up and monitor the execution process, compare the expected performance of the solution to its actual performance, and make adjustments to the execution plan when necessary.

Process

Value management has been recognized as a team based approach designed to define the objectives of clients and achieve best value not necessarily about cost cutting (Bowen, 2010). Value management process is being carried out from the early stages of a project development for achieving maximum benefits (Mesbah, 2014). Spaulding (2005) observed that the VM process is a more systematic approach to ensure specific functions are satisfied to the standard requirement for the least cost. It assesses a range of possible solutions against the values required by the client. Value management exercises can also be used to recover cost divergence (costs diverging from the budget) that may become apparent when design

reports are prepared. Under these circumstances, the client may have to choose priorities, or decide to increase the budget.

VM implementation process helps with decision making at all levels of project delivery (Tashir et al., 2016). The concept of value relies on the relationship between satisfying many differing needs and the resources used in doing so. The fewer resources used and the greater the satisfaction of needs, the greater the value. Stakeholders (including internal and external customers) may all hold differing views of what represents value. The process of VM is to reconcile these differences and enable the client to achieve the greatest progress towards its stated goals with the use of minimum resources. Suhaimi (2014) recognized that, in an effort to reconcile the client needs with the limited resources required to achieve value, the project should be well planned and designed to ensure that a value management plan is drawn up and incorporated in the project execution plan. Therefore the VM implementation process establish more activities at key stages of implementation:

- Project inception – this activity identifies the needs of the stakeholders and informs the decision on whether a project is required or not. VM serve as a tool for strategic options assessment and making a choice to do something or not. This results in a description of the stakeholder needs and priorities confirming the need of a project.
- Options appraisal – this activity identifies key priorities and constraints required to identify and examine possible solutions. This makes explicit the client's values and priorities, the project needs and objectives, and key project constraints and risks. The activity aims to recognize and eradicate the need for late changes by resulting in a description of the project on what has to be done to meet the project's objectives and priorities. It helps the project design team to produce the project brief clearly and precisely.
- Procurement strategy – to appraise the available procurement options and define the procurement strategy. This activity help to ensure that the procurement option selected will meet the objectives set for the project development. It result in a clear statement of the processes to be provided and a preferred procurement approach and contract strategy. This forms the basis of a case for the continuation of the project and VM in making choices between the design options.
- Output specification – this considers the output specification against the background of project needs, priorities and the objectives hierarchy developed at the earlier activity. It results in a thorough assessment of the output specification and clear recommendations for a response from a new external procurement. It forms the basis of a submission for final approval to invite registrations of interest for bidders for the design and construction of the project.
- Outline design – this is to ensure that the required functionality and quality are confirmed before proceeding to detailed design.
- Detailed design prior to the approval to begin construction – VM activity of the design focuses on the project design team's expertise in improving buildability so that works are implemented faster, more efficiently and safely and at lower whole-life cost construction to resolve any issues on site as required.

Each of these activities provides an additional opportunity to undertake concurrent risk assessments on the options under consideration. The precise format and timing of activities will vary according to circumstances. Lessons should be captured and learned about particular approaches that improve speed

of construction, reduce whole-life costs and/or improve value, including health and safety. For large or complex projects there may be a number of value management reviews, each focused on individual elements of the design. Green and Liu (2007) advocated that structured workshops led by an independent facilitator the usual way that value management is being implemented.

Job Plan

Suhaimi (2014) noted that VM Job Plan is a guide detailing such matters as pre-study preparation to define the VM which has the potential to enable the integration of project objectives into the early stages of project development. Figure 2 shows the tasks involved in conducting the information phase as the first task to understanding the decisions that may influence the development of the proposed design and uses of Function Analysis System Technique (FAST) as a method to understand the project through the perspective function of project delivery. Further in creativity phase, design team generate as many ideas, brainstorm and emphasize alternative means of achieving the client's needs. Next, go through the next phases to evaluate the ideas developed into alternatives that increase the value of the project in terms of getting more benefits. These might be in the form of design sketches, illustrations, drawings, diagrams and calculations, information and other specific materials (Tashir et al., 2016).

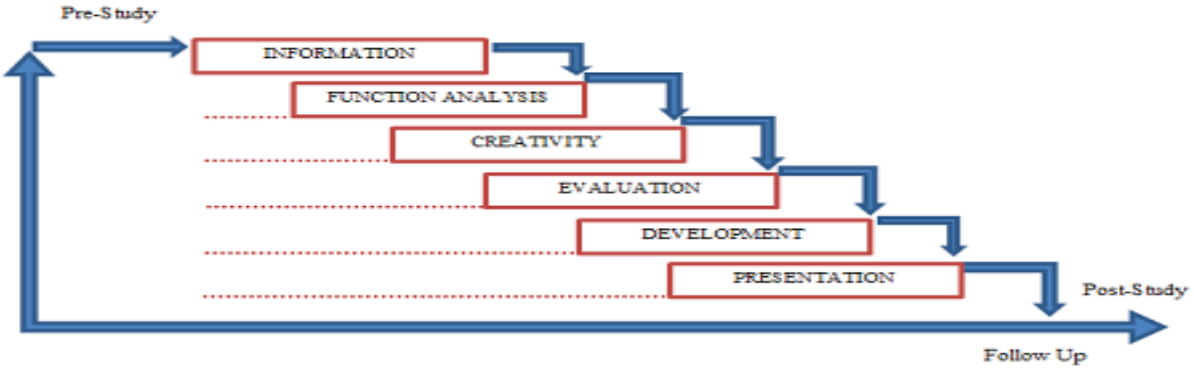

Figure 2: Value Management Job Plan developed by Tashir et al. 2016

Value management usually follows a job plan, which involves a series of steps that need to be followed in order to determine the most promising options or proposals:

- Orientation/identification – this involves the identification of the business problem, the customer needs and priorities.
- Information – this step involves the collection of information/data regarding values, costs, risks, programme and other project constraints.
- Speculation generation – this involves the generation of ideas to meet the needs and priorities previously identified. This is usually best undertaken via a workshop with all the stakeholders and project team members. The principle is that ideas are generated in a 'criticism-free' atmosphere, which promotes freethinking and creative ideas.
- Idea evaluation – this step identifies the most promising options from the last stage.
- Idea development: the most promising options are developed and appraised. This may be undertaken by sub-groups of the workshop.

- Recommendation/decision/implementation – the results from the last stage are presented to the workshop group and a decision is made on which proposal to pursue. An action plan is prepared to take the proposal forward.
- Feedback – the success of the options implemented is assessed to provide lessons learned and inform future projects.

UTILIZATION

Pre-Construction is the early stage of construction which consists of planning and designing a project (figure 3). It plays an important role in the project execution to emphasize a few important criteria to ensure that a project that will be constructed in a satisfactory condition, comfortable, easy to maintain, according to its operations and weather conditions (Alalshikh and Male, 2009; Suhaimi, 2014). The design concept and VM approach have been clarified in numerous previous studies. They specified the importance of utilizing the VM concept at the early stage of the project development that could influence the cost and function for the whole project during the operational and maintenance stage (Kelly and Male, 2005; Bowen et al., 2007; Oke and Aigbavboa, 2017).

Figure 3: Building construction stages

The preliminary design stage is the most effective time to implement value management as it has more potential to provide significant cost reductions as more appropriate solutions are developed based on a consideration of all major stakeholder issues and concerns (Ajator, 2004). It was noted that the greatest possible savings can be achieved during the planning and definition phases, which will ensure that appropriate investment decisions are made (Planning construction procurement, 2016). Many studies have emphasized the key opportunities attached to the utilization of value management practice at the preliminary design stage of the project development (Austin & Thomson, 1999; Kelly & Male, 2005; Oke & Aigbavboa, 2017). Such stages include: conception; feasibility, pre-design, and detail design stage of the project development. The key opportunity points in these stages involve: during the concept stage (to help identify the need for a project, its key objectives and constraints); during feasibility stage (to evaluate the broad project approach/outline design); during scheme design (to evaluate developing design proposals); during detailed design (to evaluate detailed design proposals).

Utilization of value management at regular stages of the project development especially on projects that attract high capital outlay can achieve the following (Planning construction procurement, 2016):

- establishing what value means to the client in terms of business benefits and priorities
- identifying and agreeing business needs

- identifying and evaluating options (including delivery model options) for meeting business needs
- selecting and agreeing the best option to meet business needs (that is, confirming whether or not a project is required)
- defining clearly and agreeing the project objectives (through stakeholder buy-in)
- selecting and agreeing the best project option, drawing on the expertise of independent client advisers
- setting and weighting the selection and award criteria for the appointment of the supply team
- evaluating the supply teams' bids against the selection and award evaluation criteria refining the design to maximise value and eliminate waste and those aspects not directly related to meeting the project objectives
- Identifying and selecting project options to deliver maximum benefit when budget is constrained.

Planning construction procurement (2016) advocates Value Management as a continuous process throughout the project lifecycle and its activities inform key decision points. Table 1 shows the main points in the procurement process where value management activities take place and summarizes its activities.

Table 1: value management activities during procurement process

Stages involve during procurement process	Value management approach
• Inception stage	• VM should be considered to identify stakeholder needs, objectives, outcomes and priorities.
• Strategic assessment on alternative options	• VM study to evaluate options that could meet user needs
• Business justification & options	• VM to develop output-based specification, to refine and evaluate options that satisfy project brief, objectives and outcomes.
• Focus on delivery strategy	• VM to apply selection and award criteria
• Focus on investment approach	• VM study to optimize whole-life design quality and cost. Project team to assess buildability of options
• Focus on design concept	• VM study to optimize whole-life design quality and cost. Project team to assess buildability of design considering quality and cost as a factor.
• Detailed Design	• VM for detail of finishes etc.
• Readiness for service	• VM review and feedback of lessons learned

Source**:** Planning construction procurement, 2016

CONCLUSION

The construction cost management practice has been identified as the main challenges of the Nigerian construction industry especially at the design stage of the project development. Several efforts have been made by NIQS and QSRBN to mitigate these challenges through different approaches and strategies and yet absolute resolutions have not been made. Therefore, the study examined these challenges through extensive literature survey and presented the needs and relevance of VM practice during project planning, designing and construction as a means of reducing the high cost of construction projects in the country. The survey has observed and provided an insight into how value management can facilitate the

collaborative working required to resolve high construction cost in developing countries like Nigeria. However, it is observed that lack of government commitment to support the implementation of VM through its procurement system was determined to be the major factor limiting VM application. Findings of the study have also identified the key roles of the value management practice: achieving better value and cost; providing most effective design; promote sustainable and effective project delivery; clients achieve value for money; and improved communication and team working. It is evident from the findings that value management is a problem solving system aimed at reducing cost whilst maintaining or increasing performance and this can be achieved in the procurement process of construction projects delivery. Furthermore, the study discovered that value management has good potential to provide increased value and cost effectiveness at all stages of the project life cycle. Lastly, the process and strategy of implementation and utilization of VM for effective application in the construction industry has been realized. Based on the findings, it is recommended that government should encourage the use of VM practice especially at the early stage of the project development as this is the most critical stage capable of providing significant cost reduction as more appropriate solutions are developed based on a consideration of all major stakeholder issues and concerns. This will greatly help in suggesting significant changes to the practice of cost management in the construction industry towards improving value and reducing cost of construction projects in Nigeria.

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INTRODUCTON TO ELEMENTAL DESIGN ANALYSIS (EDA) AND ITS INTEGRATION INTO BIM

Keh Liang Chin, Perunding PCT Sdn Bhd

At the initial 3D BIM stage where the Architect produces only LOD 100 drawings for a proposed building for the QS to produce a cost estimate based on the same, the QS can only use cost/sq.m. from a similar building (or commonly called the 'Unit Method') to compute such estimate. If the Architect/building client changes the configuration/shape of the proposed building, the upgrade/downgrade the finishes used, increase/decrease the numbers of rooms and/or toilets, etc. as parts of a cost study on the design of the proposed building at this early stage of the design, the QS can only use the change in the GFA/CPA (if there is any change) to come out with the revised estimate which is NOT reflective of the changes made.

Such method has inherent inaccuracies due to 'price level', 'quantity' and 'quality' factors. 'Price level' inaccuracy arises when the unit rate adopted might be outdated due to the fluctuation in materials, labour and/or plant costs. 'Quantity' inaccuracy arises when, for example, if there are more toilets & bathrooms in the proposed building than the previous similar building, then there will be an underestimation of the cost on sanitary fittings, and the related finishes, 'Quality' inaccuracy arises when, for example, if the finishes used on the proposed building is of a higher quality than the previous similar building, then there will be an underestimation of the cost on finishes.

In today's competitive market coupled with the ever-increasing prices, the discerning building client has placed more emphasis to build a value-for-money building and within its initial cost budget. As such, the traditional method of cost estimates cannot satisfy such exacting requirements.

Elemental Design Analysis (EDA) technique is a groundbreaking cost planning technique which can fulfil such requirements as it eliminates the three factors mentioned above.

This technique differs from the traditional methods of cost planning in two main aspects, namely,

i) The production of EDA of an existing building is based on the analysis of its design data and, to a lesser extent, the cost data from its priced BQ and drawings, instead of solely cost data; and
ii) The cost estimate of a proposed building produced by the application of EDA at LOD 100 stage of the design comprises a priced Simplified BQ whereby, it shows the allocation of the up-to-date cost to each major item of works within each element with its unit rate and approximate quantity, and a cost plan with a concise specification and essential design information, instead of only a lump sum total cost estimate.

By virtual of the fact that EDA technique can produce a priced Simplified BQ at LOD 100 stage of the design, there is a possibility that the EDA technique can be integrated into the 3D software to produce 4D and 5D BIM at the LOD 100 stage of the design.

This paper aims to give an overview of EDA technique by delving into three key aspects, namely,

i) the production process of EDA and the principles behind;
ii) the application of EDA; and
iii) the conclusions which deal with the possibility of integration of EDA into the 3D software to produce 4D and 5D BIM, and its spin-offs

ISO 41000 SERIES: INTERNATIONAL FM STANDARDS AND THE IMPLICATIONS FOR OUR BUILT ENVIRONMENT

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Purpose

Increased awareness of ISO 41000 Facilities Management (FM) and related standards, specifically the implications for the Quantity Surveyor (QS) and Life Cycle Costing.

Approach

The International Standards Organization (ISO) was founded in 1947, as an independent, non-governmental international organization and currently has a membership of 163 national standards bodies. Through its members, ISO brings together experts to share knowledge and develop voluntary, consensus-based, market relevant international Standards that support innovation and provide solutions to global challenges. Specifically, these Standards provide world-class specifications for products, services and systems, to ensure quality, safety and efficiency. They are instrumental in facilitating international trade.

ISO/TC-267 was approved in 2011 to develop a series of Facility Management (FM) standards which have significant relevance to the Built Environment life cycle.

FM is an "organizational function which integrates people, place and process within the Built Environment with the purpose of improving the quality of life of people and the productivity of the core business" ISO 41011:2017.

The release of the first ISO 41000 international FM standards in 2017 are intended to contribute directly to the Sustainability, Productivity and Liveability of the Built Environment as the product of property – construction – facilities industry and professions worldwide. The ISO 41000 series is a game changer and provides a framework for FM and impacts on the operational efficiency of facilities and productivity of organizations and associated individuals. Now ISO 41001:2018 provides a Management System Standard for FM.

There are other related standards will be considered, such as ISO 14000 Environmental, ISO 31000 Risk Management, ISO 55000 Asset Management etc with implications for those responsible for the designing, delivering and managing the Built Environment. Further our industry should be aware how these relate to FM and translate into a range of professional statements, practice notes and industry guidelines in support of best practice.

This includes the Quantity Surveying (QS) and related professionals.

Findings/Results

FM as a discipline are increasingly focused on being a contributor to organizational value and achieving related defined outcomes not just being an operational cost centre.

These international FM standards provide Facility Managers with a common language and a framework to support global consistency in the delivery of services, fine-tune performance and manage risks while allowing businesses to operate in a more effective, efficient and sustainable manners. However such FM standards should not be viewed as separate to the design and construction phases of the Built Environment, but embraced by all. Life Cycle Costing is just one example of an area that needs to be improved to realize the potential of ISO 41000 series.

The complexity of modern assets and facilities, and their relationship to risk management provides industry professionals and participants with an opportunity to enhance the strategic significance of a responsibly managed and operationally efficient and effective Built Environment in a challenging world.

According to the IFMA-RICS 'Strategic FM Framework' (2018) conceptual cost management for FM should consider:

- economy – the procurement of goods and services at the best available price per unit
- efficiency – the use of the least quantity of resources to achieve the required output and
- effectiveness – the achievement of the required outcome at the lowest total cost.

Modern FM as a discipline is about much more than the management of buildings and services: it is arguably critical to the successful functioning of every organization which occupies property. This provides the QS and other professions with both challenges and opportunities.

Implications

There is a need for increase consistency and transparency of professional practices across the global to achieve truly integrated building life cycle strategies.

This is in part addressed by the arrival of new ISO standards for FM including:

- ISO 41001:2018 FM – Management System Standard – Requirements with guidance for use Vocabulary
- ISO 41011:2017 FM – Vocabulary
- ISO 41012:2017 FM – Guidance on strategic sourcing and the development of agreements
- ISO 41013:2018 FM – Scope, key concepts and benefits technical report

All should be approved as Australian Standards before the end of 2018, and more work items and standards are under development by ISO/TC-267 with 45 counties now involved.

The presentation will also address the leadership and culture issues surrounding ISO 41000 series, and the impact of standards on managing our Built Environment for improved Sustainability, Productivity and Liveability.

Keywords:

Facility Management (FM), Built Environment, Sustainability, Productivity, Liveability, Life Cycle Cost, Quality of life and Standards.

LEGAL CONSENSUS AS TO EMBARGO CLAIMS IN THE GULF REGION; AN INVESTIGATIVE STUDY

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- Purpose

Certain political sanctions were recently imposed against Qatar by Bahrain, Egypt, Saudi Arabia and the United Arab Emirates. Given the fact that Qatar is very busy constructing a number of projects in preparation for the FIFA World Cup in 2022, it's unsurprising that the Quantity Surveyors have had some requests for advice from contractors whose operations in Qatar have been affected by the sanctions and who are looking for a means of claiming extensions of time and/or damages. The purpose of this study, under circumstances, is to explore the legal consensus pertaining to the embargo in Qatar.

- Design/methodology/Approach

Qatar is a country governed by civil codified law provisions influenced by Islamic principles. The approach designed is multidimensional. A thorough literature survey was conducted at the outset including standard forms of contracts adopted in the procurement of public works, recent arbitral awards, mediation outcomes and technical papers from industry personnel as well as legal research papers. An opinion survey was carried out among the law experts and experts in claims consultancy. Author's firsthand experience on drafting and review of claims was also inescapable.

- Findings/Results

Basically, the clause 19 of the Conditions of Contract for public works mandates that the Employer shall indemnify and save harmless the Contractor against and from the same and against and from all claims, damages, cost, charges etc. The Employer shall compensate the Contractor from any loss or damage to property of the Contractor with regard to Special Risks. In pursuant to the Clause 19.3; Contractor's Responsibility, the Contractor shall promptly notify the Engineer and shall endeavor to continue to perform his obligations as far as reasonably practicable. The Clause 19.4; Employer's Responsibility mandates the Employer also to promptly notify the Contractor and make every possible endeavor he can to continue to perform his obligations as far as reasonably practicable. Also revealed is that embargo is, in certain bespoken contracts, a matter of force majeure. As a matter of certainty, contractors put forward in point form the salient features of the relevant legal provisions and the way the special risks and open market vacillations have been treated and judicially recognized, as a part of their claims in nutshell.

The doctrine of force majeure is recognized under Law No. 22 of 2004 in the Qatari Civil Code in the State of Qatar. Articles 204 and 258 both articulate the concept of force majeure and provide relief to the non-performing party in the circumstances where another party's loss can be attributed to an external cause, or, more in-line with the traditional concept of force majeure, where the non-performance itself is due to an extraneous cause. Article 171(2) of the Civil Code provides that where, as a result of exceptional and unforeseeable events, the fulfillment of the contractual obligation, though not impossible, becomes excessively onerous in such a way as to threaten the obligor with exorbitant loss, the court may, according to the circumstances and after taking into consideration the interests of both parties, reduce the excessive obligation to a reasonable level. Article 188(1) of the Civil Code provides that, where the performance of one of the parties' obligations becomes impossible (i.e., more than just difficult) for an extraneous cause beyond its control, the corresponding obligation shall cease

and the contract automatically rescinded. Article 191 of the Civil Code provides a potential way to deal with frustration as it provides that a party may decline to perform its obligation if the other has failed to perform its corresponding obligation. Article 700 of the Civil Code provides that an increase in the price of raw materials, labour or other expenditure shall not give rise to an entitlement of the contractor or otherwise vary the obligations imposed by the construction contract. This is except where the price escalation came about as a result of an "exceptional incident" such as embargo for example.

- Implications/Originality/Value

The Qatari diplomatic crisis is a qualifying event for contracts that contain a similar definition and its civil procedure offers a series of legal remedies and obligations underlying the operation of contractual relationship. Equitable principles codified in the Qatar Civil Law include the requirement for parties to a contract to conduct themselves "consistent with the dictates of good faith" and an implied duty of the employer to cooperate with its contractors and not to delay or prevent their contract performance. Furthermore, where a contractor has suffered excessive losses arising from exceptional events (as a ripple effect of the embargo, blockade, shortage etc) the contractor may be able to raise an exceptional event's argument pursuant to Article 171 of the Qatar Civil Law, and if successful, the approach is to reduce the contractor's burdensome obligation to a reasonable limit after balancing the interests of the parties.

Key words: damages, disruption, embargo, force majeure, special risks

LIFE-CYCLE COST OPTIMIZATION MODELS FOR GREEN BUILDINGS: A LITERATURE REVIEW

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ABSTRACT

Green Buildings is one of the main solutions considered in minimising the adverse impacts to the environment through the building construction. The initial cost premium always acts as a significant barrier to the green building implementation. However, the perceived benefits and savings are not captured in the initial cost of green building and therefore; there is a significant requirement to make a paradigm shift to use life-cycle cost instead of initial cost in the decision making stages. This paper reports an extensive literature review on the life-cycle optimization models developed by researchers. There are many parameters considered to evaluate green buildings. However, all the life-cycle cost models considered either two or three common parameters to identify solutions with optimum life-cycle cost. Majority of the life-cycle cost models provided optimum solutions considering either energy parameters or material parameters opposed to the life-cycle cost. It is found that in the existing studies, other criteria such as water use and indoor environment quality are significantly overlooked. Even the widely discussed life-cycle cost models with criteria such as energy and material always focused on very specific parameters. As an example, there are many types of research focusing on identifying the optimum insulation thickness of the material with a lower life-cycle cost. However, the thickness of the material is only one parameter in material selection, and numerous other factors need to be considered when selecting materials for green buildings. Therefore, there is a clear research gap for developing a life-cycle cost model that identifies optimum solutions considering all the criteria of green buildings holistically.

Key words: Green buildings, Life-cycle cost model, Optimization

INTRODUCTION

In order to achieve the sustainable development of construction industry, the development of green building has become the inevitable choice of all countries in the world (Yin and Bai, 2014). Therefore, green building is one of the widely discussed topics in the construction industry. However, whenever the green building discussion comes up the initial cost premium acts as one of the main barriers. Usually, green buildings are designed to reduce operating costs by reducing energy consumption (Shrestha and Pushpala, 2012) and so on. These savings occurring in the building life-cycle is not captured in the initial cost. The initiatives taken for a better wellbeing of occupants in green buildings have an impact on the life-cycle costs (Cole, 2007). Therefore, life-cycle cost methods have a very positive influence on popularizing savings over the life cycle of green buildings (Xie et al., 2014, Park et al., 2014). As a result, life-cycle costing is gaining considerable attention particularly within the context of sustainable construction (Dwaikat and Ali, 2018). However, imperfect understanding of life cycle costing methodology and application is considered one of the key barriers to a widespread application of life cycle costing in the construction industry (Dwaikat and Ali, 2018).

Green buildings have many sustainable requirements. There are many criteria that the green building must accomplish. Therefore, green building encompasses a wide range of inputs and

outputs for the designer, engineer, building owner and manager, including waste, energy efficiency, cost, and environmental Impact(Robinson et al., 2012). Green buildings will substantially impact the energy consumption and volume of emissions and therefore, life cycle analysis of building materials and life cycle management of products are necessary in order to select the materials for high performance green buildings (Subramanian, 2007). Further, innovative technology used in green buildings achieves broader environmental, economic, and social goals throughout the complete life cycle of a project and also reduce life-cycle building costs for owners (Doyle et al., 2009, Flynn and Traver, 2011). However, the application of life cycle costing in the construction sectors is still limited and facing practical problems (Dwaikat and Ali, 2018).

Menassa and Rexrode (2010) identifies life cycle cost analysis as one of the methods that provide flexibility to value different alternative solutions for the buildings under conditions of uncertainty especially those related to demand for green space, fluctuating cost of energy and the perceived savings in the building operation and maintenance costs. However irrespective of its importance life-cycle costing is not commonly used in the initial stages of green buildings. According to Zuo et al. (2017), there are many reasons for the lack of use of life cycle costing and yet for many decades these issues keep arising. Similarly, after a thorough literature review Zhang et al. (2018) proposed to research on comprehensive evidence about life-cycle costs of green buildings. Considering these facts this research aim to conduct an extensive literature review on life-cycle cost optimisation models developed for green building implementation. Green buildings have many criteria to satisfy. Each of these criteria has an impact to the life-cycle cost of the green building. These life-cycle cost models can be effectively used to make informed decisions in initial stages of green buildings.

RESEARCH METHODOLOGIES

The research methodology for reviewing literature followed a two step process. Initially, this research study selected relevant literature based on examining the titles and keywords. Search rules were used to find specific words in abstracts, titles and keyword using Scopus and Web of Science databases. Afterwards, the selected research articles were thoroughly evaluated to removed duplications, irrelevant researches, researches not focusing on life-cycle cost models and green building research without any focus on life-cycle costing. Table 1 below reports the selection of research articles for this review.

Table 1: Selection of review articles

Source	Number of articles
Journal articles	31
Conference proceedings	26
Books/book chapters	05
Trade publications	02
Total	64

This research study carried out a literature review pertaining to the life-cycle cost model used in green buildings. When considering the selected and reviewed research articles, there are two main categories namely; articles focusing on material selection and energy consumption of green buildings. All these research studies used life-cycle costing as one of the parameters to evaluate options in either material selection or energy consumption. However, there are many research articles focusing on other categories such as green roofs, using building information modelling for green buildings and various life-cycle cost models for specific projects. Therefore, this research study discusses on life-cycle cost models on material selection, energy efficiency and other selections

separately. Finally, based on the literature, this research study draws conclusions focusing on life-cycle cost model for green buildings.

LIFE-CYCLE COST OPTIMISATION MODELS

Life-cycle cost models for material selection in green buildings

Material selection is one of the most important factors in green building implementation. It directly affects many other factors such as energy consumption, indoor environment quality, and aesthetic appearance and so on. Further, these material has a significant impact on the life-cycle cost of the building as well. Certain materials require higher maintenance and regular replacements. Therefore, life-cycle cost analysis is important in material selection.

Initially, Lippiatt (1999) developed a tool that measures the environmental performance of building products using the environmental life-cycle assessment approach specified in international standards. Further this research focused on life-cycle cost method when selecting products and also considered the life-cycle stages such raw material acquisition, manufacture, transportation, installation, use, and waste management. Further, Lippiatt and Boyles (2001) developed this tool and included actual environmental and economic performance data for 65 building products. The main purpose of the proposed tool is to support purchasing decisions by providing key science-based information often lacking in 'green' product selection so that the project stakeholders can make cost-effective decisions with minimum environmental impacts.

Cheng et al. (2006) also developed an assessment tool that appraises life cycle cost and performance of building materials and components. This study was developed focusing photovoltaic panel and water recycle system at a newly commissioned substation (Cheng et al., 2006). Similarly, Majid et al. (2010) investigated the influence of construction material on reducing energy consumption and lifecycle cost by using building information modelling (BIM).

Feng and Peng (2010) analysed the effects on construction investment and returns by using exterior insulation of residential buildings using energy-saving measures. This research study used life-cycle assessment and life-cycle cost using net present value technique. Similarly, Zhu et al. (2014) also carried out an analysis on four external insulation materials considering the life-cycle cost and other parameters. Energy savings is also another factor considered in this research study. Insulation of building directly affects the energy consumptions of building. Therefore, when analysing the materials for insulation, usually energy savings are considered in the models. Further, energy savings occur within the life cycle of the building. Life-cycle costing is essential to capture these savings throughout the life-cycle.

Marzouk et al. (2013) presented a framework that integrates BIM with green buildings, taking into consideration Leadership in Energy and Environmental Design (LEED) rating system. In this framework, BIM is used to create a model that is not only a geometrical representation of a facility but also a representation of information and properties that can be used by the parties involved in the project utilizing Genetic Algorithms (GA) Optimization as a decision making tool to select the optimum building materials (Marzouk et al., 2013). This model was recently further developed to implement a stochastic life-cycle cost model for building to select the optimum building materials alternatives and discover the most influential building system in each cost element starting from initial cost to end on life cost (Marzouk et al., 2018).

Chong et al. (2011) carried out a life-cycle cost calculation as an economic analysis for a proposed innovative wind-solar hybrid renewable energy generation system with rainwater collection feature

for electrical energy generation. Similarly, Tam et al. (2017) presented an analysis on the life cycle cost of timber materials in their various applications for residential buildings in Australia and thereby provides guidance on how to best meet the requirement set out in the timber credit in the Green Start rating scheme. In both these research studies, specific systems and materials are selected and life-cycle analysis is carried out.

He et al. (2013) developed an optimization model to find an optimal design scheme; the entropy decision making method was used to support the decision maker to compare the different design schemes, and to calculate the best materials with lowest life-cycle cost values. This optimisation model focused on design selection. Similarly, Latief et al. (2017) developed a model to optimize building construction performance towards green building premium cost, achieving green building rating tools with optimizing life cycle cost. This research study initially collected data of green building in the Indonesian construction industry such as green building fixture, initial cost, operational and maintenance cost, and certification score achievement (Latief et al., 2017). After that, optimized green building fixture based on building function and cost aspects were identified using value engineering methods (Latief et al., 2017).

Life-cycle cost models focusing energy consumption in green buildings

It is usually difficult to satisfy several conflicting criteria, especially, economical and environmental performance of buildings. Therefore, Wang et al. (2005a) developed a multi-objective optimization model that could assist designers in green building design by employing life cycle analysis methodology to evaluate design alternatives for both economical and environmental criteria. This model selects optimum solutions using a multi-objective genetic algorithm considering the exergy consumption and cost.

Gu et al. (2007) developed life cycle green cost assessment (LCGCA) method, which can evaluate building environmental load and economic performance throughout its life cycle comprehensively. In this method the operating energy consumption, life cycle environmental load, life cycle cost and green payback time of different envelope schemes have been compared (Gu et al., 2007).

Initially, there was a research carried out focusing on the importance of rightsizing air-handling units for the construction of green buildings is discussed (Sellers, 2005). According to Sellers (2005) rightsizing helps in reducing life-cycle costs and in improving performance. However, this research only focused on the air handling units and rightsizing them for optimum life-cycle costs. Similar to the previous research Issa et al. (2008) calculated and analysed life-cycle cost data and sustainability data collected from 33 different schools: 10 conventional schools, 20 energy retrofitted, and 3 green schools in Canada. This study also analysed the collected data and presented the results. However, there was no any optimisation of life-cycle cost carried out.

Briller and Hamilton (2011) illustrated how integrative design strategies used to achieve high LEED certification ratings for federal buildings in USA can simultaneously result in substantial fossil fuel consumption reductions. The research used two specific strategies and these are discussed in terms of their energy savings potential and life cycle costs (Briller and Hamilton, 2011, Briller, 2008). Once again, this research only focused on two options and the solutions are based on the energy savings and the life-cycle cost.

Massimo (2009) proposed a decision support system aiming to support planning and design of building sustainable conservation. This decision support system is based upon powerful geographic information system (GIS) tools, which coordinate allied software for both energy management and

cost estimate as well as for life-cycle valuation of conservation and energy optimisation interventions. Singh et al. (2011) used the life cycle cost analysis (LCCA) framework to calculate the potential economic gains of indoor environment quality (IEQ) improvements to the organizations. The preliminary findings of this study assist building owners/investors/policymakers in making better-informed building decisions towards IEQ improvements in buildings from the economic perspective of sustainability (Singh et al., 2011).

To help the owner get an appropriate green building design that can meet the owner's budget and achieve low energy consumption, Chen et al. (2013) proposed a BIM-based framework. However, this framework only focused on optimizing energy. Similarly, there are many research studies on optimising energy performance and life-cycle cost using BIM (Jalaei and Jrade, 2014, Jalaei et al., 2015, Abanda and Byers, 2016).

Dwaikat and Ali (2016) empirically examined the earned value management (EVM) approach to measure the actual life cycle cost performance of energy in green buildings. With slight methodological and terminological adaptations, it is found that the EVM approach can be applied to conduct a holistic cost performance measurement of the actual energy consumption in green buildings(Dwaikat and Ali, 2016).

Kim et al. (2016) develop an optimization model for the optimal green systems by considering the thermal comfort in and energy consumption of an educational facility. In addition, the optimal design scenarios were analyzed considering their economic and environmental effects and for which life-cycle costing is also used (Kim et al., 2016).

Invidiata and Ghisi (2016) assessed the energy performance of four window shading systems in a house using life-cycle energy analysis and life-cycle cost analysis. Life –cycle cost analysis was also used to determine not only the most energy-efficient strategy, but also the most economically feasible one (Invidiata and Ghisi, 2016).

Other life-cycle cost model used in green building implementation

Bennett et al. (2000) analysed three city buildings applying the LEED green building rating system, the criteria used to select green building options, and the first costs, life cycle costs, and societal costs associated with greening these buildings. This research had a holistic approach yet it did not present a model or any software to select the optimum solutions using life-cycle cost.

Bartlett and Howard (2000), carried out a whole-life costing calculation for two case study buildings considering two options each. In this research, Bartlett and Howard (2000) considered the environmental impact and other external impacts and the study is not confined only to the life-cycle cost of the options available. Similarly, Wang et al. (2005b) developed a multi-objective genetic algorithm for green building design to minimize two conflicting criteria: the life-cycle cost and the life-cycle environmental impact. Environmental impact categories considered in this study include energy and non-energy natural resources, global warming, and acidification and the variables focus on building envelope-related parameters (Wang et al., 2005b). In this research the variables are selected considering the building envelop.

Shyam Sunder et al. (2008) explained on developing rigorous metrics and tools for assessing the life-cycle economic and environmental performance of tall buildings. In this research the economic performance is measured using standard life-cycle costing methods and environmental performance is measured using life-cycle assessment methods that assess the "carbon footprint" of tall buildings as well as 11 other sustainability metrics (Shyam Sunder et al., 2008).

Carter and Keeler (2008) used data collected from an experimental green roof plot to develop a benefit cost analysis (BCA) for the life cycle of extensive (thin layer) green roof systems in an urban watershed and also calculated the net present value (NPV) for a green roof. In a research study carried out by Blackhurst et al. (2010), market prices of materials, construction, energy conservation, storm-water management, and greenhouse gas (GHG) emission reductions were used to evaluate private and social costs and benefits. However this research was very specific on the green roofs and there are no optimum solutions presented through the results. Similarly, Clark and Adriaenssens (2010) used various life cycle assessment techniques to examine the carbon dioxide emissions from the production of key materials used in the construction of a landmark pedestrian bridge and how those emissions add to the financial cost of the bridge. There are many other research studies focusing on the life-cycle cost aspects of green roofs as well (Liu and Hong, 2012, Berardi et al., 2014, Sproul et al., 2014, McRae, 2016).

By systematically analyzing the factors that influence the comprehensive benefits in the full life cycle of water-saving projects for green building Chai et al. (2010b) developed a comprehensive benefit economy model for water savings in green buildings. Further this model is simulated and applied to a water-saving demonstration project for green building in West China to verify its rationality and practicality (Chai et al., 2010b, Chai et al., 2010a). However this model provides the optimum solutions based on the life-cycle cost and the water conservation. Similarly there are many research studies carried out focusing on life-cycle cost and water savings of green buildings (Hongxiang and Wei, 2013).

Bastian (2011) described an engineering management tool developed for project managers at Fort Bragg's Directorate of Housing and Public Works in USA used to determine the most cost-effective route to building certification using LEED. This tool considered life-cycle cost of credits in LEED and selected optimised solutions to suit the goals of the organisation. However, this model is very specific to the specific organisation.

Chen et al. (2011) identified the incremental costs and benefits in the life cycle of green buildings and developed the evaluation indexes of incremental cost-benefit analysis, considering the social benefits and environmental benefits to evaluate the economy of green projects. Assad et al. (2011) introduced a framework for green buildings design in order to support planners to choose optimum customized building envelope design (orientation, walls, windows & roof) with least possible costs over the building lifetime. The proposed framework had unique focus on using sustainable approaches (material efficiency, indoor air quality, energy efficiency, passive solar design and natural illumination) to meet least life-cycle costs (Assad et al., 2011). However this framework provided options considering the building envelope only.

Cao and Dong (2012) categorized various costs generated over the whole life cycle of green buildings considering possible changes of resource prices, the discount rate and the generation time of non-annual costs during the building's operating phase. Afterwards Cao and Dong (2012) developed a model for cost benefit assessments of green buildings to evaluate the life cycle costs of water conservation facilities of a green residential community. This life-cycle cost analysis model is confined to water a conservation facility which is one of the limitations of the study.

Sacks et al. (2012) analysed the cost-effectiveness of the heat recovery ventilation (HRV) technology against a direct-expansion (DX) ducted system of conventional practice utilising the life cycle cost analysis to determine if the sustainable option is the better choice. This analysis is specific and there was no any model or framework developed which can be used for future projects. Similarly, Guo et al. (2012) carried out a particular study on a construction project targeted at low income people to

assess its environmental impacts from the life cycle perspective, with the objective to identify the largest environmental impacts and take measures to control them. This study is also very specific and focused at residential buildings for low income owners. Marzouk and Azab (2017) also analysed housing projects for low income earners in terms of life-cycle cost representing the economic parameter and LEED certification.

Alborzfard (2012) created a framework for the life cycle cost assessment of sustainability features in the areas of mechanical, electrical, and plumbing components; further subdivided into "green" and "non-green" base construction, consumption, operations and maintenance costs to generate savings or added cost. Kim et al. (2013) developed a conceptual model of life cycle cost based life cycle CO_2 ($LCCO_2$) analysis. The model consists of 5 subsystems, such as life-cycle cost, $LCCO_2$, cost-carbon effect and energy analysis system including decision-making support system focusing on apartment buildings (Kim et al., 2013). Similarly, Tsai et al. (2014) also focused on the CO_2 emission costs and low-carbon construction methods, and proposes a 0-1 mixed integer programming decision model for integrated green building projects, using an activity-based cost (ABC) and LCA approach.

Dobiás and Macek (2014) objectively assess buildings that were certified under the LEED certification system and to determine the financial effectiveness of the invested resources in the construction process in relation to the operational and environmental benefits. Assad et al. (2015) introduced an integrated framework to allow building design stemming from basic sustainable approaches. The framework can function as an optimization/simulation platform to automatically improve building designs (Assad et al., 2015).

There is a study assessing the life cycle cost of green certified industrial manufacturing building and that of a conventional building to establish the impact of sustainable features on life cycle cost (Weerasinghe et al., 2017). Khan et al. (2018) also proposed an integrated web-based automated analogue computerized programming that applies green building rating assessment tool, green technology and life cycle cost analysis. This model emphasized to identify variables of life-cycle cost to be integrated and developed in a framework then transformed into automated analogue computerized programming (Khan et al., 2018).

CONCLUSIONS

The review of literature illustrated that there are various models developed focusing on life-cycle cost of green buildings. However, the uptake of life-cycle cost is rather slow in the construction industry. The available literature suggests that most of the life-cycle models are very specific to certain project types and sometimes confined couple of products.

When considering the life-cycle cost models focusing material selection, there are couple of research carried out focusing on the building insulation (Cheng et al., 2006, Feng and Peng, 2010, Zhu et al., 2014). In most of the cases, the life-cycle cost model only focused on a specific material or its properties. Therefore, there is a clear lack of life cycle cost models considering material selection to a green building as a whole rather than focusing one element such as building insulation.

There are certain researches that integrate BIM, life-cycle cost and material selections. Most of the decisions are made considering the based on the green building evaluation system such as LEED and integrating other software. This provides optimised solutions in material selection. Further, these models embed energy savings as well which is very much important.

According to the literature, almost all the life-cycle cost models focusing on energy consumption evaluated various options in minimising the operating energy and providing IEQ of green buildings.

Most of the valuation options were regarding the design solutions to green buildings. However, there are many factors that affect the energy consumption buildings. Therefore, the life-cycle cost models further need to be developed to cater for all these parameters.

There are multi-objective optimisation models developed by many researches. However, these objectives are defined by the researches. Therefore, future research can be carried out to develop life-cycle cost optimisation models based on criteria identified by various green building assessment tools. This would provide a holistic approach to optimise the life-cycle cost of green buildings.

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LIFE-CYCLE COSTING: INSIGHTS, OVERSIGHTS, FORESIGHTS

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Abstract:

The potential benefits of performing Life Cycle Costing (LCC) are well documented in the extant literature. However, there are many practical and methodological challenges that limit their reliability and adoption for building project evaluation. The aim of this paper is to present the state-of-the-art of LCC in buildings and to map-out the methodological and practical challenges in LCC approach. The paper details a critical analysis of the modelling approaches, building-types and data sources used in the LCC modelling.

Our study argues that existing LCC modelling techniques are generally static and are not flexible enough to incorporate decisions taken over the life of the buildings. The impact of disruptive technologies like Big Data, BIM and virtual prototyping, hold a real potential to enhance the accuracy of LCC methods and enhance their usefulness over the lives of building assets.

Specifically, we observe that LCC is a complex subject. It thrives on the assumption of hypothetical variables and drives decisions that affect an unknown or unknowable future. This paper, therefore, seeks to provoke a critical discourse and rethink of existing methodological approaches to LCC in an attempt to develop approaches that might be better at capturing the data required in LCC of buildings. In addition, we advocate for Big Data as a frontier to improve the processing, visualisation and synthesis of data in LCC modelling. In conclusion, we articulate the insights, oversights and foresights that underpin life-cycle costing in buildings.

Keywords: Building Appraisal, Life-cycle costing (LCC), Modelling, Uncertainties, Big Data

INTRODUCTION

Buildings are inanimate - they embody a crucial part of human advancement and ambition. Buildings are somewhat imperishable; their lives could be indefinite (Ashworth, 1996). Buildings are in principle, a cluster of many parts consisting of systems, materials, components, and affected by the external space they occupy. Buildings have embedded costs, often conferred by location, perception and design. In building projects, life-cycle consideration could largely focus on building spaces, as places where human interactions occur while ignoring its economic and social context, thus simplifying the variables in life cycle costing. In this paradigm, the regular 'clock-time' period of interactions in these buildings becomes crucial. Schools, for instance, differ from hospitals, homes or leisure centres. This school-of-thought is noticeable in the works of Salway (1986), Ashworth (1996) and Hoar and Norman (1990) amongst others. The characteristic of such inclusion largely relates to the magnitude of operational and maintenance cost variables, staff or occupant cost, and also disposal costs (Cole & Sterner, 2000; J. R. Evans & Olson, 2001; Hughes, Ancell, Gruneberg, & Hirst, 2004).

The need for buildings to be costed and valued is the basis of the quantity-surveying profession *vis-a-vis* cost engineering (Rawlinson, 2017). However, the principles of building appraisal especially when considered on a life-cycle basis leaves much to be desired. The conception of life-cycle costing (LCC) as a definitive science has been richly ingrained in the psyche of estimators and building practitioners.

There is, however, evidence that the science is poorly understood (Gluch & Baumann, 2004). The roots of life-cycle costing (LCC) in buildings can be traced to Flanagan and Norman (1983) in a research sponsored by the Royal Institution of Chartered Surveyors (RICS) in the UK. Since then, its principles have hung on the tapestry of building appraisal science, and yet there have been asymmetries in matching its intent and purpose, to the objective realities of buildings.

Life-cycle costing (LCC) is a complex subject - it thrives on the assumption of hypothetical variables, and drives decisions that affect an unknown or unknowable future. In many public sector building projects, LCC has become a pre-requisite in many tender pre-qualification processes (Boussabaine & Kirkham, 2008; Davis-Langdon-Management-Consulting, 2007), yet its results are rather questionable, and the context is mostly missing (Zuo et al., 2017). Notwithstanding, LCC has been found beneficial in providing a more comprehensive perspective on building costs (Goh & Sun, 2016). In addition, LCC helps in selecting the most effective choice amongst a spectrum of competing building designs (Mohammed Kishk, 2005). Zuo et al., (2017) summarised the challenges of LCC as:

i. A dominant lack of understanding regarding its purpose and intent
ii. Inability to establish its scope and context
iii. Difficulty in identifying and obtaining relevant and reliable data
iv. Limitations in the methodological tools and techniques

The aim of this paper is to present the state-of-the-art of life-cycle costing (LCC) in buildings by critically examining the extant literature to map-out the methodological, theoretical and practical challenges in LCC approaches. The intention is to provoke critical discourse and a rethink of existing methodological approaches to life-cycle costing in an attempt to develop approaches that might be better at capturing the uncertainties and complexities in LCC of buildings. The rest of the paper is structured as follows: a background on LCC is provided; insights regarding the methodological advances in LCC are stated, oversights pertaining to the existing methods and then foresights accomplished through Big data is articulated.

LIFE CYCLE COSTING

Industry awareness on the principles of Life Cycle Costing (LCC) dates back to the 1950's, when the Building Research Establishment (BRE), UK sponsored a research on the "costs-in-use" of buildings (Mohammed Kishk et al., 2003a). Afterwards, professional bodies such as the Royal Institute of Chartered Surveyors (RICS) started taking more interest as demonstrated in the work, published by Flanagan and Norman (1983), through a funded research, by the RICS Education Trust. Since then, there has been a progression of studies on the subject of LCC.

The BSI - ISO:15686-5 (2008), is the first international standard for property life cycle costing, and defines LCC as a "methodology for the systematic economic evaluation of life cycle costs over a period of analysis, as defined in the agreed scope". LCC is a cascade of costs across the continuum of a building's expected life. The principal phases in the life-cycle cost assessment of a building are the construction and operational phase. In recent times, phases such as refurbishment, disposal and maintenance constitute valid consideration in LCC calculations (Aye, Bamford, Charters, & Robinson, 2000). The refurbishment, disposal and maintenance periods, however, tend to be much shorter and their cost impacts on buildings are more difficult to ascertain.

LCC is often used by clients and building owners in establishing whether a higher capital cost is justified based on the potential reduction in future costs and helps in assessing the cost-effectiveness amongst a host of competing alternatives. Aye et al. (2000) utilised LCC in comparing four options in a commercial building – renovate existing property, buy another property and renovate, buy land and build or do nothing. Neroutsou and Croxford (2016) also conducted LCC using a residential building undergoing retrofitting, based on a range of insulation and energy-efficient measures. The major issues with LCC based on both studies i.e. Aye et al. (2000); Neroutsou and Croxford (2016), are the risk and uncertainty pertaining to data, scope changes in building design, the reliability of cost data and lack of information about future decisions. These issues bother on the quality of data and the integrity of methods uses in life cycle costing assessment.

Data-requirements in Life Cycle Costing

Life-cycle costing (LCC) is a data-intensive process. Three main sources of data in life-cycle costing include historical records, manufacturers and supplier's specifications, and predictive models (Roger Flanagan, Norman, & Meadows, 1989). Historical data are obtainable from existing buildings but these tend to be contextually embedded and may not be readily transferable to other contexts (Ashworth & Perera, 2013). For instance, energy or maintenance costs from one project may not be exactly the same for another. However, building price books which are commonly location-dependent, may also not accurately recognise such contextual disparity. Ferry and Flanagan (1991) advised that extensive historical data are not indispensable to life-cycle cost (LCC) modelling.

Common practice in LCC often separates cost data into capital and future elements. The general basis of this approach relates to the time of occurrence of each cost element. Usually, for purposes of ease and convenience, many life-cycle costing exercises separate costs into just "initial capital" and "running" cost categories. Kishk and Al-Hajj (1999) expressed that by separating costs into capital and running categories, a peculiarity has been established. Capital costs are predictable with some degree of certainty at the design stage of a project. However, future costs are largely unpredictable due to future legislative changes in buildings, changes in resource consumption (i.e. energy, water, sewerage) and alterations to facilities throughout life) (Ashworth & Perera, 2013). This generalisation tends to harness data attributes based on the period of occurrence but fails to recognise the contextual drivers such as rates from utility providers, technological adaptations, and building occupancy levels. Also, the impact of uncertainties in life-cycle costing analysis based on these contextual drivers is not sufficiently treated (Geng et al., 2017; Goh, 2016).

According to A Al-Hajj et al. (2001), life-cycle cost data constituents can be broadly mapped into four levels. The first level of data required in a typical life-cycle costing (LCC) exercise is the economic data, regarding the discount and inflation rates, over the analysis period. Gluch and Baumann (2004) argue that the most influential variable in LCC is the discount rate. This is because discount rates are politically determined (Morrissey, Meyrick, Sivaraman, Horne, & Berry, 2013), and the values used by respective estimators tend to subjective and arbitrary (Tan, Anderson, Dyer, & Parker, 2010). The second level of data includes the capital cost, maintenance costs, and utility costs. Capital costs are often based on elemental costing in buildings. Capital cost can also be estimated from proprietary cost databases, such as the Building Cost Information Service (BCIS), or CoStar group. Commercial sources of this kind of data tend to provide generic information based on the Gross Floor Area and Location. The maintenance costs and utilities cost in a typical LCC study, as well as the staff and business operating costs constitute a significant proportion of the running costs (R. Evans, Haryott, Haste, & Jones, 2004; Hughes et al., 2004), although in some cases, disposal costs could be included. The maintenance cost is dependent on the behaviour of the occupiers, and the quality of building materials and components used. Sources of maintenance data include historical data from clients and surveyors' records, cost databases and building price books (Mohammed Kishk et al., 2003a), such as Wessex, Rawlinson or Laxton. Another possible source for maintenance and utility cost data in a

typical LCC study is through heuristics (Havard, 2013). The third level of data in a typical LCC study includes the times in the life cycle of the project. This is hardly predictable, and even more difficult to verify. The actual life of a building will depend on a number of factors including the type of building, physical characteristics of the building materials, exposure to the elements, maintenance regime, the frequency of use, as well as the behaviour of the occupiers (Cort, Dirks, Hostick, & Elliot, 2009)

Life-cycle cost modelling has traditionally focussed on "hard-data", which are quantitatively defined (Healy, 2015), and have failed to harness subjective, and less-quantitatively defined data, which could enrich the data interphase in LCC modelling, and enhance the credibility of LCC predictions. There are different genre of data in life-cycle costing – real data (obtainable from case studies including i.e. economic data - discount rates, social data - demographics and demand-level, political data - legislative changes), hypothetical data and simulated data based on forecasts. *Table 1* provides a description of each data-type and summarises their advantages and disadvantages.

Table 1 Data Genres used in Life-cycle Costing of Buildings

Data Type	Advantages	Disadvantages
Real-life	• This provides objective assessment in buildings • It has high credibility	• It is very difficult to access • It is expensive to obtain
Simulated	• It provides an alternative to real data • It provides a cheaper way to conduct LCC	• It has limited credibility • It is mostly applicable to a singular context
Hypothetical	• It helps to illustrate the features of a model	• It has no empirical basis

The purpose of life-cycle costing is to facilitate logical and realistic decision outcomes in building investment appraisals (Ashworth & Perera, 2013). To achieve this, the data used in LCC needs to have reasonably high fidelity. The evidence from the built environment literature, however, raises doubt on the ability of LCC models to robustly appraise buildings. There is a need to recognise that LCC scenarios involve a complex set of decision events, actions, outcomes, with significant interdependencies (Tokede & Ahiaga-Dagbui, 2016). Therefore, LCC exercises may not solely establish the scope and level of cost data, but also an appropriate means of representation.

Methods in Life Cycle Costing

In the current built environment literature, there are different approaches in evaluating the life cycle costing (LCC) estimates of buildings. LCC methodologies can be broadly classified into three types: Closed-form mathematical, Probability-based, and Real-Option-based methods. *Table 2* below provides a summary of the potentials and limitations of each LCC modelling approach:

Table 2 Summary of Life-cycle costing (LCC) modelling approaches

Method	Strengths	Weaknesses
Closed-form LCC method	It is straight-forward and easy to follow It provides precise descriptions for	It assumes little uncertainty Opportunities for future decisions are ignored

	systems with little complexity	
Probability-based LCC method	It allows variability in the cost items to be represented. It allows input from statistics, regression and other artificial intelligence techniques	It only accounts for uncertainties as a result of randomness.
Real-options LCC method	It allows certain decisions to be taken in the future with better information It allows different kind of uncertainties to be represented.	It heightens computational rigour in LCC Its practical benefit remains unproven

The most common approach in LCC in buildings is the mathematical closed-form (M-CF) approach. Table 2 details some of the strengths and weaknesses of the different methods adopted in LCC. These methods, however, only address specific facets in LCC modelling. However, there is a scope to integrate the features of these techniques in order to harness their full benefits. The practice of LCC modelling in buildings has mostly focused on individual facets, thus perpetuating a rather incomplete perspective in building appraisal.

Closed-Form LCC Models

The closed-form mathematical (M-CF) approach, commonly known as the standard method summarily aggregates costing elements into capital cost, operation cost, maintenance cost and other relevant costs to yield a single estimate (Mohammed Kishk, 2005). Mathematically, the LCC formulae can be represented as:

$$LCC = \sum_{t=0}^{T} \frac{C_t^i}{(1 + D_R)^{\,t}} \qquad (1)$$

Where C_t^i = Equivalent cash flow,

$D_R = \text{real discount rate}$

$\mathrm{t}, \mathrm{T} = \text{time (in years)}$

Over the last three decades, a number of works have proposed modified closed-form mathematical algorithms, to improve on the future cost forecasts of building investments in life-cycle costing scenarios. The LCC model developed by Bromilow and Pawsey (1987), for instance, considers maintenance activities, as non-annual recurring costs while Al-Hajj (1996) developed cost significant factors to further enhance the data inputs in LCC modelling. Kishk (2005) concludes that many of these works, have had limited impacts on the practice of life-cycle costing. Caplehorn (2012) surmised that industry perception LCC in buildings, has hardly changed since its inception. The closed-form (M-CF) approach is fairly straight-forward and simple to follow. The major challenge with the M-CF, is its reliance on robust and clear identification of all cost elements over a building's life. While initial costs are relatively clear and predictable at the design stage, the future costs are rather volatile and

uncertain (CIFPA, 2011; Pellegrini-Masini, Bowles, Peacock, Ahadzi, & Banfill, 2010). Over the years, there have been a number of improvements in M-CF modelling. Even with advanced uncertainty modelling techniques, the data required cannot be reliably ascertained, and hence life-cycle cost estimates remain difficult to verify. The closed-form mathematical expressions tend to provide precise descriptions for systems with little complexity and hence assume little uncertainty (Ross, 2009).

Probability-based LCC Models

Another common approach to modelling, largely based on consideration of uncertainty are probability-based models. A good example of the probability-based approach is the whole life-cycle costing approach developed by Boussabaine and Kirkham (2008). In the probabilistic LCC approach, all uncertainties are assumed to comply with the behaviour of a random process (Mohammed Kishk et al., 2003b). This implies that uncertainties are a product of stochastic variability, and can be modelled by means of a Probability Distribution Function (PDF). Monte Carlo simulation (MCS) is perhaps the archetype of simulation efficiency, as far as probabilistic techniques are concerned. MCS allows the evaluation of multiple uncertain variables (Keršytė, 2012), in a manner that produces the fairest summary. The computational efficiency of the MCS has enhanced its popularity in uncertainty modelling for different industrial applications, as well as in LCC evaluations. There are a few conceptual shortcomings regarding the use of MCS for uncertainty modelling. Hollmann (2007), stated three of these, namely – dependencies between model variables not properly considered; the relationship between risk-drivers and cost outcomes not explicit; and lastly relationship between market risk (which is, diversifiable) and technical risk (which is undiversifiable) not recognised. MCS is also limited in accommodating asymmetries in cashflow distributions introduced by the recognition of real options (Keršytė, 2012).

The benefits of statistical techniques in life-cycle cost modelling have been discussed by Mohammed Kishk and Al-Hajj (1999). Regression, neural networks and other artificial intelligence techniques have proven to be valuable tool in life cycle cost analysis. Regression requires systematic collection of relevant cost data, to decipher the relationship between individual cost elements (Smith & Mason, 1997). However, the benefit of regression is limited to buildings with similar configuration. Given that buildings evolve over time, the regression model developed for buildings erected about thirty years ago will most likely be different from those constructed in recent times. Regression also relies on the accumulation of cost data, which could be onerous to obtain. Neural network is another powerful tool in establishing cost estimating relationships (Seo, Park, Jang, & Wallace, 2002). Neural networks have no restrictions on the number of variables because they have the inherent ability to self-organize and learn (Ahiaga-Dagbui, Tokede, Smith, & Wamuziri, 2013). De la Garza & Rouhana (1995) have argued that the formulation of the neural network architecture for life-cycle costing could be problematic.

Heuristic LCC Models

Heuristics are another approach that has also been employed in life-cycle costing scenarios. Tietz (1987) illustrated a situation in which the future costs of a building estimated over a 50-year period is likely to be 0.8 – 1.3 times the capital cost. Heuristics have equally been popular in LCC computations. Heuristics minimise the laborious computations in LCC and eliminates the need for expansive accumulation of data. Heuristic models are useful in shortlisting a host of competing building options prior to conducting more precise analytical comparison (Cole & Sterner, 2000) and provides a snapshot into the proportion of cost expended in different building development phases.

In heuristic LCC models, the context of buildings are however seldom addressed and there is a possibility for making sweeping assumptions about data to be made. It is therefore unsurprising, that there is little agreements regarding the relative proportion of LCC data in buildings. For instance,

Holness (2010) stated that in the life-cycle of a building, initial construction cost represents only 2%; operational and energy cost are 6%, while the rest of the 92% is the cost of occupants. Evans *et al.,* (2004) under the aegis of the Royal Academy of Engineering, conducted a study on the long-term cost of owning and using buildings, and proposed that the construction cost, maintenance cost, and business operating cost of commercial office buildings in the UK, over their lifetime have a ratio of 1: 5: 200 respectively. Hughes *et al.,* (2004) have contested this ratio, and based on another set of published data opined that the more realistic ratio is 1: 0.4: 12, over an estimated life of 25 years. Heuristic models could be realistically termed ill-structured analytical models (Asiedu & Gu, 1998), with an inclination to produce a satisficing solution. Kishk and Al-Hajj (2000) further suggest that LCC does not fit completely into the framework of probability and statistics theories. However, this opinion does not seem to have been well taken in the practice of life-cycle costing in buildings.

RESEARCH APPROACH

This work attempted to critically examine the existing approaches to life-cycle costing, draw-out the challenges and methodological weakness, in an attempt to establish the basis for charting possible direction for future LCC research. The research conducted a systematic literature analysis to identify the various research methods, modelling approaches, building-types, and data-sources used in the LCC modelling. The research therefore considered different semantic descriptions of LCC such as through-life costing, terotechnology, life-cycle costing, total costing, whole-life cycle costing, and whole-life appraisal. The work also identified diverse and heterogeneous literature sources including books, journal papers, thesis, reports, conference proceedings and government publications. *Table 3* provides examples of published work on life-cycle costing spanning four decades. These works have been selected based on the modelling foci, in their development. Table 3 presents the sources of data, and the modelling methods used in LCC of different genre of buildings. From *Table 3*, the predominant data used in LCC are hypothetical, and in some cases simulated. The evaluation mechanism in many LCC exercises hinged on closed-form mathematical modelling. The underpinning of the models is largely directed at determining an overall LCC estimate, with much less emphasis on justifying and accommodating economic decisions in respective building scenarios. However, focusing on the output rather than the processes in LCC undermines the benefits of the technique.

Table 3: Modelling techniques in LCC for Buildings

	Closed-form expression	Heuristics	Probability	Fuzzy Logic	Monte-Carlo simulation	System Dynamics	Simulation	Neural Network	Statistics / Regression	Genetic Algorithm	Real-Options	Decision Techniques
R Flanagan and Norman (1983)	●											
Roger Flanagan et al. (1989)	●		●									
Bromilow and Pawsey (1987)	Δ											
Tietz (1987)		●										
A. N. Al-Hajj (1991)	♦	♦										
Zhi (1993)							●					

Assem Al-Hajj and Horner (1998)		Δ							Δ			
Sobanjo (1999)				•								
Aye et al. (2000)	Δ	Δ										
Bartlett and Howard (2000)	•											
Mohammed Kishk and Al-Hajj (2000)	•			•								
M Kishk, Al-Hajj, Pollock, and Aouad (2002)	•	•		•								
Kirkham, Boussabaine, and Awwad (2002)	♦								♦			
Mohammed Kishk (2004)	•			•	•							
R. Evans et al. (2004)		•										
Hughes et al. (2004)	Δ	♦										
Mithraratne and Vale (2004)	Δ						Δ					
N Wang, Horner, and El-Haram (2004)	•	•		•								
W. Wang, Zmeureanu, and Rivard (2005)	Δ									Δ		
Ellingham and Fawcett (2006)	•		•		•						•	
Ive (2006)	Δ	Δ										
Boussabaine and Kirkham (2008)	•		•		•			•	•	•		
Kshirsagar, El-Gafy, and Sami Abdelhamid (2010)	Δ					Δ						
Pellegrini-Masini et al. (2010)	Δ		Δ									
Tuhus-Dubrow and Krarti (2010)	Δ											
Wong, Perera, and Eames (2010)	Δ		Δ				Δ		Δ	Δ		
Nannan Wang (2011)	•			•								•
Sacks, Nisbet, Ross, and Harinarain (2012)	♦											
Smit (2012)	•				•		•					
Ammar, Zayed, and Moselhi (2013)	•	•		•								
Goh (2016)		•										
Bonomo, Frontini, De Berardinis, and Donsante (2017)	•	•										

• hypothetical data, ♦ case studies Δ simulated data

From Table 3, the predominant use of closed-form mathematical method used in aggregating capital costs and future costs of buildings. The practice of aggregating capital cost and future costs has been criticised widely as it can result in an inaccurate estimate for the time-value of money in LCCs (e.g.(Assaf, Al-Hammad, Jannadi, & Saad, 2002; Ellingham & Fawcett, 2006; Mohammed Kishk et al., 2003b). Furthermore, Ferry *et al.* (1999) and Bordass (2000) added that it is inappropriate to equate capital costs and future costs, as this may be akin to adding apples and oranges.

Figure 2 highlights the mathematical variants of LCC used in buildings. Out of the 32 papers, 26 implemented closed-form mathematical modelling (M–CF); 6 incorporated some form of fuzzy logic mathematical modelling procedures (M-FL), 6 utilised some probabilistic modelling including Monte Carlo simulation; 4 utilised simulation (excluding Monte Carlo) and 1 attempted to use system-dynamics. There was a clear distinction in the methods based on the years of publication. Works from the 1980's mainly considered closed-form mathematical modelling (M – CF). It was not until the 2000's that system-dynamics became a prime consideration. Simulation seem to have started a bit later, but the earliest work found was from 1993. These perhaps indicated that closed-form mathematical modelling has been the predominant approach in LCC although this is being more recently augmented by fuzzy logic (M – FL), and in some instances, probabilistic modelling (M – PL). System-dynamics is being considered, but this approach seems to have been less popular due to difficulties in obtaining data required for long-term costing.

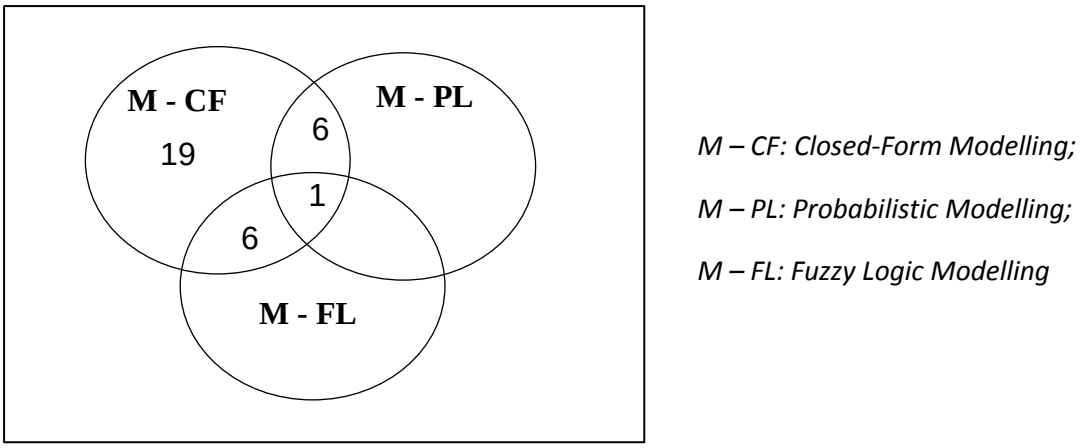

Figure 1 Mathematical modelling variants in life-cycle costing

Also, the type of buildings investigated in these works were mostly generic. These was indicative of the data used in the research. It can be seen from Figure 2, the building types commonly assessed in LCC exercises. 26 of the 32 works assumed a generic building-type and did not specify the type of building used. While nine of these buildings were commercial buildings; out of which seven were offices. Another 9 buildings were used for different buildings including teaching, residential, laboratory, retail, leisure, and recreational facilities.

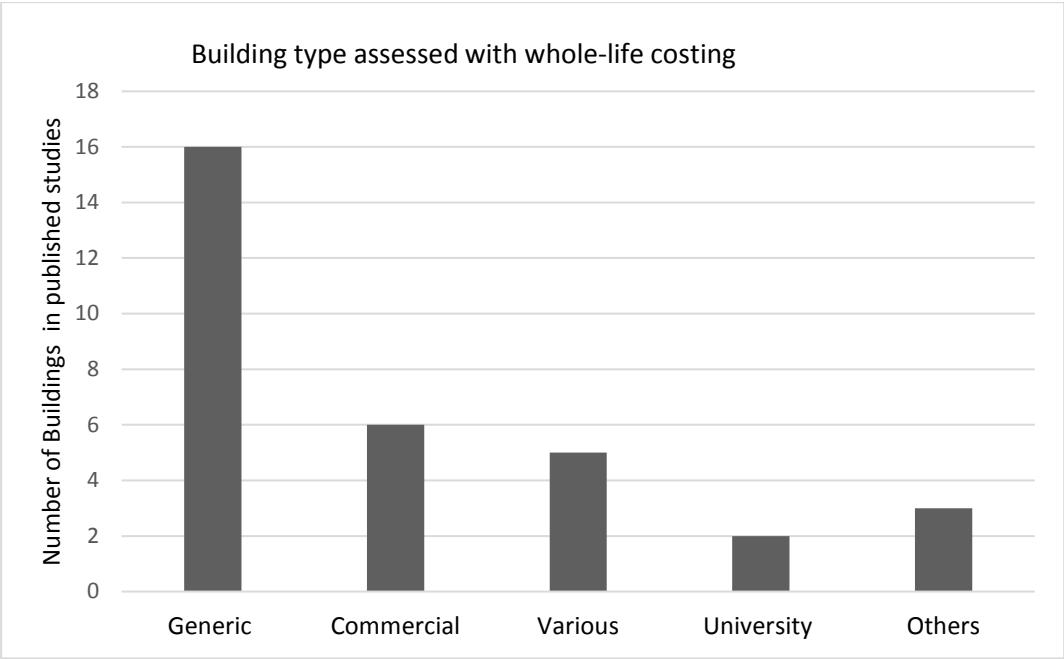

Figure 2 Building type assessed with life-cycle costing in the survey

These perhaps suggest that commercial buildings provide the most convincing context for life-cycle costing (LCC) analysis. Regarding the data type used, in the 32 modelling works – 17 used hypothetical data, 11 utilised simulated data and 4 were based on case-studies. The invalidated data capture in LCC modelling of built assets, as previously stated by Kirkham (2005) therefore seems justifiable.

The research on life-cycle costing seems to be truncated, recursive and largely speculative. Many early

researchers including Flanagan, Kirkham, Kishk, Al-Hajj, Boussabaine, and Clift, have expressed insightful thoughts on LCC, but the relevance and credibility of estimates remain unproven. The impacts of modern discoveries, such as BIM and virtual prototyping, which holds the potential to enhance improved processes has not permeated the practice of LCC.

DISCUSSIONS

Existing LCC techniques are static (Ellingham & Fawcett, 2006; Koskela, Siriwardena, & Rooke, 2008; Tan et al., 2010), they consider buildings as investment projects, with clearly known variables. Buildings could often be retrofitted, refurbished or reconfigured and this could impose new variables. A number of variables that could emerge include:

- sustainability cost – cost to ensure that building incorporates features that make it more environmentally-friendly;
- revocability cost – the potential for variability in the future costs of owning a building;
- disruption cost - cost over which a building may be unusable due to repair or refurbishment work.

These variables are often products of decisions taken over the life of the building by their owners and stakeholders. Building variables could thus be unknowable, and transcend traditional classifications such as 'initial' and 'future' costs that constitute the principal components in LCC calculations. A number of authors have therefore argued that future costs are indeterminate during the initial design of a building (Kirkpatrick, 2000; Mohammed Kishk & Al-Hajj, 2000; Vennström, Olofsson, Fawcett, Dikbas, & Ergen, 2010). The complexities in LCC is therefore intricately bound to the conception of the model, and the fidelity of its claims. An approach to counteract the difficulties in LCC valuation is to allow for uncertainties in the modelling process. However, this requires an understanding of the nature, scope and type of uncertainties affecting LCC variables

Potentials for Big Data in LCC Modelling of Buildings

Life-cycle costing has a complex scope of variables and influencing factors to consider. This thus requires a holistic approach in advancing the processes in life-cycle costing. A new field of interest that has shown promising potentials in handling the growing data volume in LCC is termed Big Data. "Big data refers to both large volumes of data with high level of complexity and the analytical methods applied to them which require more advanced techniques and technologies in order to derive meaningful information and insights in real time" (HM-Government, 2014, p. 2). According to a report by Manyika et al. (2011), opined that Big Data will facilitate transparency in decision-making, enable experimentation, segmentalise populations to customise action, replace/support human decision-making with the automated algorithm and ensemble competitive advantage.

Many industries like construction focus on just numerical and text data, whereas more advanced sectors had multimedia data encodes including video, images, audio. The Big Data revolution is understandably pioneered by internet companies such as Google, Amazon, Yahoo and the likes (HM-Government, 2014), but its impact is fast-reaching other sectors such as medical technology, finance, agriculture, biotechnology and many others. Big data is the next frontier in driving innovation, productivity, growth, value capture, and new modes of competition.

Big-data builds on traditional data analytic principles and encompasses descriptive, predictive and prescriptive analytics. However, LCC in buildings has mostly utilised the descriptive and predictive analytics and more so at a low-level of technology. There is a need for construction organisations to

develop sophisticated approaches to process, visualise and synthesise meaning from big data in construction and buildings. Building Information Modelling is a frontier where data capture and retention has been improved. However, the data captured in BIM tends to be mostly numerical data, and hence may still be limited to the opportunities provided by Big Data. Goh and Sun (2015) conclude that the potential benefits accruable from BIM are speculative, and evidence on this remains inconclusive.

Conclusion

This paper undertakes a critical review of life-cycle costing (LCC) and examines the insights, oversights and foresight with regards to data and the modelling techniques used in building appraisal. This paper acknowledges and highlights the practical difficulties in matching the intention of LCC to the objective reality of buildings. Specifically, we conclude that life-cycle costing (LCC) is a complex subject. It thrives on the assumption of hypothetical variables and drives decisions that affect an unknown or unknowable future. In this paper, we articulate the insights, oversights and foresights underpinning life-cycle costing in buildings.

Our intention is to provoke a critical discourse and rethink of existing methodological approaches to LCC in an attempt to develop approaches that might be better at capturing the data in LCC of building. The paper also details a critical analysis of the modelling approaches, building-types and data sources used in the LCC modelling. There is scope to further enhance the impact of modern discoveries, such as BIM, virtual prototyping, and Big Data which holds the potential to enhance improved LCC modelling. Future research should, therefore, seek to develop integral modelling approaches that allow interdisciplinary and collaborative data capture in LCC exercises.

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LIFECYCLE PREDICTIVE MODELLING USING DATA SCIENCE

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Purpose

Organisations procuring infrastructure need to be cognisant of lifecycle costs and reliability for assets. Taking a strategic approach to asset management planning, where the risks and costs are understood, enables better maintenance and operational planning. Maintenance budgets need to targeted to optimise outcomes. Understanding why critical assets fail is important for ensuring reliability of performance with planned interventions based on knowledge of likely failure intervals.

This paper examines how advances in data science enable insights into future cost and reliability performance for assets by analysing both internal and external data. This case study involves a large Australian utility provider with high value assets dispersed over a wide geographical area with a variety of operational and environmental variables impacting the outcomes.

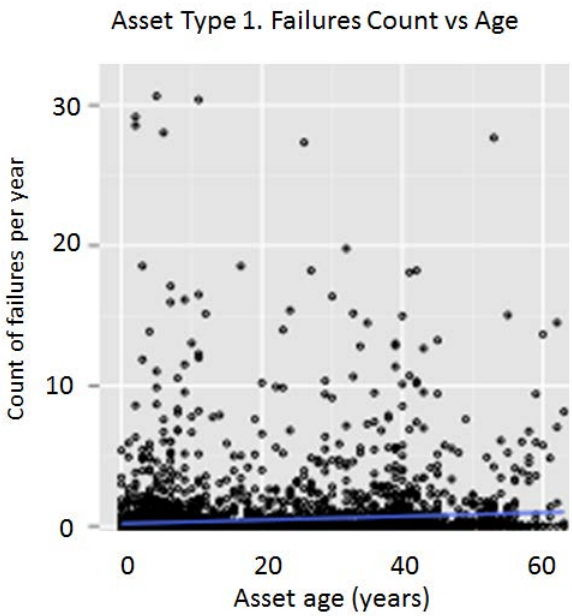
The organisation sought a more strategic approach to optimising its maintenance and lifecycle spend, while at the same time increasing the reliability of essential infrastructure services to the community. Significant media attention and regulatory oversight made it imperative for the utility provider to implement an evidence-based strategy to enable it to prioritise which assets to upgrade based on the likelihood of failure causing outages.

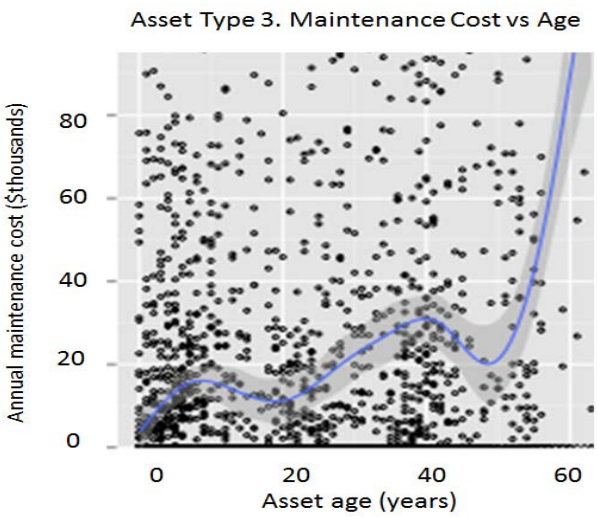
Methodology

In consultation with subject matter experts, the relevant factors that had potential to influence asset maintenance cost and failure occurrence were identified and data collected. The resulting data covering 15 years comprised millions of records and up to five hundred variables including:

- Asset type, model and manufacturer;
- Installation and maintenance information;
- Operational performance statistics;
- Management variables such as regional policies; and
- Environmental data including location, proximity to the coast, temperature, rainfall, humidity and wind.

Data assessment and auditing revealed that the analysis results were potentially affected by complexity of the data, most notably a high level of random variation. Failure Counts vs Age are shown for Asset Type 1 and Maintenance Costs vs Age are shown for Asset Type 3 below. Conventional wisdom is to predict failures and cost using age, however the distributions show 'random' variability and no discernible patterns.





A modelling approach was devised to deliver superior predictive power by utilising modern Data Science techniques. These techniques derive maximum value out of data while effectively addressing various data limitations. They have been proven to be effective in cases of noisy, sparse and otherwise suboptimal data and are widely used in many industries with great success.

The techniques used included Random Forests; Stochastic Gradient Boosting; LASSO regression; Multivariate Adaptive Regression Splines (MARS); and various types of Regression Trees.

To counteract the effect of the limited number of failure records for certain asset types, Synthetic Minority Over-sampling Technique (SMOTE); and Random Over Sampling (ROSE) were also used.

First, the factors predictive of the outcome were established among all available variables. This was done by using advanced feature selection approaches based on a combination of Random Forests and Stochastic Gradient Boosting.

Next, a number of suitable modelling approaches were identified and applied to the selected predictors. Performance was compared and the models that best fitted the data were chosen. The modelling methods included generalised linear mixed models (GLMM); Zero-Inflated Regression models; Hurdle models; MARS; LASSO regression; and Regression Trees as well as combinations of the above methods.

Finally, model fit was thoroughly assessed by relevant statistical criteria. The assessment showed that the selected cost and failure models exhibited good fit and strong alignment between observed and expected values across the range of responses.

Findings

What appeared initially to be random variation in asset performance, was demonstrated to be due to complex interactions between key variables including:

- age, model and type of equipment;
- location factors including weather and proximity to the sea;
- maintenance programs; and
- operational parameters.

A key objective of the project was to identify the assets likely to incur the highest cost and failure occurrence and thus enable the organisation to develop strategies for intervention. The models identified the at-risk assets. This is illustrated by the gains chart below.

The horizontal axis of the gains chart shows cases ranked by the model-predicted outcome such as cost or failure count, from the highest to the lowest grouped into deciles. The vertical axis shows the cumulative percentage of total cost, or failure count. The assets responsible for the highest proportion of cost or failures are ranked at the left side of the plot and easily identified.

The overall shape of the gains chart reflects the proportion of assets responsible for known proportions of total cost or failures: the steeper the curve, the better the model identifies at-risk assets.

Implications

Understanding the causes of costs and failures enabled the organisation to better plan their asset management to minimise outages and achieve better performance for their maintenance budget.

This approach is applicable for any organisation for planning maintenance and lifecycle replacement of critical infrastructure assets, using evidence-based, informed decisions to reduce asset failure rates and minimise maintenance costs.

Keywords: Asset management, facility management, lifecycle, Big Data, data science, predictive modelling, machine learning, random forests, stochastic gradient boosting, LASSO regression.

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MEASURING END-USER DELIGHT: IS SUCCESS IN PROJECT DESIGN AND DELIVERY ENOUGH?

Muath Abu Arqoub, Prof Craig Langston & Greg Skulmoski, Bond University

ABSTRACT

This paper explores a new approach for measuring project success, and makes the case that end-user delight is a necessary part of performance review. Regardless of project type, there are three generic phases that all successful projects must navigate: initiate, implement and influence. These are translated into their primary goals of design, deliver and delight. Evaluation of any project can be undertaken using the lenses of its financial, social, political and environmental context. The aim in this paper is to unpack the method for measuring delight via satisfaction surveys of project customers, such as client, end-users and local community. Two 5-point Likert scales, with scores multiplied together, are recommended to assess opinions, enabling a four-quadrant model to be produced reflecting 'wants' and 'needs'. Successful projects, therefore, can be described by the percentage of respondents who have a positive view that their wants and needs have been largely achieved.

Four specific success factors for measuring end-user delight are proposed in this paper, and comprise desirable (i.e. attractiveness), adaptable (i.e. flexibility), practicable (i.e. fit for purpose) and serviceable (i.e. enduring). They too are generic. These factors form part of a larger framework, known as *i3d3*, which can assess and rank project success and provide an opportunity for feedback that closes the loop between designer intent and customer effect. This paper sets out a possible way forward to compare future projects in a consistent and objective manner, with particular emphasis on the post-delivery phase.

Keywords: *adaptable, desirable, practicable, project success, serviceable*

INTRODUCTION

In the project management literature, projects typically end at the point of delivery (or handover) to the project sponsor (Serrador and Pinto, 2015; Serrador and Turner, 2015), marking the commencement of its operationalization. This is clearly recounted in the well-respected *PMBOK® Guide* (PMI, 2017). Jugdev and Muller (2005) further posit that project success is typically and prematurely evaluated at the end of the implementation phase because of the availability and indeed convenience of traditional outcome measurements based on actions to date.

However, success ought to be evaluated over a longer time horizon (Anbari et al., 2008; Davis, 2016). The introduction of operational success, including the satisfaction of project end-users/customers is gaining momentum among some researchers (e.g. Ghanbaripour et al., 2017). In recent times, the importance of extending project management and the measurement of its success into the post-delivery period has appeal, as it enables financial, social, political and environmental impacts to be properly considered (Williams et al., 2015). Such extension underpins the importance of formally evaluating benefit realization on projects (Serra and Kunc, 2015), although this evaluation is rarely evidenced in practice at the moment.

The post-delivery period presents an opportunity to assess whether the project actually meets its intended purpose, and supports design feedback and proof of concept. Anbari et al. (2008) highlighted that the post-delivery phase should explore lessons learned, an explanation of what went well and what didn't, and ensure that future projects benefit from this feedback. This implies that project evaluation does not end at handover. Post-occupancy evaluation (POE), which is widely advocated for building projects, is another example of the need to wait – in this case, typically a full year (four seasons).

Design cannot be divorced from usage. For example, sustainability performance is not validated by design modelling, but rather should be demonstrated convincingly in practice. Emphasizing this, Marcelino-Sádaba et al. (2015) explained that the policies of local, national and regional governments are usually of importance in meeting the challenge of sustainability as widely demanded by society. They implied that project testing is critical, and even after approval there are elements that need to be validated objectively. Any project that is ratified by a government authority or affects the safety of members of the community carries the promise of ongoing compliance with statutory requirements (Pope et al., 2004).

Sustainability is only one aspect of success that should be measured after project delivery and handover. According to Joslin and Müller (2015), the dimensions of project success may also include its efficiency, organizational benefits, satisfaction of stakeholders and the project's future potential. From this list, efficiency (including success in schedule, budget, and delivery of objectives) is best measured at the time of implementation (Serra and Kunc, 2015). Other dimensions are not fully understandable until further time has elapsed (Aarseth et al., 2017), and although they can be theoretically stated, are best quantified in the context of actual utilization. Therefore, while project delivery may have come to an end, the level of success of the project (as evidenced by sales, end-user experiences, reflection, product performance, testing, customer feedback, etc.) takes time to manifest.

The consideration of project success beyond implementation, while not a new concept, is a largely unpractised one. Such time extension enables a more complete evaluation of project performance and connects design intent to perceived value (Serra and Kunc, 2015). This includes the contribution of the project to business strategy and stakeholder value. Williams et al. (2015) suggested that the creation of a generic model for the assessment of project value – beyond the usual success factors of scope, time, cost and risk – needs development.

Langston et al. (2018) first proposed a method for measuring success over time suitable for use on any type of project regardless of size or location. Their model, known as *i3d3*, comprised three generic phases that underpin the life of all projects: pre-delivery, delivery, and post-delivery. Although there is a range of labels used in different contexts, they share a common sequence of (1) develop/plan, (2) execute/control and (3) operate/utilize. End of life is part of post-delivery. However, we do not need to wait that long to finalize our opinions on success. The *i3d3* framework with its focus on design, delivery and delight is shown in Figure 1.

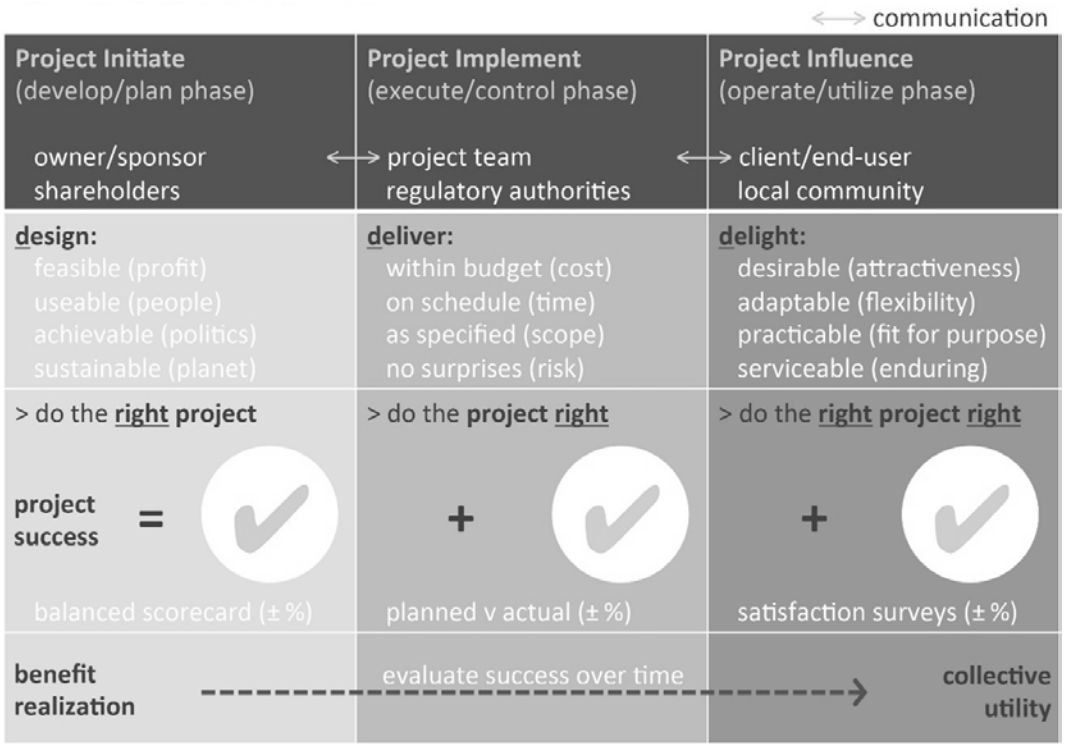

Figure 1 The *i3d3* framework (source: Langston et al., 2018)

During each phase, different sets of stakeholders have higher power and interest than others in regard to the evaluation of project success. For example, the opinion of project recipients (such as end-users or customers), can only be collected after handover. Any measure of success must surely take account of how well projects are able to realize the initial vision from the perspective of their target audience. There is an overarching focus on measuring benefit realization that leads to positive collective utility. It should be noted that stakeholder communication across each phase is critical in ensuring that common purpose and vision are maintained. The passage of time is clearly necessary to draw an informed and reliable conclusion.

LITERATURE REVIEW

The importance of the influence phase

Considering the differing dimensions of project success, it is possible that successful projects at the initiate and implement phases may fail to be successful at the influence phase. Therefore, a project may not be assumed to be successful simply because it was well designed and delivered according to expectations (Zidanea et al., 2015). Achieving project success goes beyond delivering the project to the satisfaction of the project sponsor (Williams, et al., 2015). Most projects need to satisfy requirements pertinent to a range of stakeholders (Davis, 2016), including the client/end-user and/or the local community. Effective project management involves the integration of all stakeholder needs from the beginning to the end of the project (Heravi et al., 2015), and in order to incorporate the opinions of those who are tasked to use the deliverables that arise from this endeavour, the end point needs to extend into the operate/utilize phase. So a wider view of project duration is essential.

Time is a significant criterion when gathering information and when making informed opinions about projects. Turner and Zolin (2012) developed a model for predicting performance indicators for managers to study success perception by stakeholders. They showed that this perception changes over time. Their conclusion was that in order to gain an understanding of project success, one must take into account the opinions of various stakeholders over multiple time frames.

Most managers perceive that when a project reaches the beginning of the operate/utilize phase, it has reached maturity. But maturity may take much longer to emerge, particularly if benefits are expected to be realized over a long time horizon. Benefit realization is an important aspect of success (Laursen and Svejvig, 2016). There is also evidence to suggest validation of benefits is not handled very well in practice (Musawir et al., 2017).

Stakeholder analysis

Stakeholders are groups or individuals who may have an impact on or be impacted by the outcomes, processes and contexts of a project (Eskerod et al., 2015). They are of importance to the success of projects because of their financial and non-financial contributions, their potential for resistance (which may have a negative impact on the project) or because the stakeholders in many cases come up with their own criteria for the evaluation of project success. This view calls for the need to perform stakeholder analysis in order to gather sufficient resources to drive the success of the project and to enable an understanding of the concerns and interests of these stakeholders (Missonier and Loufrani-Fedida, 2014).

Stakeholder analysis would particularly be of help in enhancing the probability of the success of project management in terms of product performance, sustainability and risk management (Sánchez, 2015; Yang and Zou, 2014). Project influence requires stakeholders other than those already considered in design and delivery to be heard.

Initial research considered stakeholders as having dyadic relationships with the project and the project management firm, meaning that each individual stakeholder group should be considered in the context of project deliverables. Using this perspective, some of the factors that were considered in the analysis of stakeholders were their power, urgency and legitimacy (Mitchell et al., 1997). Further, stakeholders are grouped into primary and secondary categories. Primary stakeholders are often those who play an important role in the survival and well-being of the organization. Such groupings enable the consideration of stakeholders in a hierarchical manner according to characteristics like power and interest.

Social network theory

When applying social network theory to explain stakeholder relationships, it is possible to create a description of the manner in which aspects of the stakeholder network for an organization (such as centrality and network density) impact on the response of the organization to the demands of their shareholders (Missonier and Loufrani-Fedida, 2014). Density is an attribute that is present for the whole network and is a measure of the approximate number of ties that provide a link to actors within a network, while centrality is defined as the position of an actor in the network relative to other actors (Ribeiro et al., 2017). An increase in the network density leads to an increase in the number of ties between members, which ultimately results in increased efficiency of communication within networks. This enables the diffusion of values and norms as well as shared expectations. Aside from that,

stakeholders with the highest level of network density are considered to be the most important, and ought to attract attention in order to increase the probability of project success (Haverila and Fehr, 2016).

The sponsor is central in project management because of the need to initiate and accept the project, pay for it, and commission it. However, Haverila and Fehr (2016) argued that customer/beneficiary satisfaction is also critical, although often not assigned an appropriate level of importance. Unfortunately, their narrative of project phases does not include an operational perspective. Stakeholders are networks of individuals and organizations within a project setting, and may include authorities, customers or end-users, the project management team, shareholders, owner or project sponsor, the local community and other actors (Davis, 2016).

In the *i3d3* framework, there is an important change in primary stakeholder during each of the project phases. In the initiation phase, the stakeholders include the owner/sponsor and shareholders. In the implement phase, the stakeholders are the project team as well as regulatory authorities. However, in the influence phase, the stakeholder base broadens to include the client/end-user of the project and the local community.

Stakeholder view of success

The acknowledgement of success is often a result of the realignment between the expectation of stakeholders and the final outcome as described by cognitive dissonance theory (Henoekl, 2015). Davis (2016) reported on an earlier study that attempted to measure success using multiple stakeholders. Although this view of success was based on traditional cost, time and scope parameters, the contractor was an added stakeholder in the measure of success. She stated that not many studies have been carried out that pertain to the stakeholder view of success, with themes such as the relationship of the customer with the organization, acceptance of the project by the customer, appreciation and collaboration, and benefits of the project to the organization and customer. These require further empirical work.

The difficulty of managing and measuring the expectations of stakeholders has resulted in the problem of coming up with an appropriate model. In many cases, the expectations of stakeholders are usually regarded as unmet and particularly because different stakeholders have varied definitions of project success. This is reiterated by Mir and Pinnington (2014) who stated that project success may be variously interpreted by different stakeholders. Conflict of interest between stakeholders is also a potential problem.

The objective of the *i3d3* framework is to eliminate the controversy that has guided the success of a project in the past by proposing use of better criteria to reach an overall opinion of success recognizing that different stakeholder groups will act as judges at different times. Further, the model proposes techniques through which success can be measured at each phase, including project influence, and still remain generically applicable to all projects. The extension of the traditional project life cycle to include operational 'testing' is necessary if appropriate conclusions about success are to form. Communication between phases is also critical to the adoption of this approach in practice. Effective communication, interestingly, is generally regarded as fundamental to successful outcomes and underpinning stakeholder relationships. It is no surprise that the project manager/team sits between sponsor and end-user in regard to communication flow.

MEASURING END-USER DELIGHT: A WAY FORWARD

The operational phase in *i3d3* is represented as 'influence'. Here, the major stakeholders include clients, end-users and the local community who may benefit directly or indirectly from the project's impact. Although projects usually end at the point of delivery, their success can only be ascertained through examining whether the project brought 'delight'. Torbica and Stroh (2001) asserted that if end-users are satisfied, then the project should be considered successful. However, success should be evidenced across all three phases if benefit realization is to be translated into collective utility. At the project influence (operate/utilize) phase, the objective is simplified as: 'do the right project right'.

In this phase, factors of success are evaluated according to whether the project is desirable, adaptable, practicable and serviceable. These factors are considered to be generic across all project types, and form the basis of a questionnaire to assess the level of agreement by customers/beneficiaries. Questions will vary according to the context within which the project is located.

For each of the factors, 10 context-specific questions are raised to collect satisfaction feedback. The feedback ought to be collected after sufficient time has elapsed to make an informed comment, enabling users to gain familiarity with the project, explore its full functionality and overcome the initial fears or possible resistance to change. Time is also of importance because it allows any delivery frustrations to dissipate.

Table 1 describes the collection of user opinion for each question using a central 5-point Likert scale (ranging from -2 to +2). Table 2 describes user relevance for each question using a linear 5-point Likert scale (ranging from 1 to 5). Opinion and relevance are multiplied together to obtain a weighted satisfaction score between -10 and +10. Across all questions pertaining to each of the four success factors, and across all respondents to the questionnaire, a positive mean score is good. A high score suggests a strong level of satisfaction with the project in its operate/utilize phase, while a negative score suggests dissatisfaction.

Table 1 Respondent opinion scale (-2 to +2)

Personal Opinion	Score
Strongly agree	+2
Agree	+1
No opinion	0
Disagree	-1
Strongly disagree	-2

Table 2 Respondent relevance scale (1-5)

Personal Relevance	Score
Very important	5
Slightly important	4
Neutral	3
Slightly unimportant	2
Not important	1

Desirable is a generic success factor that addresses the attractiveness of the project and speaks of the fundamental value to the client/end-users or local community. It involves the determination of whether the stakeholders are willing to associate with it and whether they are proud of it or seek ownership of it. This is crucial as it determines the willingness and the enthusiasm to adopt the project and use it. Qualities contributing to the fascination of a project by the client/end-users or local community include elegance, beauty, aesthetics, quality, plus other insubstantial attributes that bring delight and pleasure.

In regard to the *adaptable* success factor, it relates to the elasticity of the project and its ability to be subject to change without having too much disorder or churn. Some of the qualities of this factor are the change of purpose and avoidance of becoming precipitately old-fashioned, and the ability to customize the project to their individual circumstances. For instance, in an information technology project, adaptability would mean that the project can accommodate minor changes to the way the system is programmed for it to be aligned with organizational culture, systems and processes. Flexibility involves the ability to modify the project to suit changes in market demand, technology and organizational dynamics.

The *practicable* success factor is related to the project being in a position of meeting the expectations of the client/end-user or local community in terms of functionality. This is the determination of whether the project solves the needs of the users. These needs may not be just technical performance specifications in nature, but include simplicity, ease and user-friendliness. It also underscores efficiency and effectiveness in the use of project deliverables.

Serviceable is a success factor that addresses how the project can endure the challenges that come along in the future. The project needs to be treasured in the years to come and is capable of upgrade when required. Serviceability may also include issues of sustainability, future-proofing and ongoing contributions to those it aims to serve.

While the four identified success factors are generic and share the same method of assessment and arrival of an overall satisfaction score, the necessarily contextual questions to assess them will need to be customized to the peculiarities of the project itself. For example, an office fit-out project might consider contextual questions for desirable, adaptable, practicable and serviceable criteria concerning issues such as décor, workstation configuration, secure storage space and energy star rating respectively, while a live concert project might consider the popularity of the headline act, provisions in case of inclement weather, sound and lighting innovation and safety of the crowd on the day of the event. Contextual questions cannot be generic, and may even need to be tailored to different groups of stakeholders (such as employees, local community, visitors, etc.).

Note that there are horizontal connections between the success factors listed in each phase of *i3d3*. These connections relate to financial, social, political and environmental attributes. For example, 'desirable' is largely a financial issue because it seeks to maximize satisfaction in the context of worth. In the initiate phase, financial is expressed as being 'feasible', and in the implement phase, financial is expressed as being 'within budget'. The application of these four overarching attributes is useful because all projects possess them to some extent or other.

DISCUSSION

The literature indicates that the stakeholders connected through a network have a profound impact on project success, even following the implementation period. This makes it of importance for project

managers to go beyond just the delivery of projects, to ensuring that projects succeed in realizing positive impact and value. A need for the development of a generic model for determining success at this level is clear.

In *i3d3*, the objective of the influence stage is to achieve 'delight'. This is anchored on four broad classifications of measures of user satisfaction: desirable, adaptable, practicable and serviceable. These attributes are derived from attempts to measure success in both product and service oriented projects. In software development, for example, measurements often involve variables such as perceived usefulness (Henoekl, 2015), which translates broadly in the assessment of practicable outcomes.

Since the relevant stakeholder group is customer-focused and is likely to have a wide range of opinion about the delivered project, the use of a Likert scale questionnaire is appropriate to find a consensus. More particularly, the 5-point Likert scale is ideal. However, not all questions are important to different groups, so a parallel 5-point scale focused on relevance enables weighting of opinion to be computed. Essentially each respondent will have their answer to each question recorded as a number between -10 and +10. It is proposed that the questions will be written in the first person so that responses based on their personal feelings are encouraged. The quantification of feelings into a numeric score via a questionnaire is a common method for measuring user satisfaction (Pinto and Prescott, 1988).

Jenkins and Ricketts (1979, cited in Henoekl, 2015) reported on a study in which stakeholder views were measured through a 7-point Likert scale of twenty bipolar adjectives. In Nzekwe-Excel (2010), project success was measured under a set of five determinants that are the same as those of the service industry (SERVQUAL). These were reliability (just do it), responsiveness (do it now), assurance (know what you are doing), empathy (show care and concern) and tangibles (look sharp). Other satisfaction models include KANO that employs a four-quadrant model comparing satisfaction of service with implementation of service (Nzekwe-Excel, 2010). Sánchez (2015) measured project success through the use of the balanced scorecard, while Henoekl (2015) conducted a study where evaluations were based on a holistic dimension of whether the project was ugly or beautiful, good or bad. All of these studies are attempts toward measuring project success using quantitative techniques.

In the case of *i3d3*, a four-quadrant approach is adapted from research on workplace ecology (Langston and Al-khawaja, 2018). They compared workplace ecology index (a form of satisfaction) with workplace performance index (a form of implementation). Each respondent to a set of questions about job satisfaction (organization), comfort (space), productivity (technology) and job complexity (expectation) was transformed into x and y coordinates each using a scale of -10 to +10. The quadrant represented by positive x and y values was used to measure the success of workplace change to a range of end-users including management, employees and visitors. The change was deemed successful if at least 75% of respondents were plotted in Quadrant 1. Al-khawaja (2015) found that 53.83% of respondents had a positive view of the change process. His target for a successful project was 75%. Using a scale from 0 to 100, the percentage of positive support (as shown within Quadrant 1) could be used to rank success. Figure 2 summarizes the combined findings for five reported case studies.

This is the approach to be used for measuring delight in *i3d3*. As there are four success factors to be considered, two pairs will be formed and identified as 'wants' (the mean of desirable and adaptable scores) and 'needs' (the mean of practicable and serviceable scores). Values that fall outside of Quadrant 1 are used only for the purposes of calculating the satisfaction ratio. This method is applicable to any project type.

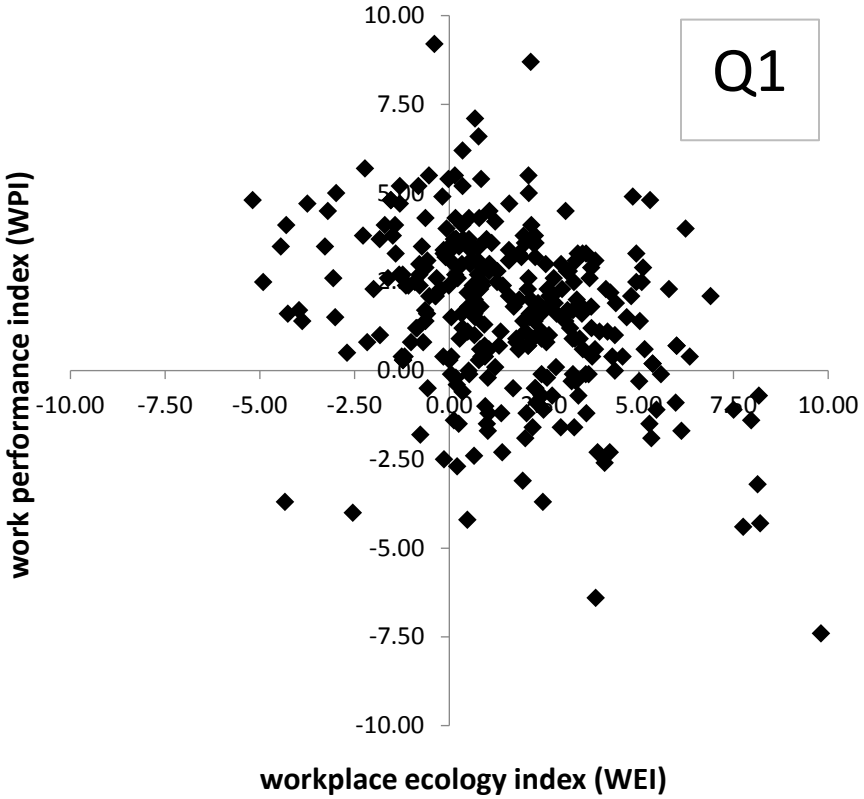

Figure 2 Workplace ecology assessment (adapted from Al-khawaja, 2015)

Sir Alexander John Gordon (1917-1999) served as President of the Royal Institute of British Architects (RIBA) from 1971-1973, and it was during this time he wrote a paper on the future shape of architecture. He argued that buildings should be designed for "long life, loose fit and low energy" (Gordon, 1972). While his peers did not immediately embrace this idea, over time it became a mantra that helps to define good architecture and its role in modern society. The idea of designing for permanence, yet incorporating flexibility to accommodate future change and minimizing environmental consequences (i.e. durable, adaptable and sustainable design objectives) is not necessarily limited to architecture. It arguably applies to any product, and perhaps to any project as well.

No one has ever demonstrated that long life, loose fit and low energy are mutually exclusive. Nor has it been proven that beauty and performance are incompatible. Cost is usually also an important factor in the sense that, all else being equal, people appreciate value for money or affordable outcomes. The technique of life cycle costing (LCC) is able to express costs over many years into a comparable figure today, enabling decisions concerning future value to be more objective. Once again, this technique can apply to any endeavour. Langston (2014; 2015) made the case that pursuit of long life, loose fit, low energy design for buildings, although possibly incurring higher construction costs, often leads to lower life cycle costs over a building's life. Hence 'least cost' might be added to Gordon's design trinity.

Long life, loose fit, low energy and least cost can act as a language that aids communication between designers and end-users. They reinforce the objective of the designer and the needs and wants of the end-user. This idea is summarized in Figure 3.

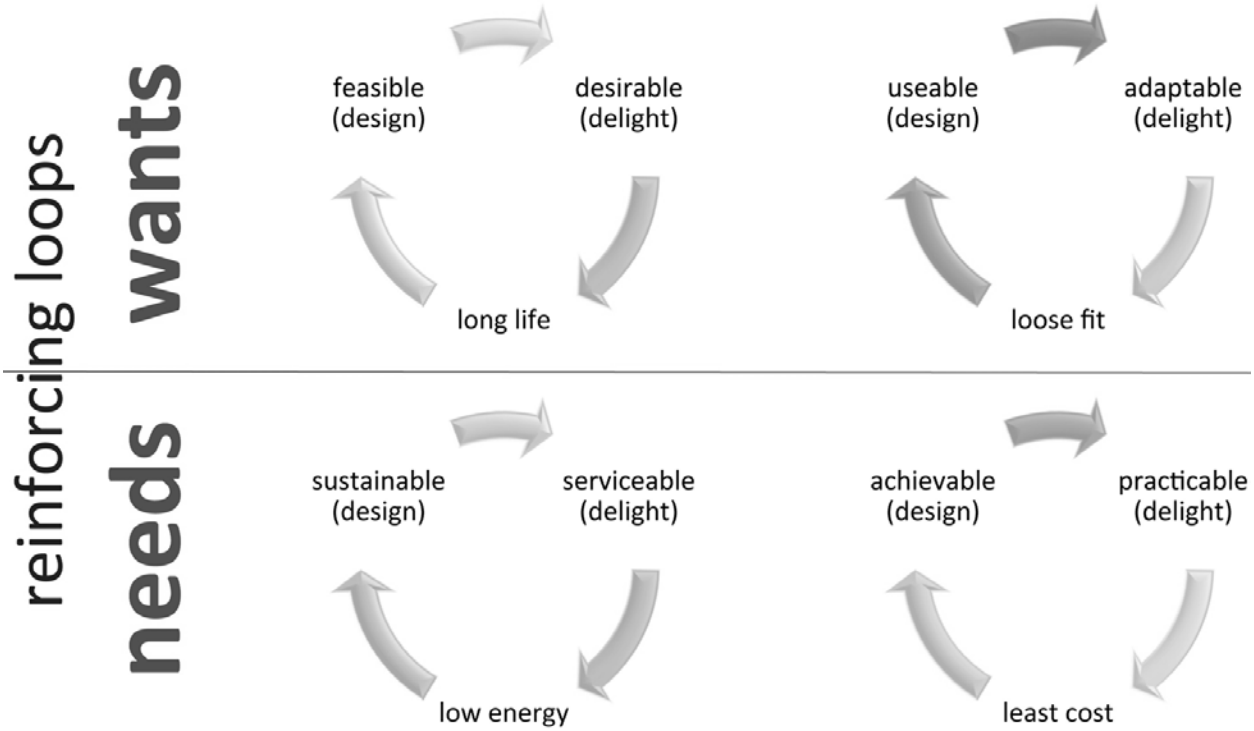

Figure 3 Reinforcing loops for end-user needs and wants

CONCLUSION

In response to the need for a generic model of measuring project success, and considering the differing views of stakeholders, this paper introduces a new model for analyzing project success from the perspective of customers (client, end-users, local community).

It is proposed that the measurement of success be based on satisfaction surveys concerning the four generic success factors of desirable, adaptable, practicable and serviceable. Satisfaction surveys, as confirmed in other studies, are more appropriate in bringing divergent opinions together to judge the extent of consensus. Furthermore, considering the larger *i3d3* framework, the measurement process is not an end in itself, as it can constitute feedback to earlier stages of the project, and thus provide an opportunity for learning lessons for the future. This can be achieved through reinforcing loops for each end-user success factor assisted by a common language of long life, loose fit, low energy and least cost adapted from the architecture profession. Success can ultimately be measured in terms of financial, social, political and environmental performance by different stakeholder groups, at different times, for any project type. It is concluded that success in project design and delivery are not sufficient to make a successful project.

One major weakness of the model is its practical application. Although the concepts are logical and well presented, the extension of project management beyond the implement phase needs to become normal practice. Currently, it is not. Project teams are often temporary and disband upon handover to work on new projects, so staying together into the influence phase and collecting data on satisfaction may have cost implications.

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Olympic Feat: How Los Angeles Metro in Managing Transit Upgrades

Julie Owen, Los Angeles County Metropolitan Transportation Authority

Abstract

Los Angeles Metro has the second largest public transportation system in the United States. Recent sales tax initiatives have committed $160 billion into transportation upgrades preparing for the 2028 Olympics.

In this presentation, you will learn how Los Angeles Metro is leveraging technologies to promote innovation and deliver projects. Enterprise scheduling is implemented to provide project, portfolio and program level performance information for executives and constituents. A centralized solution is implemented for tracking transit project risks. Capital project lifecycle management solutions are utilized and integrated with corporate financials and executive dashboard analytics to ensure project delivery on-time and within budget.

Introduction

The Los Angeles County Metropolitan Transportation Authority (LA Metro) is responsible for the continuous improvement of an efficient and effective transportation system for Los Angeles County. This mission has been challenged in recent years by continuous population growth that stressed existing infrastructure and would continue to do so for decades to come unless significant investment was made to the county's transit and highway system.

With the increased population, and expected growth in automobile usage, air quality and environmental impact is also a growing concern. Significant investments were made to LA County's transportation infrastructure in the 1980s, 1990s and Measure R in 2008, but more recently, funding for capital improvement projects had been insufficient to match the growing transportation demands of the community. In recognition of the transportation needs, LA County voters passed sales tax initiatives for Measure M. Adding further complications is the selection of Los Angeles to host the 2028 Olympics. In response, a variety of technologies were implemented to improve capital project delivery.

Background

Metro deployed a Program Management Information System (PMIS) to facilitate program-wide project tracking, administration and management reporting. PMIS was implemented to maximize efficiencies through automation, standardization, and provide program performance transparency. The system utilizes Oracle® Primavera software that has been configured to support the program-wide reporting

requirements. Software applications include Oracle® Primavera P6™ Professional, ProjectStatus, Oracle Primavera Contract Management (PCM), Oracle Primavera Unifier and EcoSys®. All applications are integrated to the organizational financial system in Oracle® Financials. The system architecture is shown below in Figure 1:

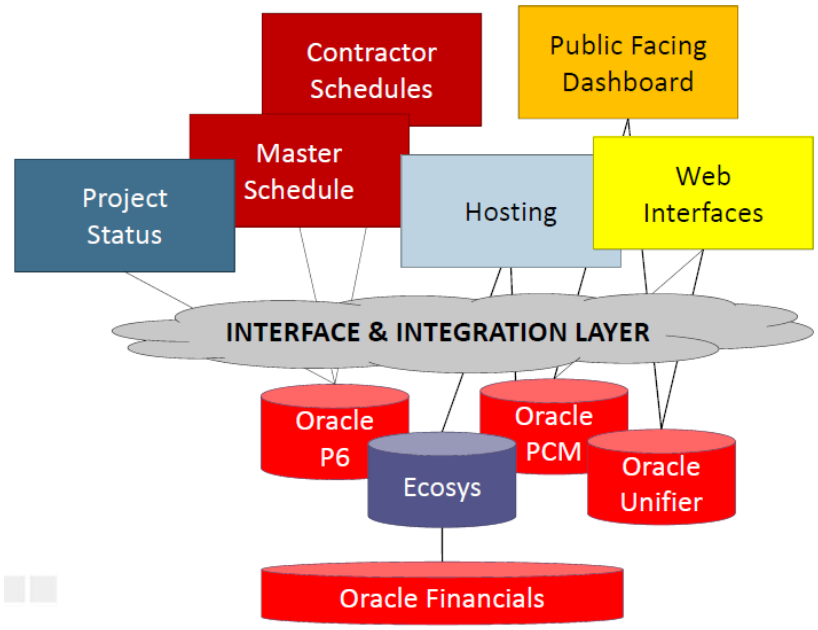


Figure 1 – PMIS General System Architecture

Enhancing Enterprise Scheduling

Metro implemented the best of breed enterprise portfolio project management system by Oracle® Primavera P6™ and incorporated custom configuration and integration utilities. Enterprise scheduling was performed to deploy all project schedules into a single database. Designs were established to standardize all P6 data structures across departments and business units. Requirements were established to define how and when P6 would be used as the system of record for maintaining data for reports. A standard work breakdown structure was established to ensure detailed schedules rolled up for management reporting purposes. Master schedules were produced and distributed to all departments to ensure project status was communicated and delivery expectations met.

Improving Risk Management

Metro desired to provide for a centralized solution for tracking transit project risks. A collaborative team was developed consisting of the transit client, risk management consultant and technology partner in the development of the overall solution. The implemented solution consisted of ProjectStatus a proprietary web-based, centralized solution whereby all risks could be tracked and stored in a centralized location, Oracle® Primavera P6™. United States Federal Transit Administration (FTA) risk management guidelines are discussed along with benefits of applying standardized risk management

approach. The new functionality provides the ability to look across multiple projects at similar risks thereby offering insight for organizational strategic decision making.

Promoting Capital Project Document Collaboration

Metro upgraded document and cost management systems as one existing application ended its useful life. Opportunities were realized to consolidate multiple applications into one product and enable automated routing of contractor documents for approval. The technology enhancement involved replacing older products with Oracle® Primavera Unifier™.. This process change offered opportunity to minimize the manual paper flow and improve processing turnaround time. The new technology also provided document interaction via email and also supported mobile technologies. Unifier was integrated with the financial accounting systems and served as the analytic tool for financial reporting, cost forecasting, and "what-if" scenario analysis. Finally, the solution provided cash flow reporting drill down capability to the transaction level, and detail item cost reports.

Conclusion

LA Metro faces a daunting task to upgrade transportation across Los Angeles County in preparation for the 2028 Olympics. The large number of capital projects occurring simultaneously requires innovative management approaches and technology enhancements. Improvements to project control practices are implemented to address challenges, improve oversight, and provide accountability.

OWNER COST ESTIMATE REVIEWS

Allen C Hamilton & Douglas Leo, Project Management Associates

ABSTRACT

A critical point in the progression of any project is the decision to commit significant resources and implement the project. Before proceeding for approval, project teams find it useful to have a third party review the cost estimate. The review is to ensure the technical basis; cost data and assumptions are consistent with expected project outcomes and identify any areas of concern. The paper will primarily address the appropriation estimate but other cost estimate reviews will be covered. The planning, interviews, reviews and report for the cost estimate review will also be discussed. The authors will present his extensive experience and hands on work in the understanding of these activities.

Keywords: owner, estimate, review, cold eyes, estimate validation

INTRODUCTION

The purpose of this paper is to present a suggested methodology for the review of cost estimates. During the authors 30-year career he has reviewed a large number of capital cost estimates. These reviews have been on both internal projects and on third party projects. The reviews have included multi-million dollar projects and multibillion dollar projects throughout the world. The emphasis of the paper will be from the point of view of the owner, the methodology can also be used by contactors. The reference documents used in the review can be obtained from AACE International. The methodology will cover the review by estimate classification as it is important to review projects as they progress through the stage gate system. A stage gate is a business technique in which investment projects are divided in stages and must pass the stage criteria in order to proceed to the next project phase.

The methodology will also outline the preparation for the cost review. Many reviews suffer because of lack of preparation. Some simple and useful advice for preparation is to *be prepared and be flexible*. The preparation will automatically enable the reviewer to implement the review with the tools which we will outline. Finally, the content of the report will be discussed and this will also reflect the preparations.

The quality of the validation/review will be dependent of the amount and quality of the project information that is shared with the third-party team. A mega-project will entail large volumes of cost data and supporting backup information before or early in the review process. As the third-party team is being assembled, it is important upfront to determine the kind of information that will be requested beforehand. Additionally, it is desirable to have some level of familiarity with the project before arriving at the site. And lastly, the extent of project team members' availability and cooperation will play a huge part in the degree of success for the third-party team. An overview briefing of the project scope and individual interviews with project team members need to happen as soon as possible, once the team is at site. Any upfront conference calls between the third part team and the project team are very helpful pre-arrival.

Factored into the third-party review/validation plan, needs to be the understanding, that because of sheer volume and given time constraints, all project information cannot be thoroughly reviewed. Large cost drivers, and strategically important costs will need to be the main focus. It has been our experience that costs typically follow a "Pareto 20/80" type distribution with a small amount of scope driving a larger portion of the project costs. This is where initial attention needs to be concentrated.

WHY COST ESTIMATE REVIEWS

Why do we need to review a cost estimate? First and foremost, the organization needs to know that the estimate was prepared in a certain way and with a certain quality. If the project group presents the estimate as suitable for appropriation then the supporting information will need to be present. Second, many organizations employ a stage gate project review system in order to determine if a project should be continued, delayed or cancelled. Project personnel feel that if a project fails to meet the stage gate and it is cancelled, it is a reflection on their competence. Cancelled projects should

preserve the company's resources for better opportunities. Some of the most successful companies are known to employ predictable and consistent evaluations of projects and if necessary cancel the ones that do not meet the criteria. Third, if project teams realize that a review will be performed the opportunity for shortcuts will be seriously considered. Short cuts are acceptable if they are in the context of the estimate class. The knowledge that someone will ask what you did in the estimate and why, should provide the project personnel with incentives to perform the estimate correctly.

WHAT IS AN OWNER COST ESTIMATE REVIEW?

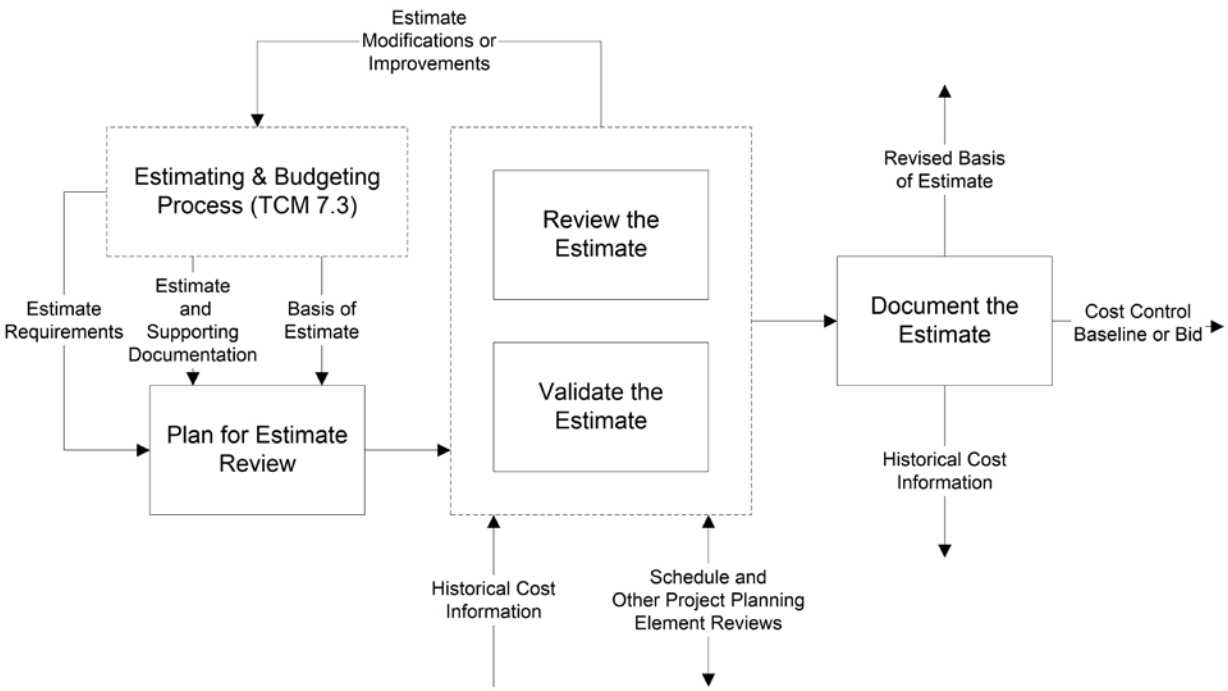
A cost estimate review as presented in this paper is the formal presentation of a cost estimate to a third party for the purpose of confirming the estimate quality supporting the targeted estimate class. The reviewer will communicate with the project team with requirements including documentation, location, personnel to be interviewed and the report to be produced. "By owner" means the company making the capital investment or having a material interest in the project (company, bank or surety).

COST ESTIMATE REVIEW VS. COST ESTIMATE VALIDATION

TCM discussion & graphic

Before discussing the planning and subsequent meeting with the project team at the site, a brief overview of the Estimate Review / Validation process is helpful. AACE Recommended Practice 31R-03 addresses the estimate /review exercise. [1] It differentiates between the process of reviewing and validating the cost estimate.

Table 1 – Estimate Review, Validation and Documentation Process



The *estimate review* is seen as a qualitative exercise. As a third-party reviewer, the interest is on the estimating process and how transparent and understandable is the cost estimate. It looks at such things as: the project scope document, the estimating/engineering deliverables, the

Estimating Plan, the Basis of Estimate, the transparency of the estimate. Is the estimate easy to follow, understandable and complete? Is there an integrated project team and has turnover of team members been minimal? Are there a defined Construction Plan, Engineering Plan, Purchasing Plan, Fabrication Plan, and Modularization Plan? Has the schedule and cost estimate been integrated? All of these types of items are important, because as RP 31R-03 suggests, if the project has followed a defined project process and all the right types of activities in developing the estimate were performed, the resulting cost estimate has a high probability of being a quality product.

On the other hand, the *estimate validation* is more of a quantitative exercise. The focus involves such things as looking at cost metrics, verifying material takeoff quantities (MTOs), and the validation of commodity and equipment pricing and unit pricing. The degree and methods of risk identification, assessment, mitigation and contingency determination are also examined. The validation process will involve access to a wide array of project information and a substantial amount of access to project team members. The validation requires a high degree of analysis of project information that must be transparent, understandable and traceable.

In order for the third-party review / validation to be meaningful, there needs to be substantial analyses of both qualitative and quantitative project cost information. The challenge during a time constrained estimate review / validation process, will be the availability of the correct cost information, the right mix of project team personnel and the time in order to understand the information and analyze in a way that will provide meaningful information to the client.
High level differences and strategies between Estimate Review and Estimate Validation, being aware that if the process is sound, more than likely outcomes will be reasonable, are as follows:

Estimate Review is Qualitative – examination and analysis include:

- Exposure and Understanding of the complete project scope.
- Project Estimating Plan
- Project Implementation Plan (PIP)
- Design Basis Memorandum
- Basis of Estimate & Organization of Estimate
- Understanding of the Estimate Summary contrasted to the Estimate Detail
- How integrated is Project Team composition? How involved is the CM & Operations?
- Degree of turnover of Project Team Members
- Degree of teamwork and cooperation among team members
- Risk management and contingency determination process
- Cost Escalation Process
- Any limitations or exclusions to the estimate imposed by the owner

Estimate Validation is Quantitative – examinations and analysis focus on:

- Any limitations or exclusions to the estimate imposed by the owner
- Design maturity – especially important if design is not complete
- Material Takeoff's (MTOs)
- Unit Rates
- Labor Rate Buildups
- Commodity Metrics
- Project Performance Metrics & Benchmarking
- Any errors, omissions, duplications

ESTIMATE REVIEW BY ESTIMATE CLASSIFICATION

AACE International (AACE) Recommended Practice No. 18R-97 [2] outlines the Cost Estimate Classification System in the process industry. There are 5 classes defined by AACE called Class 1 to Class 5. In order to simplify the discussion in this paper the ANSI Standard Z94.0 [2] of three classes will be used. The ANSI is descriptive and generally used in the industry. Both the AACE & and the ANSI estimate classes are shown below:

Table 2 - Estimate Classification Matrix [2]

AACE Estimate Class	End Usage Typical Purpose	ANSI Standard Z94.0
Class 5	Concept Screening	Order of Magnitude (OOM) Estimate
Class 4	Study or Feasibility	Budget Estimate
Class 3	Budget, Authorization, or Control	
Class 2	Control or Bid	Definitive Estimate
Class 1	Check Estimate or Bid	

Cost estimate reviews can take place at any stage of the estimating process. Most gates are consistent with estimate classes. The stage gate project review process generally requires the project teams to document and or demonstrate that estimate meets established criteria for passing the gate. With or without a formal stage gate process all estimates should be reviewed. This can be a memo, a document sent to a distribution list or a presentation at a meeting. Cost estimate reviews are most often done prior to authorization. The financial authorization is a critical point for any project as it is the turning point for commitments of resources and money. Independent reviews are less often done at the Order of Magnitude (OOM) Estimate stage or the Definitive Estimate stage. Complex projects may justify a review at an OOM estimate stage. If a review is done at the definitive estimate stage it may be because there is a problem such as significant scope creep or cost increases significantly beyond the contingency allowance.

COST ESTIMATE REVIEW CRITERIA

Cost estimate reviews can be performed with custom checklists or with recognized independent standards such as those from AACE. The advantages of AACE Recommended Practices and Standard are their wide distribution within the cost management profession. A recommended practice developed by a professional association has a perceived independence and objectivity. The practices and standards within AACE have a long history of support including updating and revising. The author

has been a contributing author for some of the recommended practices. The AACE Recommended Practices and Standards that are typically referenced in a cost estimate review are as follows:

- 10S-90: Cost Engineering Terminology
- 16R-90: Conducting Technical and Economic Evaluations: As Applied for the Process and Utility Industries
- 17R-97: Cost Estimate Classification System
- 18R-97: Cost Estimate Classification System: As Applied in Engineering, Procurement, and Construction for the Process Industries
- 20R-98: Project Code of Accounts
- 21R-98: Project Code of Accounts: As Applied in Engineering, Procurement, and Construction for the Process Industries
- 22R-01: Direct Labor Productivity Measurement: As Applied in Construction and Major Maintenance Projects
- 28R-03: Developing Location Factors by Factoring: As Applied in Architecture & Engineering, and Engineering, Procurement & Construction
- 31R-03: Reviewing, Validating and Documenting the Estimate
- 34R-05: Basis of Estimate
- 40R-08: Contingency Estimating: General Principles

Reviews are best if they recognize the uniqueness and variability of a given project. Standard checklists need to be modified for the particular project being reviewed. For example, OOM estimates for unique process technologies justify a more intense look at the technical basis. If there are unique pieces of equipment that are essential to the project, the check list can be altered to focus questions that are particular to the project.

WHO PERFORMS THE COST REVIEW?

The question of who performs the cost review is important. It has been demonstrated that an independent party not connected with the project team has the best opportunity to make an objective review. The stakeholders that will receive the review will want to know if the cost estimate has any issues that need to be addressed by the team. An independent and objective review will confirm and communicate to the stakeholders what quality the estimate represents. Most important is the communication of deficiencies. Third parties are in a better position to present bad news and observations that require corrective action.

Two types of individuals are best qualified to perform the review. First, a third-party consultant hired by the company will have a fresh unbiased view of the information being presented. Consultants do not have a history with the project and their evaluations and conclusions should focus on the content and not on the politics. Consultants may also be viewed as a friendly outlet to discuss the challenges of a project that may be difficult to discuss with an internal party. The consultant may also be viewed as an ally to discuss any issues that need to be presented in a constructive way to management. Second, an independent internal party not connected with the project may be considered. This type of individual works best if the organization is large enough to draw expertise from other company divisions. Large organizations with a matrix structure including project or cost functional groups are

well prepared for this type of review. It should be stressed the reviewer should be independent and objective.

REVIEW TEAM VS INDIVIDUAL REVIEWER

The need for a review team composed of multiple members vs. an individual is dependent on a number of characteristics of the review including:

- Project Size
- Project Complexity
- Owner Request
- Project Development – OOM, Budget, Definitive Estimate
- Normal Quality Assurance & Validation Review
- Catastrophic Cost Overrun Review
- Legal Implications of the Cost Review
- Cost Claim Implications of the Cost Review

Most of the author's cost estimate reviews have been with 1-2 members and a few with a team. Usually the owner needs a cost estimate quality assurance and an individual can perform this request. The individual will need to be generally familiar with the industry if they are reviewing the technical, cost and implementation basis. However, an experienced competent cost professional can review a cost basis on any project.

REVIEW LOCATION

Order of Magnitude (OOM) Estimate – The review for this type of estimate will usually take place in the offices of the owner or the contactor tasked to perform the early basic engineering and design. A site visit is usually not required unless there is an issue with a proposed location where the cost is tied to key location specifics.

Budget Estimate – The review for this type of estimate takes place at the office of the engineering company. The review should take place at the office where the engineering, cost and implementation are performed. It is not recommended for the engineering company to go to the owner's offices for the review. During the review, access to the engineering staff and documentation is important. One technique is to review items at random or by selection and ask for supporting documents to be retrieved. Although with the use of data bases and distributed document access, the task might be just a click on the screen. It may also develop that discussions indicate supporting staff may be called to clarify items under review. Being physically present at the office where the work takes place simplifies the access and prevents the excuse that the document or person is at another office.

It is recommended the review of a budget estimate require a site visit. For a new undeveloped site this may be brief but should be made. For a plant modification, revamp or expansion a site visit is essential. The site visit should include interviews of the project management team.

COST REVIEW PREPARATION

The cost estimate review should begin and end with the client request. A written description of the request should be received from the client. The request should specify the work to be performed, the project to be reviewed and the cost estimate to be evaluated. The coordination contact should be identified. The coordination contact may be a business manager but should reference the project manager. If there is no written request and the communications have been verbal, a description of the request should be assembled and sent to the client as a confirmation of the request. It would be unusual to not have the request in writing but the timing may be rushed. Tell the client what they requested and tell them what you are going to do.

The second part of the preparation is to talk with the key responsible parties. This will include the owner representative, owner project manager, engineering manager and the estimating manager. On smaller projects this may include the owner representative and the engineering manager. On larger projects this may include other key parties. The calls will be high level discussions of the review, the timing and expectations. At a minimum, have a coordination discussion with the owner representative and the engineering representative. If a non-disclosure agreement has not been signed it would be appropriate for the reviewer to suggest one be completed prior to receiving any documents.

Third, the client and engineering companies will need to be informed of the general and specific documents that need to be sent to the reviewer prior to the visit and the documents that need to be available when the interviews will be done. The documents that will be sent in advance of the interviews include:

- Summary of the project business plan
- Summary technical description
- Latest project report
- Cost summary latest milestone
- Cost summary prior milestone
- Cost backup for sub projects by major code of accounts
- Summary implementation plan
- Schedule, Level One bar chart

The client and the engineering companies will also need to be informed of the documents that will be available during the interviews. The documents include full versions of the line items listed above. Specific documents include but are not limited to:

- Business Plan
- All documents related to the scope of work
- All project reports
- Cost estimate summary and all supporting details
- Bid tabulations for all major equipment
- Implementation Plan
- Schedule, Levels 1,2,3

Fourth, the interview plan with respect to when and who will be interviewed should be sent to the client and engineering coordinator. The request should include the interviews at the engineering office and the site visit. The prior coordination calls will have established the best mutually agreeable

interview time and schedule. It is also advisable to inform all parties to complete all essential tasks to facilitate a productive review. The interviews should include, depending on the project specifics, the project manager, technical manager or project engineer, estimating manager or estimator, and the scheduling manager or scheduler.

The interview locations should be agreed based on the location of the staff and the documents. The interviews should take place where both elements are present. One technique of the interviews is to request documents based on the interviews and request they be brought to the meeting. If the documents are a hard copy then the interview location has to take this into account. If most or all the documents are electronic then this is not as important.

Plan the interviews for early to mid-week and leave time for extra days in the event of delays and interviews taking longer than expected. It is recommended to inform the parties that there is flexibility for the interviews but that they will take place as planned. It is not recommended to end the planned interviews on a Friday or prior to a holiday.

If an engineering contractor is being interviewed and a third-party consultant is performing the review, it is recommended a representative of the owner attend the interviews. The owner representative usually participates in responses to the questions and is helpful in clarifying responses to the questions. In the event the contractor becomes defensive the support of the owner representative is helpful.

The timing of the interviews should recognize the availability of the staff being interviewed and the receipt of the advance information. All of the key staff being interviewed should be available. The personnel who will answer questions on the cost and technical basis are particularly important. Some supporting members may be absent but the key managers should be present. It is recommended the interview wait until these individuals are available. One option is to perform telephone interviews if the supporting staff needs to answer key questions.

PLAN OF ACTION – AT CLIENT LOCATION

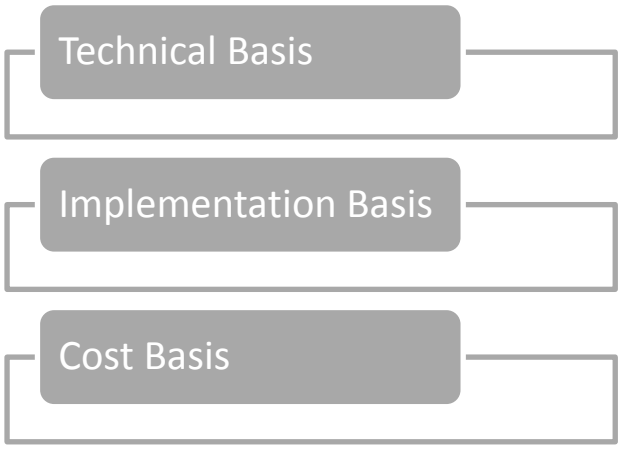
As soon as the Third-Party Review Team arrives at the client site, an overview of the project scope and a document review needs to start. Time constraints dictate the project team members need to be available immediately. The Third-Party Reviewers need to again communicate to the client team:

- The overall agenda of desired activities during their time at the client location.
- The timeframe for when project documents needs to be transferred to the Third-Party Reviewers. It needs to be stressed that any wait times for document transfers will put the quality of the review/validation and the desired completed review at jeopardy.
- The schedule times for interviews with team members need to be finalized. Meetings with team members may occur with individuals or with groups of team members. Time constraints and project needs will require some flexibility with scheduling and any subsequent rescheduling of these meetings. Continual communication with the client representative will need to happen to insure all sessions are covered and no wasted time is allowed.

- Access to team members must be given to the Third-Party Reviewers to handle any questions, reschedule of activities, and assistance in receiving project information/documents. It is best practice that the client management or project manager communicates to the project team the importance of the review/validation exercise. The success of the third-party process is enhanced with open access to project documents and project team members.

REVIEW SECTIONS

A cost estimate depends on three essential elements:



Some may mistakenly think the cost basis is the most important or even the sole element but this is not true. First a project team has to define the *technical basis* or scope which will need to be acquired for the project to achieve its goal. Second, the basis for when and how the project will be *implemented* needs to be defined. Third the definition of the way in which the cost estimates will be carried out needs *(cost basis)* to be defined. All three of these elements are interrelated and any deficiencies in one will impact the quality and accuracy of the final cost.

TECHNICAL BASIS

It is best to start the interview with the technical basis. The technical basis naturally leads into the implementation and cost. The other two sections will depend on the degree of completeness of the scope. The implementation plan and the schedule can go next. The cost basis should be last as the discussion will reference the scope, implementation and schedule.

The review of the technical basis will be conducted by the reviewer (cost consultant) or the technical representative if the review is being performed by a team. This was discussed in the *Who Performs the Cost Review* section.

The technical basis is the documents which define the scope of work to be estimated. Depending on the project size there may be separate sections for business, marketing, environmental and scope. In this section we are primarily concerned with the documents related to defining the scope of work to be included in the cost estimate. These documents may include but not limited to specifications,

drawings, sketches, equipment lists, process flow diagrams (PFD), piping & instrument diagrams (P&ID), and one line electrical diagrams. They may be actual paper documents but an increasing amount of project information is electronic. Furthermore, the electronic information is in a network and may be controlled by content management software such as Documentum or similar.
Prior to the interviews, inform the group which will be interviewed, the technical scope discussions will be based on:

- AACE International Recommended Practice No. 18R-97
- Cost Estimate Classification System
- As Applied in Engineering, Procurement, and Construction for the Process Industries
- TCM Framework: 7.3 Cost Estimating and Budgeting [3]

An electronic copy should be sent to the concerned groups and reference made to the Estimate Input Checklist and Maturity Matrix.

Table 3 – Estimate Input Checklist and Maturity Matrix -General Project Data [2]

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
General Project Data:					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined

For the General Project Data in the checklist the degree of completeness is as follows:
None → Assumed / General → Preliminary / Approximate → Specific / Defined

Table 4 – Estimate Input Checklist and Maturity Matrix – Engineering Deliverables [2]

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Engineering Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans		S/P	C	C	C
Process Flow Diagrams (PFDs)		P	C	C	C
Utility Flow Diagrams (UFDs)		S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)		S/P	C	C	C
Heat & Material Balances		S/P	C	C	C
Process Equipment List		S/P	C	C	C
Utility Equipment List		S/P	C	C	C
Electrical One-Line Drawings		S/P	C	C	C
Specifications & Datasheets		S	P/C	C	C
General Equipment Arrangement Drawings		S	C	C	C
Spare Parts Listings			P	P	C
Mechanical Discipline Drawings			S/P	P/C	C
Electrical Discipline Drawings			S/P	P/C	C
Instrumentation/Control System Discipline Drawings			S/P	P/C	C
Civil/Structural/Site Discipline Drawings			S/P	P/C	C

For the Engineering Deliverables in the checklist the degree of completeness is as follows:
Started → Preliminary → Completed

The Estimate Input Checklist is the primary document to use for the technical basis review. The advantages of the checklist is that it is published by a professional society, generally accepted by the industry, and is part of a group of documents dealing with the cost management of projects. The further advantage of the checklist is that it can be used in the report to score the estimate based on satisfying the technical criteria for a given class of estimate. The checklist should be modified for additional items or deletions specific to the industry or project.

Prior to the interview, based on the review of the preliminary project documents the project technical basis can be evaluated with the checklist. During the interview the check list is used as the actual questions.

The interview can proceed at the top of the checklist with the General Project Data and continue with Engineering Deliverables. In the Check List the line items starting with the Integrated Project Plan and

continuing thru Contracting Strategy are covered in the cost and implementation sections. The transmittal of documents prior to the interviews will make the discussion of each technical line item more efficient and effective. For example, block flow diagrams are usually limited in number and content. They are useful in giving a high-level picture of the project. Depending on the stage of development of the project and the interest of the interviewer the document can be requested to be seen and retrieved if necessary. The individuals being interviewed should be able to answer all questions related to the technical basis.

IMPLEMENTATION BASIS

The second major review area is the implementation basis. The implementation basis is the plan to manage the development of the project from design to start-up. The implementation basis would include the planning and resources for:

- Project Management Team
- Design
- Contracting
- Engineering
- Procurement
- Construction
- Start-up

The implementation basis would be assembled in a document referred to here as the Implementation Plan (IP). The IP would range from a few pages for a small OOM type project to hundreds of pages and references to many other documents including the cost and schedule for a complex project.

The organization being reviewed would have been notified prior to the interview that the implementation basis would be reviewed. It is possible the IP could be transmitted prior to the interviews or a table of contents. It is possible the implementation basis sections would be segregated in separate sections maintained by functional groups. The lack of an IP that integrates all the sections would be a deficiency in the estimate review. The review would need to establish if the lack of an IP was a serious deficiency that jeopardized the viability of the cost estimate.

The IP sections would vary from a complete outline and descriptions to summary sections that referred to the details. The design and engineering sections would contain enough content to ensure clearly supporting the goals of the project as indicated in the other sections. The IP would contain the following items depending on the estimate class:

- Project Management Team
    - Coordination Procedure
    - Organization Charts
    - Responsibility Flow Diagrams
    - Cost Development Plan
    - Schedule Development Plan
    - Reporting/Control Procedures
        - Cost
        - Schedule

- Design
    - Job Specification
    - Design Basis/Specification
    - Block/Process Flow Diagram
    - Conceptual Process Design
- Contracting
    - Contracting Plan
    - Subcontracting Plan
    - Bidders Lists
    - Change Order Procedures
- Engineering
    - Detailed Engineering
- Procurement
    - Inspection & Expediting Plan
- Construction
    - Constructability Reviews
    - Field Engineering
    - Safety Planning
    - Mechanical Completion/Turnover Plan
- Start-up
    - Commissioning Procedures
    - Operating Manual

The review of the implementation basis would emphasize the presence of the above documents and a demonstration of the content which supports the objectives and goals of the project. The implementation basis would need to explicitly support the cost basis. For example, the completion basis used to calculate escalation in the Estimate Basis Memo would need to match the procurement and construction schedule.

An additional aspect of the implementation plan is the issues it addresses with respect to the *location* and region of the project. Is the project remote and are there issues that are present and addressed in the planning? Are appropriate shipping, logistics, taxes and duties address in the implementation and cost basis? If the project required a large construction force has the project recognized where the people will come from and how they will be housed? For some locations *permitting* is a scheduling issue, if this is the case has it been recognized in the cost and schedule?
What are the planning assumptions for the *contracting* of the project? Is the primary contracting basis direct hire, lump sum? Will the project be contracted as an EPC basis or split vertically or horizontally? If the contracting is split, is the coordination of the contracts noted. Does the work break down structure support the contracting plan & the schedule?

The review of the implementation basis answers the question of how the company is able to fit all the pieces together in a coherent document. The evaluation of this question is how it supports the cost estimate.

The *schedule* review is an essential part of the cost estimate review. The schedule should support the information indicated in the technical and implementation plan. The review should cover the scheduling tools and the way in which these tools are used in the project. Is Primavera or MS Project being used? What version of the tools is being used for the schedule? How many discrete activities are in the project schedule? How many activities are applicable to engineering, procurement and construction? How is the schedule organized with respect to the implementation plan and the work breakdown structure? What does the schedule say about the current stage of project completion?
It is important to have the schedule review with the scheduler and not the project manager.

COST BASIS

Many people think a cost estimate is a number or summary sheet of estimate categories and subtotals adding up to a grand total. This is incorrect; the cost estimate is composed of the following:

Table 5 – Cost Basis Elements

What technical basis does the estimate represent	➔	**Scope of Work**
What quality does the estimate represent	➔	**Estimate Classification**
Where the estimate applies and the source of cost information	➔	**Pricing**
When is the estimate intended to reference	➔	**Pricing & Escalation**
How were the cost derived	➔	**Techniques & Methods**
What is the risk management value	➔	**Contingency**

The estimate as describe above should be outlined in a document which specifies the sources of cost information and the key parameters to be used in the estimate such as wage rates and escalation. This document may be called the *Estimate Basis Memo* (estimate memo) or similar title. The estimate memo details will reflect the estimate classification. The length of the memo can vary from a few pages to over one hundred. An estimate memo for a definitive estimate should be thorough and proscriptive in providing instructions to the estimators as to what should be done in the estimate, where the information is coming from, what techniques and methods apply and how to file the results. Most successful estimating organizations will issue the estimate memo *before* the estimate starts. It is not as useful to develop the estimate memo on an ad hoc basis. The estimate memo should be updated at the conclusion of the estimate to reflect any departures from the original memo.
The information used in the cost estimate review should include the estimate to be reviewed and the prior estimate. The primary reason to have the prior estimate is that many reviews are requested

because of significant differences between the current and prior estimates. A cost comparison is useful to get a quick look at changes. A cost reconciliation is preferred because it will established equivalencies between estimate groups and include more accurate reasons for differences.

The estimating guidelines, checklists and procedures established in the planning will be implemented for each of the three basis sections including the cost basis. Two AACE recommended practices, 18R-97 Cost Estimate Classification System and 34R-05 Basis of Estimate were addressed earlier. These two are key reference documents in the review of the cost basis.

Scope of Work - The first questions are to establish the link between the technical basis and the cost basis. The value of the cost estimate is undermined if there is no explicit link between the technical basis and the cost basis. Is there a list of drawing, specifications, equipment lists, P&IDs that are the reference documents to the cost estimate? These documents are frequently called base line documents, although base line is more frequently applied to cost control documents during construction. Another category of documents that will refer to the cost estimate is Issued for Design (IFD), Issued for Engineering (IFE) and Issued for Construction (IFC). Each has application to OOM Estimates, Budget Estimates, and Definitive Estimates. The definitive document linking the technical basis is a listing of all documents, their title, date and revision and the estimate it defines.

Estimate Classification - Next the estimate basis should support an estimate classification and perceived quality. It is necessary to link any company or internal classification system to an industry standard. AACE Recommended Practice 18R-97 Cost Estimate Classification System (2005). Any classification system from a company has to be linked to a standard, it may be necessary for the reviewer to evaluate any differences between the internal classification and the standard. The AACE documentation should resolve these questions.

Pricing – The estimate in its details is a collection of prices for various categories of costs. The source and reference for all should be established.

What is the *equipment pricing* and did it originate from an internal source or an external source? The internal source could be a company library or data base. If it is an internal library or data base is the data normalized and indexed? Normalizing would convert the equipment to a standard item that could be used for any future project. Indexing would convert the pricing of the equipment pricing to a reference date and then could be used with an index for any future date. The external sources would be third party estimating programs, vendor quotes or purchase orders. The third party estimating programs should have appropriate application to the industry or modified for use by the user. The use of vendor quotes should be clearly noted as budget quotes or firm quotes. Quotes can be tested to establish the technical quotation basis and the values in the estimate.

What is the *bulk material pricing*, where did it originate and how was it used in the estimate? The internal vs. external questions are similar to the discussion about equipment pricing above. An additional question about bulk material pricing is the magnitude of quantities and discounts that are applied. Does the pricing include or exclude discounts? If excluded, where are the discounts calculated and applied.

What is the *labor* pricing basis, where did it originate and how was it used in the estimate? Is the labor on a direct hire or all-in-subcontract basis? If an all-in-subcontract basis is used what cost elements are included in the rate, especially small tools and construction equipment? Is the wage rate applied as a project or location average or are there rates by trade? If an average rate is used what is the weighting of trades used to derive the average? Is there a reference of the wage rate to prior projects? Is there a reference to union agreements that can be verified? What is the labor productivity basis and can it be referenced to prior projects, third party estimating program or an industry standard? Can the wage rates and productivities be tested and validated?

Pricing & Escalation – All pricing for equipment, bulks and labor should be clearly indicated as to the time period. For OOM estimates and some budget estimates it is common for a reference date to be used for the estimate details such as 4Q2013. Escalation is then applied overall or by estimate element to an expenditure period. The escalation would then represent the monies expended to achieve a project completion. The escalation rates should be justified and substantiated and validated to external values. There are various third-party sources of information available in the technical publications or for purchase.

Techniques & Methods – What are the estimating techniques and methods, where did they originate and how where they used in the estimate? Is the estimate organized with the use of a work breakdown structure (WBS) and a code of accounts? Does the WBS support or reference the schedule? Is the WBS and schedule planned to be integrated? Do the techniques and methods support the estimate classification? The level of detail should be reflected in the expected accuracy. An OOM estimate may show techniques such as unit cost proration from other projects and time periods. A budget estimate may have a mix of high level estimating and semi-detailed estimates. A definitive estimate will have a majority of detailed estimating. Sophisticated estimating organizations can quantify the methods used in the estimate by summary, proration, semi-detailed, quotes and detailed. The use of allowances should be specified in the estimate memo and be appropriate to the estimate class. Exclusions are important if they potentially have an impact on the project or are under the control of external parties.

Contingency – What is the estimate approach to risk and how is it calculated? Were the project's risks and opportunities adequately determined and assessed by the Project Team? The reviewer should establish the way in which contingency was calculated and is it appropriate to the estimate class. Does the estimating group have a history of performance on similar projects which reflects the contingency? Are tools used to statistically derive the contingency such as Monte Carlo simulation? How was the simulation performed and derived? Has the company tracked the performance of projects including the comparison of appropriation value vs. final project cost? Does the company employ any continuous improvement process such as Total Cost Management?

The final analysis of the cost basis is the question of how the project compares to other projects. It is frequently referred to as benchmarking or project metrics. The principle of benchmarking is that similar activities in projects will conform to a reference value or band of reference values. It should be clear what is the basis and quality of the reference values. Values outside of the reference will require investigation or explanation. Some of these values are strategic such as dollars invested per unit of output. Other benchmarks are semi-detailed such as overall labor productivity. Other benchmarks may be keyed to code of accounts such as average work hours to install a cubic yard (meter) of

concrete. Another code of account benchmark is average pipe diameter on the project and average work hours to install a diameter inch (cm) of pipe. The benchmark parameters are calculated and compared to other similar projects. In the event there are differences an explanation should be available. If a potential problem exists, it should be resolved.

INTERVIEW BRIEFING & REPORT

First and foremost, can the third part reviews say with confidence that the intended project estimate accurately reflects the intended project scope and was the estimate appropriate for the design status it is based on? This is a desired and critical question that needs to be addressed.
Prior to departing the interviews, the reviewer will want to brief the concerned parties. The briefing should include general comments as to how the review proceeded. If there are any deficiencies it may be appropriate to express concern about the issue. An objective & balanced briefing that will be supported in the report will serve to alert the concerned parties as to what is coming. It may be necessary to analyze some content before concluding about a given issue. In that case it would be appropriate to withhold it from the briefing. The politics of the review will be evident when it is requested or discovered during the interviews.

The report is the key document in the process of the estimate review. It serves to record what was requested, what was revealed in the review and what the reviewer recommends needs to be followed up. It is the author's experience that most reviews with competent owners and contractors serve to confirm the cost estimate. The question that is frequently unasked but evident is "Do we have anything to worry about with this project?"

The report should outline the request, the dates, times and content of the reviews. The parties interviewed should be documented. The review materials should be included or referenced such as AACE 18R-97 Estimate Classification and AACE 34R-05 Basis of Estimate. Key tables and figures should be included. Reports of this nature are usually sent as draft in the event content needs to be modified. It is useful to provide a clear indication of the comments with respect to the sections and sub sections that were reviewed. These are:

- Meets Acceptable
- Needs Improvement: where and why
- Deficiencies: where, reason for deficiency and potential impact

It is the author's experience that deficiencies need to be clearly stated, supported by object reasons, and references. There is an unavoidable reaction to these types of observations unless it has been coordinated with the concerned parties.

CONCLUSION

Projects reach key points where the decision to proceed and spend significant monies is reached. These decisions are often meaningful in the company achieving financial success. Many projects fail because of the lack of a critical review at periodic points of a projects development history. It has been clear in many post mortems on a project failure that a project cost review would have shed light on risk and deficiencies. The expense of a project review should also not be avoided because of the lack of any significant failures. Total Cost Management and continuous improvement stresses the need to confirm success and correct failure.

The paper has also stressed the need for an independent third party to review the cost estimate such as an outside consultant or an internal person not on the project team.

The cost review should confirm the work performed is consistent with project development and control criteria. This criterion is well represented by AACE Recommended Practices and Standards. The two standards which are key to this review are: 18R-97 Cost Estimate Classification System and 34R-05 Basis of Estimate.

This paper is a composite of two papers which appeared in AACE International's technical magazine Cost Engineering in 2015:

Owner Cost Estimate Reviews, Allen C. Hamilton CCP, Cost Engineering, Vol. 52 No. 10, AACE Intl.
Third Party Cold-Eyed Estimate Review and Validation, Douglas W. Leo CCP CEP, Dr. Stephen Warhoe, PE CCP CFCC, Vol. 52 No. 4, AACE Intl.

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3. Total Cost Management Framework, Second Edition, H. Lance Stephenson, Editor 2015
4. Owner Review Process for Mega-Project, Douglas W. Leo, Cost Engineering, Vol. 52 No. 10, AACE Intl.

QUANTITY SURVEYOR'S INITIATIVES IN BIM CONVERSION AND ENHANCEMENT PROCESS

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In BIM implementation, Quantity Surveyors prepare cost estimation based on the quantities generated from the BIM 3D model, but the estimation process is not entirely automatic. Quantity Surveyors have to prepare an own method to apply the abstracted quantities into the current cost estimation format and standard method of measurement. In Malaysian quantity surveying profession, several quantity surveying firms are building 3D modelling for taking-off and costing purposes, but the 3D model is not further enhanced to a BIM model to obtain the benefits of BIM due to the limitation of the BIM platform. Therefore, this paper aims to propose Quantity surveyors to take the initiative in BIM 3D modelling implementation by converting and enhancing the 3D model prepared for costing purposes in a designer BIM platform and serve the BIM 3D model as a speciality or service for developers. A case study has been conducted on a residential building while the 3D model is created based on the local standard method of measurement and exported to an Industry Foundation Classes (IFC) file for conversion and enhancement in a designer BIM platform. Developer and contractors are expected to utilise the enhanced BIM 3D model at the post-tender stages for scheduling, interim payment, finally account as well as management and maintenance purposes.

Keywords: 3D Model, building information modelling, conversion, enhancement, industry foundation classes.

INTRODUCTION

The new emerging and innovative concept of Building Information Modelling (BIM) has delivered changes in the efficiency and effectiveness of management in the developed countries. Those developed countries consist of numerous multidisciplinary consultant companies, commonly adopting industrial building systems, and commonly practising the design and build procurement. They are advantageous for project collaboration which eases the process of BIM implementation. However, majorities of the construction projects in Malaysia are still implementing traditional procurement, in-situ construction and conventional practice notably 2D CAD drawings and CAD measurement which were entirely adopted in the Malaysian construction industry. (Yan & Demain, 2008).

Generally, Industry culture change for the promotion of construction IT including BIM is necessary but AEC industry is hesitate to learn new concepts and technologies (Wong & Fan, 2013) (Gu and London, 2010) Organisations are reluctant or even incapable of forcing BIM use based on propriety software or standards. (Porwal & Hewage, 2013) Moreover, BIM constraints namely technical, process and policy constraints are identified in BIM implementation (Succar, 2010). In short, this novelty of the application of new technology tools is beset with barriers to supplant the public conventional working processes.

MAIN TEXT

In BIM implementation, the practice of quantity take-off under BIM platform comprises of four steps: BIM 3D model, quality verification, property verification and quantity take-off. Quantity Surveyors prepare cost estimation based on the quantities generated from the data-rich 3D model, but the estimation process is not entirely automatic. (Monteiro & Martins, 2013) Quantity Surveyors have to prepare an own method to apply the abstracted quantities into the current cost estimation format. Moreover, the accuracy of the abstracted quantities depends on the designers' 3D model and the major problem of not trusting the automatic quantities produced due to quality issues of the BIM model may be occurred. (Smith, 2014) Additionally, BIM requires the collaboration of other construction players such as architect and engineers in developing the data-rich 3D model. (Latiffi et al., 2015) The abstracted quantities from BIM model do not have sufficient data for Bill of Quantities and cost estimation preparation. Quantity Surveyors may encountered serious software interoperability problems in BIM. (Matipa, Kelliher and Keane, 2008) In short, Quantity Surveyors play a passive role in the conventional BIM implementation when BIM is becoming the mainstream in the construction industry. This signifies an alert signal for the quantity surveying profession in creating a new business strategy to keep the pace of other professionals in the construction industry to maintain the competitiveness.

In Malaysian quantity surveying profession, several quantity surveying firms are building 3D modelling for taking-off and cost estimation purposes, but the 3D model is not further enhanced to a data-rich model to obtain the benefits of BIM due to the limitation of costing software. Several quantity surveying firms have accepted that the improvement of the technology in building the 3D model in costing software managed to increase the efficiency of the working flow in the Quantity Surveying firm. In short, Quantity Surveyors should be able to take advantage of the changes in the construction industry which will flow from the increased use of this 3D model. Quantity surveyors can take the initiative in 3D modelling implementation by converting and enhancing the 3D model prepared for cost estimation purposes in designer BIM software and serve the 3D model as a speciality competency service for developers.

In the tender stage, quantity surveying firms have to be transformed in preparing the 3D model in costing 3D software for quantities abstraction purposes. During 3D modelling creation based on CAD drawings,

QS creates construction components in accordance with the Standard Method of Measurement 2 (SMM2) unit and requirement. Therefore, all quantities generated from 3D modelling can be used for Bill of Quantities preparation (4D) since SMM2 is commonly accepted by Malaysian construction industries. After the 3D model is developed in the quantity surveying 3D software, the 3D model can be converted into the OpenBIM (Ifc format) and then imported into the designer BIM software for further enhancement to develop a data-rich 3D model. Ifc format is selected in this conversion because it is a standard established by the BuildingSMART to allow for model exchange between various commercial BIM software vendors. (Hallberg & Tarandi, 2011)

Quantity surveyor manages to take the initiative in 3D modelling implementation to prepare the quantities take-off and 3D model, followed by the Ifc conversion and quality verification. However, Ifc conversion and quality verification are optional competencies for quantity surveying firms and quantity surveying firms may charge a separate professional fee for this new job scope. In short, this proposed concept extends the quantity surveyor's competencies which allows a quantity surveyor to take the lead in BIM implementation. Conversion and enhancement process from designer BIM software is relative common but 3D model conversion and enhancement from costing software are new competencies for quantity surveying firms which may allow quantity surveying firms to gain extra fee since this is not the routine quantity surveying work task and some developers are paying the BIM modeller a significant fee to develop a BIM model in the conventional BIM construction practice.

METHODOLOGY

This 3D modelling transformation and enhancement process have two stages: conversion and enhancement. Conversion refers to file format conversion from one software to another followed by scrutiny process notably property and quality verification to ensure the accuracy of the 3D model and to examine any data loss in the conversion process. Property verification involves the process of checking the number of building component while the quality verification focuses on to examine the accuracy of the 3D model. After the 3D model is converted and imported into the designer BIM software, a scrutiny process is required to examine the data loss of the 3D model conversion. A quantity surveyor is suggested to prepare a checklist for the 3D model scrutiny such as checking the number of building components notably columns, beams, slabs, doors, windows, finishes etc., followed by the scale of building components in the BIM software and components quantities etc.

Enhancement refers to the additional BIM components input, technical data as well as cost information. Some building components can be improved and added in the designer BIM software to enhance the model presentation and components details such as doors, windows, landscaping, road work and pavement, product details etc. Next, the specification of the building components, the brand of materials, and cost data for the building materials can be inserted into the 3D model components' properties in the BIM software to enhance the information of the 3D model to make it a BIM model.

An intermediate unit of terrace house is used as the case study for the designed 3D model transformation and enhancement based on the QS Lead BIM concept. A 3D model is created based on the Standard Method of Measurement 2 (SMM2) for the intermediate terrace house in software G. All quantities generated from the 3D modelling is abstracted. Next, the 3D model is exported to IFC file for the transformation process; then the file is imported into a designer BIM software for BIM data enhancement purposes.

ANALYSIS AND DISCUSSION

Table 1 Data lost in IFC file transformation – A case study.

	Column	Beam	Floor	Wall	Foundation	Finishes
Model Scale	Yes	Yes	Yes	Yes	Yes	N/A
Quantities Available	No	Yes	Yes	Yes	No	N/A
Unit	-	Volume	Perimeter, Area, Volume, Thickness	Length, Area, Volume	-	N/A
Identity / No	Yes	Yes	Yes	Yes	Yes	N/A
Level	Yes	Yes	Yes	Yes	Yes	N/A

The 3D model has successfully converted into designer BIM software, software R through an IFC file transformation process. Internal and external finishes of the building cannot be converted into the designer BIM software (software R) while columns, beams, floors, wall and foundation can be successfully converted with the correct scale and dimension.

The quantities of the 3D model do not exist in the column and foundation properties. This result is in correspondence with the findings of Ma et al. (2013) in which original geometric information would be lost. Beams, floors and walls quantities remain in the component properties which can be abstracted in the schedule and quantity report for bulk check purposes. Next, the IFC file is exported into a dwfx format from the designer BIM software (software R) for quantities abstraction purposes. Software C is used in this analysis to abstract the quantities from the BIM model. All the quantities for three different software are abstracted and listed in table 2.

Table 2 Quantities comparison before and after the IFC file transformation.

Elements	**Software G (Before)**	**(Software C) IfC (After)**	**Software R (After)**
Wall (m3)			
110mm thick brick wall with 20mm thick c/p [Exterior Wall]	428.40	542	542.43
110 thick brick wall with 20mm thick c/p [Interior Wall]	381.16	463	463.37
Box covered [Interior Wall]	9.57	10	10.10
900mm Low Wall [Exterior Wall]	18.35	20	19.89
Column (m3)			
Concrete	30.53	-	-
Beam (m3)			
Concrete	31.87	42	42.34
Floor (m3)			
S1	5.96	6	5.96
S2	58.51	59	58.84
S3	6.04	6	6.12
S2 Drop	0.58	1	0.62

All floor measurements abstracted from three software are apparently the same. Data loss for floor slab is not an issue in this IFC file transformation. However, internal walls, external walls and beam measurements abstracted from Software R and IFC are higher compared to software G. Apparently; different software has different deduction rules for quantity take-off. It should be noted that these deduction rules affect the quantity take-off results for cast in-site components because the structure model is built as a monolithic body which cannot be clearly divided into physically independent components. (Ma et al., 2013) Therefore, the measurement comparison is not a useful benchmark method for data lost scrutiny process.

Software R is a design software which is not purposely created for quantity take-off and measurement. Therefore, QS is suggested to prepare Bill of Quantities with the original quantities from the costing software. This case study shows that the quantities abstracted from software R and IFC are almost the same. The data lost is comparatively severe from Software G to IfC compared to the data lost from Ifc to Software R.

The overall conversion and enhancement process is summarised in Figure 1 which proposes QS to prepare a 3D model based on CAD drawings followed by abstracting the quantities for cost estimation purposes. Next, the conversion process takes place followed by a scrutiny process which includes property verification and quality verification. Last but not least, the 3D model enhancement process shall take place to enhance the BIM 3D model.

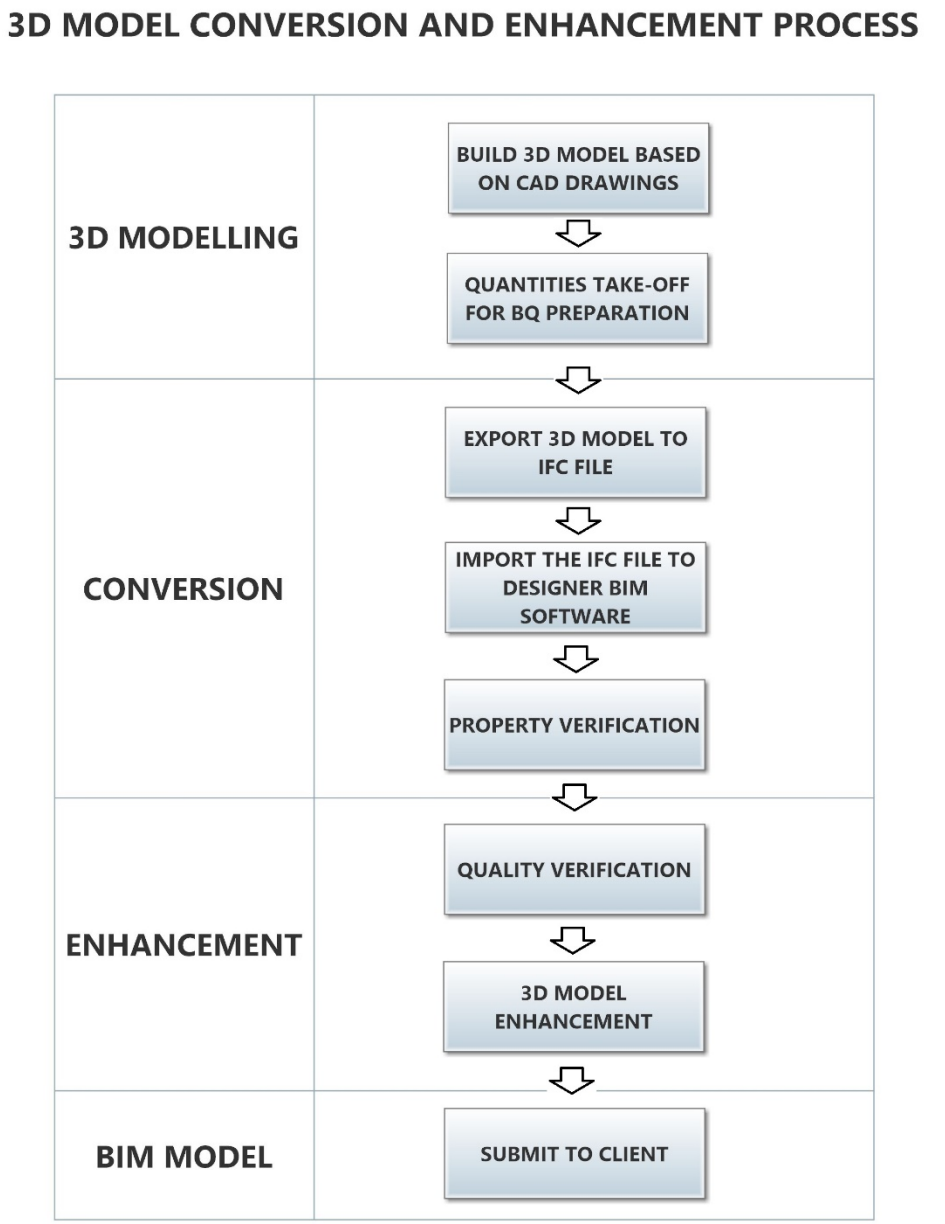

Figure 1 3D modelling conversion and enhancement process

CONCLUSION

For conventional BIM quantity take-off (QTO), the QTO process is comprised of four steps: BIM modelling, quality verification, property verification and quantity take-off. However, the proposed 3D modelling is implementing the reverse approach which comprised of five steps: quantity take-off, conversion, property verification, quality verification and BIM modelling. In the conventional BIM implementation, quantity surveyor has to prepare the quality verification and adjustment based on the standard method of measurement before the quantities take-off on the BIM designed by Architect and Engineers. In short, the implementation of conventional BIM is fully depending on construction designer' initiatives. In the proposed 3D modelling, QS manage to develop a 3D Model and lead in the BIM implementation. After the enhanced data-rich 3D model is developed, developer and contractors can utilised the data-rich 3D model

at the post-tender stages for scheduling, interim payment, finally account as well as management and maintenance purposes. Additionally, contractors can further enhance the data-rich 3D model in BIM software prepared by QS for as-built BIM in 6D BIM preparation. This new concept allows quantity surveying firms to enhance their competencies to gain extra incomes for their companies as well as diversifies the companies' business strategies.

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RELIABLE SUM INSURED: A PROPOSED COST MODEL

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Keywords: building cost modelling, insurance.

ABSTRACT

Building cost information is not readily available in the public domain in South Africa. Homeowners are either reliant on inaccurate and unreliable sources of information or are faced with the high cost of obtaining accurate, relevant and reliable cost information. This paper proposes a simple, yet effective cost model based on manipulated quantity surveying and statistical techniques to deliver improved replacement cost estimates for insurance purposes.

Quantitative data is generated and analysed statistically to illustrate the integrity of the data and thereafter the proposed model is applied to demonstrate the ease of its use and the simplicity of the results presentation. The findings suggest that the proposed cost model is fit for purpose and can produce fairly accurate estimated replacement costs based on the input of the limited variables.

The study informs residential property owners and insurance industry role-players alike of an improved estimating method that would place residential property owners and insurance industry role-players in a much-improved situation when insurance claims occur and lessen the potential financial damage to be suffered.

INTRODUCTION

Building cost research has been undertaken on a relatively small scale over the past 60 years. The research is predominantly undertaken by large quantity surveying practices to serve the practice's own needs for diversification, enhanced service delivery and increased competitive edge. Although this research leads to more effective, efficient and economic ways of achieving the same objectives and leads to the development of improved work practices more in-depth research of various aspects that contribute to the understanding of the behaviour of building costs is required (Ashworth and Perera, 2015).

Estimating and cost planning models adopted in practice are aligned to the design development stages. The accepted and practiced models include bills of quantities, elemental estimates, space estimates and unit estimates spanning the design development from the latest to the earliest design stage (Jaggar et al, 2002; Kirkham, 2007). The development of technology resulted in two approaches. Firstly, the traditional methods were computerised, and thus time-consuming functions where eliminated while estimating accuracy was improved. The second approach was based on statistical and mathematical techniques so radically different to the traditional methods that these were not adopted by practice. The latest trends in cost modelling have focused on improving cost advice at the early stage of design development as the decision-making at this stage has the most impact on the project cost.

All cost modelling requires accurate and reliable data. According to Ashworth and Perera (2015) the sizes of construction industry enterprises in the United Kingdom (UK) expressed in terms of number of employees constitutes 93% micro (maximum 13 employees), 5.5% small (14 to 59 employees), 0.83% medium (60 to 299 employees) and 0.14% large (more than 300 employees). This is a clear indication that the enterprises do not have the capacity or the necessary available data to build comprehensive cost models. Although no comparable studies could be found for construction industry

enterprises in South Africa the similarities in the general development processes in the UK and South Africa would suggest that a similar situation prevails in South Africa. With the bulk of South African enterprises also resort in the micro and small categories as defined above they also do not have the capacity and resources to develop comprehensive and satisfactory databases.

INSURANCE

Inadequate short-term building insurance, referred to as underinsurance or a protection gap, is a global phenomenon. Although the terms underinsurance and protection gap are often used as synonyms, there is a distinct difference. Underinsurance refers to the balance between the economically viable value of the property and the actual value of insurance purchased that is indicative of an intentional choice whereas the protection gap refers to the difference between the economic loss and the insured loss that is not due to an intentional choice but rather due to undervaluation resulting from a lack of information and awareness of aspects that influence the sum insured (Swiss Re, 5/2015).

The Prospect Theory that focuses on the change in wealth is based on three important principles namely that (i) the evaluation of financial outcomes need to be measured in relation to a neutral reference point (ii) diminishing sensitivities exist in evaluating the change in wealth and (iii) loss aversion is determined by a larger response to losses than to gains (Kahneman, 2011).

This theory is particularly important in relation to insurance because firstly the principle of indemnity for building insurance stipulates that an insurer will pay only the actual amount of a loss, thus returning the insured to the same position as before the loss (Rejda et al., 2014, Vaughan et al., 2014), secondly that the protection of wealth at the lower end of the insurance market is more vital than the protection of wealth at the higher end of the insurance market and thirdly loss aversion kicks in when the available outcomes are all bad. Any non-routine event that causes damage to a building has costly consequences, therefore all are bad. In the South African context, the majority of first-time homeowners entering the market, are at the lower end of the wealth chain therefore it is crucial that they be provided with sufficient information to protect their properties and their emerging wealth.

Where an insurance protection gap exists the principle of indemnity, capped by the insured amount, requires that the loss amount be pro-rated in the same ratio as the insured amount to the actual replacement cost. The calculation of the premium for insurance cover is based on the sum insured. The inclusion of an average clause in insurance policies is thus intended to discourage under-insurance. The proof that under-insurance exists vests with the insurer. Proof must be produced before the average clause can be applied (Reinecke et al., 2013).

Due to the ease of using space (R/m2) estimates it is commonplace that this method is frequently used in determining sums insured. The complication arises due to the reliability and accuracy of the rate applied. In the hierarchy of the cost estimating method versus the design development stage, the result of an R/m2 estimate is regarded as indicative for high level decision-making only and is thus fairly inaccurate. The use of this method for determining a sum insured is thus unsuitable seeing that no further design development is required.

COST MODELLING

The objectives of any cost model are to (1) create economic assurance for the client; (2) allow for a quick cost representation of a building in such a way that the cost can be analysed and tested; (3)

create a system to advise on design development decisions and (4) to create a link between cost control of the design and actual costs generated on site (Kirkham, 2007).

Cost models must be supported by updatable cost data and the cost data detail must be commensurate with the design detail. There is no purpose in attempting to generate detailed cost information based on scant design information. Although several design cost parameters are well known, no research has been done to establish the degree to which changes in parameters would influence the costs. The known design cost parameters are the building size, plan efficiency, shape, height, construction details and structural design (Kirkham, 2007; Ashworth and Perera, 2015).

Many researchers have debated the merits and demerits of product-based cost modelling and process-based cost modelling. The advocators of process-based cost modelling opine that product-based cost modelling is not founded in construction production criteria that generate the costs (Morton and Jaggar, 1995); does not represent the explicit relationship between design decisions and construction processes and fails to consider the uncertainties of the construction process (Bowen, 1993); that cost data is taken from previous projects, price books, etc. that do not represent real costs (Morton and Jaggar, 1995) and that the cost data is often manipulated by spreading the costs over unit rates and/or elemental costs (Newton, 1989).

Studies conducted in England by Fortune and Hinks (1998) and in South Africa by Bowen and Edwards (1998) indicated that the traditional product-based cost modelling techniques are by far the preferred techniques used by consulting quantity surveyors and that there was very low interest in resource-based cost modelling. Reasons cited for the unfavourable view of resource-based cost modelling is that the data is not available, the lack of understanding of the construction process, that the process is time consuming and that cost information can only be produced at a late stage in the development process (Lawther and Edwards, 2004; Ashworth and Perera, 2015). Regardless of the valid reasons why resource-based cost modelling should be more accurate than product-based cost modelling, there is no literary proof of any such cost modelling in practice (Lawther and Edwards, 2004).

Lawther and Edwards (2004) suggest that the traditional procurement method of splitting the design development process from the price determination process is the main cause for the lack of understanding of the construction process and purport that non-traditional procurement methods where the contractor is involved in the design development process may lead to increased forecasting accuracy.

Standard systems of measuring building work such as the RICS (Royal Institution of Charted Surveyors) New Rules of Measurement (2nd edition, 2012) and the ASAQS (Association of South African Quantity Surveyors) Standard Systems of Measuring Building Work (7th edition, 2015) are industrywide recognised systems upon which price determination documentation is prepared. These documents tie in with the latest strive for global consistency in presenting construction costs as driven by the International Construction Measurement Standards Coalition. Indication is therefore that the product-based cost modelling will remain entrenched for year to come. It is the author's contention that the procurement method should not necessarily influence the price determination method.

EXISTING COST MODELS FOR INSURANCE PURPOSES

Several cost models exist specifically for insurance purposes. Two of the prominent existing models are the BCIS (Building Cost Information Service) Rebuild Online used in the UK and the Cordell Sum Sure of the Cordell Information (Pty) Ltd. used in Australia and New Zealand. Both these cost models are marketed as products that help insurers and homeowners to tackle the sum insured challenge.

The BCIS Rebuild Online is based on a questionnaire that contains 13 questions that pertain to houses and bungalows, 11 questions that pertain to purpose-built flats and 11 questions that pertain to conversion flats. External works is specifically excluded from the model. The model output is in the form of an elemental estimate in accordance with the International Cost Measurement Standards (ICMS) cost classification system. The Cordell Sum Sure is also based on a questionnaire that contains 65 questions in total with 21 questions that pertain to items of external works. The model output is a confirmation of the electives and a single sum for the replacement cost (Cordell Information Systems, n.d.).

The questions included in the questionnaires clearly intend to address the design cost parameters referred to above such as, the number of bedrooms and bathrooms, type of walls and roof covering, etc.

USE OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN COST MODELLING

Several studies have been conducted on the use of different ICT techniques in cost modelling to improve the accuracy of early stage estimating. The techniques applied included multiple linear analysis (MLA), artificial neural networks (ANN) complemented by genetic algorithms and case-based reasoning (CBR).

Regressions analysis, a statistical technique that analyses historical data in a structured manor and identifies the mathematical relationship between the major construction components or variables, were already employed by Flanagan and Norman in 1978. ANN, that appeared in the 1990's, are computer systems that simulate the learning process of the human brain. The networks are set up for a specific set of inputs, similar to variables for regression models. The hidden layers and hidden neurons need to be set based on the number of inputs and outputs. Although ANN's proved to deliver accurate estimates their time-consuming learning curve negate the slightly improves accuracy and the models cannot be readily updated (Kim et al., 2004; Ahn et al. 2017; Bilal et al., 2016; Jin et al., 2012; Zima, 2015).

Much emphasis has been placed on CBR models lately due to the ease of its application and the clarity to explain the model (Kim et al., 2004). CBR is described by Riesbeck and Schnak (1989) as the process of solving recent problems by adapting solutions that were used to solve old problems. The process is based on the four activities of retrieving existing cases that closely resembles the test cases to be resolved, re-using the existing cases in their existing format, revising or adapting the existing cases through heuristic and/or human intervention to suite the test cases and if the solution to the test cases are regarded as suitable they are retained in the database for application to future cases (Perera and Watson, 1998; Jin et al., 2012).

The most important aspect about CBR is measuring the distances between cases as this is hidden information that has a considerable influence on the accuracy of the cost estimation. An attribute that has a higher weighting could unduly influence the estimate. The most common distance measure is the Euclidean distance that is measured by the square root of the sum of the sums of the of dimension differences between an existing case and a current case. By measuring the distances, the nearest neighbours to the test cases are determined to illustrate the similarities between existing cases and the test cases (Zima, 2015; Ahn et al., 2017).

Attributes can be determined in diverse ways. In previous studies Kim and Kang (2004) adopted attributes from another study, An and Kang (2005) conducted interviews with experts to obtain their attributes, Koo et al (2010) used attributes with the highest frequency from previous studies and Jin et al (2012) based the selection of their attributes on three aspects namely the deliverables in the

project initial stage, the MRA screening and attributes not included in the MRA were included in the CBR.

PROPOSED COST MODELS FOR INSURANCE PURPOSES

Methodology

The proposed cost model is based on a CBR model. The database to be used for the measurement of similarities has been populated with possible comparable cases of residential buildings. The data is prepared based on elemental estimates with the elements prepared in accordance with the (ICMS) cost classification system. Eight elements (variables) are chosen for input into the model. The elements are ground floor construction; external envelope; roof; internal divisions; furniture, fixtures and equipment, services (plumbing) and services (electrical).

The database used in this study contains a total of 20 cases with 15 are set up as training cases and 5 are set up as test cases. The 15 training cases are all assessed for similarity between their different attributes and the machine learning emanating from this process is applied to estimate the replacement costs for the 5 test cases. The intention it to identify the existing cases that are most similar to the test cases. The elements in each case are weighted according to their contribution to the total replacement cost. The attributes for use in the MRA and CBR in this study are determined by measurable design cost parameters and the MRA screening thereof.

The cases included in the database are as follows:

Table 1: Existing cases (Estimates replacement cost)

Cases	Replacement cost	Ground floor construct	External Envelope	Roof	Internal Divisions	Furniture, Fittings & Equipment	Services (Plumb)	Services (Elec & Mech)
1	R 280 992	R 566 816	R 81 542	R 49 079	R 36 335	R 1 654	R 34 311	R 25 238
2	R 295 200	R 487 373	R 88 618	R 56 546	R 37 782	R 1 650	R 34 629	R 24 791
3	R 320 600	R 228 474	R 93 650	R 61 559	R 37 889	R 1 650	R 46 748	R 25 053
4	R 337 400	R 535 524	R 105 368	R 62 739	R 38 130	R 1 650	R 47 142	R 25 062
5	R 374 000	R 503 466	R 112 232	R 75 329	R 41 767	R 1 649	R 60 727	R 25 897
6	R 413 200	R 66 075	R 119 365	R 91 215	R 47 695	R 1 657	R 61 151	R 26 041
7	R 1 525 000	R 327 777	R 458 028	R 223 794	R 121 192	R 203 947	R 96 003	R 94 261
8	R 938 000	R 219 616	R 204 200	R 130 284	R 108 093	R 92 533	R 75 677	R 107 597
9	R 968 000	R 232 314	R 282 504	R 179 573	R 80 674	R 62 159	R 50 904	R 79 871
10	R 1 294 000	R 295 262	R 281 033	R 270 751	R 126 973	R 83 822	R 82 115	R 154 043
11	R 1 901 000	R 308 697	R 444 918	R 369 081	R 219 489	R 174 980	R 147 935	R 235 900
12	R 2 465 000	R 566 816	R 443 434	R 422 957	R 368 402	R 233 902	R 176 883	R 252 606
13	R 2 270 000	R 487 373	R 438 422	R 425 021	R 283 678	R 176 100	R 126 772	R 332 635

14	R 1 116 000	R 228 474	R 180 266	R 186 877	R 159 011	R 105 841	R 120 039	R 135 492
15	R 2 665 000	R 535 524	R 402 363	R 602 429	R 314 452	R 168 549	R 229 536	R 412 146
16	R 1 990 000	R 503 466	R 233 026	R 337 008	R 235 979	R 246 018	R 147 223	R 287 279
17	R 940 000	R 206 575	R 168 069	R 157 020	R 88 566	R 90 830	R 111 907	R 117 033
18	R 715 200	R 138 854	R 149 308	R 180 195	R 110 467	R 51 738	R 32 904	R 51 738
19	R 1 772 500	R 343 780	R 380 562	R 364 004	R 268 268	R 174 135	R 147 902	R 94 659
20	R 1 435 000	R 251 765	R 242 022	R 362 459	R 165 511	R 200 956	R 91 474	R 120 813

The process of developing a CBR model that is revised by applying an MRA, needs to follow the steps as discussed below:

- The case database needs to be set by collecting the existing cases as illustrated in table 1.

- The attribute weights as determined by applying the MRA and are produced in the form of the standard coefficients (β) as displayed in table 2. The attributes used in this study attempt to address the horizontal as well as vertical design components. The attributes used are ground floor area, roof covering area, area of external envelope, area of doors and windows, internal divisions and furniture, fixtures and equipment.

- Determining the similar cases is done by calculating the attribute similarities and ultimately the case similarities. The numeral data is normalized by determining the return of the value for each attribute less the minimum value for each attribute divided by the difference between the maximum and minimum attribute value for each attribute. The normalization process converts the numeral data into weighted values between 0 and 1. The rule of thumb for determining the number of test cases to perform, is determining the square root of the number of observations. This study exists of 20 observations therefore there are 5 test cases.

- The revision process is based on the accuracy of the case similarity. The closer the case similarity is to 1 for each attribute the more accurate the replacement cost estimate of the test case will be. This also infers that the further the retrieved cases' attributes are from the test cases' attributes the less accurate the estimated replacement costs would be. Due to the limited amount of cases in the case database of this study the distances between the variables are longer than they would be if the database contained considerably more cases.

The similarity measure for this study is based on the weighted Euclidean distance which is the most commonly used distance measure.

The IBM SPSS Statistical software was used to conduct the MRA and to determine the attribute weightings as displayed in Table 2 below.

The unstandardized coefficients (β) are used to predict the replacement costs of the test cases while the standardized coefficients (Beta) indicate the weighting of the attributes. The standardised attributes are used in the revised CBR model.

The high t-values indicate the variances between the predictors and the mean. The wide confidence intervals suggest less accurate estimates. Apart from the predictor for the external envelope, all the confidence intervals contain zero which is an indication that there is not sufficient evidence to conclude that the predictors would deliver an accurate estimated replacement cost. The estimated replacement costs are calculated by multiplying the ß coefficient by the predictors of test cases as demonstrated in table 3. The wide confidence intervals are once more as a result of the limited database.

Table 2: Coefficients [a] (attribute weighting)

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for ß		Collinearity Statistics	
	ß	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	-51930.338	64 249.44		-0.808	0.442	-200089.8	96229.132		
Construction area	3174.295	2 099.93	0.685	1.512	0.169	-1668.152	8016.742	0.004	225.133
Roof area	-567.724	1 537.85	-0.17	-0.369	0.722	-4114.013	2978.565	0.004	232.516
External envelope	1832.285	492.32	0.297	3.722	0.006	696.991	2967.58	0.143	6.972
Windows and doors	1729.452	2 396.99	0.056	0.722	0.491	-3798.021	7256.925	0.154	6.501
Internal divisions	2740.081	1 522.24	0.186	1.800	0.110	-770.208	6250.371	0.085	11.72
Furniture, fixtures and equipment	-509.039	3 900.91	-0.012	-0.130	0.899	-9504.541	8486.463	0.112	8.908

[a] Dependable variable: Replacement cost

The unstandardized coefficients are used to develop the estimates for the six test cases

Table 3: Estimated replacement costs based on an MRA

Predictors	**ß**	**Test cases**											
		1	**R c**	**2**	**R c**	**3**	**R c**	**4**	**R c**	**5**	**R c**	**6**	**R c**
Construction area	3174.295	360	1 142 746	56	177 761	140	444 401	152	482 493	340	1 079 260	283	898 325
Roof area	1832.285	290	531 363	74	135 589	179	327 979	166	304 159	386	707 262	236	432 419
External envelope	-567.724	409	- 232 199	68	- 38 605	186	-105 597	217	-123 196	452	- 256 611	462	- 262 288
Doors and Windows	2740.081	87	238 387	19	52 062	43	117 823	42	115 083	162	443 893	71	194 546
Internal divisions	-509.039	68	- 34 615	2	- 916	17	- 8 654	15	- 7 636	48	- 24 434	37	- 18 834
Furniture, fixtures and equipment	1729.452	27	46 695	10	17 295	27	46 695	21	36 318	71	122 791	36	62 260
Constant	-51930.338		- 51 930		- 51 930		- 51 930		- 51 930		- 51 930		- 51 930
Replacement costs			1 640 447		291 254		770 718		755 292		2 020 231		1 254 497

The output of the MRA reveals an adjusted R^2 of 0.987 and relatively small standard error which are indications that the cost model is fit for the purpose. The high F-value however indicates a large variability in the between-group and with-in group ratios of the predictors. Once again as a result of the limited database.

Table 4: MRA output

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.996[a]	0.993	0.987	95 749.18	0.993	181.589	6	8	0.000

The high variance inflation factor (VIF) as shown in table 2 is indicative of the existence of high multi-collinearity. This is not entirely unexpected as it is common cause that the construction area and roof area would be closely related to each other and both have a considerable influence on the prediction of the replacement cost. It would however be wise to standardise the contentious predictors as the multi-collinearity could influence the calculation of the coefficients. Table 5 below displays the correlations between the independent variables (or predictors). Rethinking the predictors could also possibly improve the model. The high VIF and future corrective measures will merely enhance the stability of the model but do not influence the good fit of the model. Should the standardization not address the VIF by reducing it to an acceptable level of less than 5 a high VIF could be accepted.

Table 5: Correlations

	Replacement Cost	Construction area	Roof area	External envelope	Windows and doors	Internal divisions	Furniture, fixtures and equipment
V10	.977	1.000	.995	.839	.910	.924	.858
V14	.976	.995	1.000	.840	.907	.937	.831
V16	.921	.839	.840	1.000	.737	.869	.858
V18	.893	.910	.907	.737	1.000	.857	.802
V21	.955	.924	.937	.869	.857	1.000	.798
V25	.882	.858	.831	.858	.802	.798	1.000

Results

The revised replacement cost has been calculated and a comparison has been done between the calculations based on the non-revised CBR model and revised CBR model to verify the prediction performance of the study conducted.

The results for the predicted replacement cost estimates for the non-revised CBR model, revised CBR and the error rate are summarised in table 6 below. As shown in table 6 the average error rate for the non-revised CBR estimating model and the revised CBR estimating model are 5.1% and 13.5% respectively. Usually the revised estimating CBR model produces a reduced error rate. In this study the error rate increased by 8.4% on average.

As all the other indicators have suggested that the model is unstable due to the limited case database, the potential of the model becoming successful with improved data is evident in the error rates that range from 5.59% to 18.01%. The error rate and the similarity are closely related thus the higher the similarity the lower the error rate will be. It is generally accepted that the more cases there are in the

database the higher the probability of a higher similarity. It is thus crucial that the database needs to be populated with many more similar cases.

Table 6 Results of the non-revised and revised CBR models.

No	Test case	Prediction results by non-revised CBR model	Error rate	Prediction results by revised CBR model	Error rate
	Construction cost (a)	Construction cost (b)	%	Construction cost (c)	%
1	R 1 990 000	R 2 079 700	4.51	R 1 640 447	17.57
2	R 940 000	R 935 440	0.49	R 770 718	18.01
3	R 715 200	R 676 080	5.79	R 755 200	5.59
4	R 1 772 500	R 1 585 500	10.55	R 2 020 231	13.89
5	R 1 435 000	R 1 503 700	4.79	R 1 254 498	12.58
	Average		5.1		13.5
	Difference				8.4

DISCUSSION

The study is based on a small but diverse sample of existing cases and test cases. The weightings of the attributes used for estimating the test cases were determined by an MRA and served as the revision function in the CBR estimating model. The error rates obtained for the five test cases varied considerably from each other although the potential of obtaining accurate replacement cost estimates by applying the demonstrated CBR estimating model is clear.

It is generally accepted that the accuracy of the MRA weighting coefficients will become more accurate as the number of cases in the database increase. It is thus crucial that the database be enhances with many more additional and also similar cases.

The format of the actual output of the CBR model for use by loss adjusters, insurers, homeowners, etc. is not included in this paper. However, the intention is that the output resembles the elemental estimates that the database is populated on with indicative weighting that can be used in the event of insurance claims. Little information and assistance is offered to insureds when purchasing insurance policies, but when perils realise the insurers employ a whole host of role-players to scrutinise the event. Professional quantity surveyors are employed to fulfil a twofold exercise. Firstly, to test the sum insured and secondly to determine the value of the damage. The imbalance in the information and resources available during claims compounds the public perception of not being treated fairly by the insurance company. The settlement of a claim is further detrimentally impacted when insured realise the compounded financial loss due to underinsurance.

CONCLUSIONS

The aim of this study was to demonstrate improved replacement cost estimating through a CBR-based cost model. Quantity surveyors is general are familiar with the elemental estimating technique employed to populate the database cases as well as the MRA technique applied in the revision phase of the CBR model. The familiarity with the above-mentioned techniques, the relative simple application of the of the model, the easy of explained the application of the model as well as the positive results delivered by the proposed model should encourage South African quantity surveyors to embark on similar research for applications other than for insurance purposes.

The similarities utilized in this study and the error rates calculated are relative to the database cases that are already fairly accurate models as the data is based on bills of quantities converted to elemental estimates. It is significant that the non-revised CBR estimating model and the revised CBR estimating model fall within 5.1% and 13.5% accuracy respectively of the existing replacement cost estimates. Bearing in mind that the R/m2 estimating method, that is much less accurate than the elemental estimating method, is the most commonly applied method for determining sums insured. Information is frequently also obtained from sources not knowledgeable about building costs in general, simply because homeowners are wary about the cost of obtaining accurate replacement cost estimates. This model could be equally informative to loss adjusters, brokers, insurers and the like that also have limited knowledge of building costs.

For the model to achieve higher accuracy and reliability, the database needs to be populated extensively. Further research is needed to analyse the larger database to verify whether improved results are derived.

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RISK RESPONSIVE STRATEGIES FOR ADAPTIVE REUSE OF HISTORIC BUILDINGS: A CASE OF SRI LANKA

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ABSTRACT
There is a developing acceptance that historic buildings are important as a symbol in any society and heritage conservation which enhances the economic, cultural and social values. The concept of adaptive reuse is the best powerful strategy available for such historical buildings to survive while preserving of the cultural values. However, the concept is not much appropriately established, where the associated risks have hindered its implementation. At present, in Sri Lankan context as the case study considered, there is no proper risk management procedure espoused for adaptive reuse of buildings. Hence, the first step was taken to evaluate the risks associated to adaptive reuse of historic buildings and to provide better risk responsive strategies for the historic buildings in Sri Lanka. The research was directed under quantitative phenomenon as it focused a comprehensive risk evaluation. The 32 risk factors were encountered through literature review. The questionnaire survey was conducted among 24 industry professionals who had more than five years of experience with adaptive reuse of historic buildings in Sri Lanka, such as architects, engineers and facilities managers, to evaluate the identified risk factors. The each risk factor was analysed by using descriptive data analysis techniques and the risk rating matrix. As key findings derived, low, medium, high and extreme risk factors were determined. Among the other risk factors, design complexity, conservation guidelines, high maintenance cost, unexpected costs, planning constraints and lack of expertise and man power were identified as the most significant risk factors associated to the adaptive reuse of historic buildings in Sri Lanka. Finally, the risk responsive strategies were proposed as the main implication of this research, which may direct the risk management of adaptive reuse of historic buildings in Sri Lanka.

Keywords: adaptive reuse, historic buildings, risk management, risk responsive strategies.

INTRODUCTION
The preservation of historical buildings in developed countries has been very common, well carried out, and accumulated a wealth of experience (Hegazy, 2015). There is a rising perception that it is economical to convert old buildings to new uses (adaptive reuse) than to demolish and rebuild in both developed and developing nations (Ball, 2002; Department of the Environment and Heritage, 2004). Nevertheless, adaptive reuse is an upcoming trend in construction industry (Nabris, 2012). Adaptive reuse is an integral strategy to increase the financial, environmental and social performance of buildings (Langston et al., 2008). Therefore, the adaption of an existing building can make a significant contribution to the sustainability (Bromley et al., 2005; Cooper, 2001; Kurul, 2007). Generally many contractors are unwilling to renovate old buildings, since the risks and challenges associated to renovations can decrease the expected profit margins. This is regularly an outcome of additional risks of reuse together with unknown work, scope changes, compatibility of materials, quality of information and the operating environment, health and safety, design restrictions and decanting of occupants (Reyers and Mansfield, 2001). Additionally, the unsuitability and un-sustainability of the old buildings is the biggest barrier for adaptive reuse (Madanayake and Manewa, 2014). Bullen and Love (2011) identified some other factors influencing adaptive reuse of buildings such as, cultural and heritage significance, building life cycle, legal regulations, availability of the technology, professional involvement and existing condition of the building. Similarly, Nabris (2012) identified major factors influencing adaptive reuse of buildings such as, physical factors, economic factors, functional factors, technological factors, social factors, regulatory factors and environmental factors. These factors can increase the risks associated to adaptive reuse and thus, there should be a better risk management which minimise the consequences of risks to lowest level (Leaman, 1987). In line of thinking, the purpose of this research is to evaluate the risks associated adaptive reuse of historic buildings in order to propose a suitable risk response. Hence, the

objectives of this study are to (1) Identify the risks associated adaptive reuse of historic buildings; (2) analyse the criticality of each risk factor; and (2) propose risk responsive strategies for adaptive reuse of historic buildings. However, the study was limited to the adaptive reuse of historic buildings in Sri Lanka; thus, the findings presented subsequently can be generalised to the aforesaid with confidence.

LITERATURE REVIEW

Adaptive reuse of historic buildings

Heritage buildings are symbol of cultural values and, their conservation can affect on well-being of the community (Bullen and Love, 2011b). Similarly, Feilden (as cited in Tam et al., 2016) mentioned that historic buildings have architectural, aesthetic, historic, archaeological, economic, social and political values and they provide symbol for our cultural identity and continuity as a part of our heritage. Moreover, it is important to preserve those buildings and maintain the heritage and cultural values (Langston, 2012). The conservation of the architectural value may increase the level of significance and construction matching local landscape characteristics (Wang and Zeng, 2010). Withal, most of the old buildings require some amount of adaptation and renovation before return to its functional viability while adding a new significance for history (Bond, 2011). Yang and Chang (2012) point out that adaptive reuse can incorporate with the heritage buildings and can change the function for some socially useful purpose, find an effective approach for self-financing and form sustainable conservation. According to the Bond (2011), adaptive reuse is the most creative and constructive option for the historic buildings. Furthermore, Feilden (as cited in Sfakianaki and Moutsatsou, 2015) mentioned that, adaptive reuse may the only way to save in an economic manner historic, to keep it in use, aesthetical values and to save the significance standards of historic buildings. However, regular care and maintenance is required to ensure the preservation adaptive reuse of historic buildings (Plevoets and Van Cleempoel, 2011). Nevertheless, adaptive reuse is an upcoming trend in Sri Lankan construction industry (Nabris, 2012). In Sri Lankan context, Independence Square, Race-course Sport Complex and Dutch Hospital are some of examples for adaptive reuse of historic buildings in Sri Lanka (Abeywickrema, 2012).

Risk management for adaptive reuse

The complexities of adaptive reuse and risks may be too high for most of the clients (Langston, 2010). However, risk is an inherent factor and difficult to deal with, since it is require a proper management both theoretical and practical (Wang et al., 2004). Further, Department for Communities and Social Inclusion (2016) mentioned that a good risk management practice ensures the benefits and minimizes the negative effects of uncertainty on organizational activities. Besides, through risk management preparation organization can reduce the impact of the consequences of risks, while improving operational efficiency (Risk and Compliance Office, 2014). The most of significance outcome considerations of adaptive reuse buildings are easy accessibility to the disabilities and elders, safe and healthy built environment, convenience of building location and ability of the building to adapt future changes (Bullen and Love, 2011). Since, adaptive reuse requires the involvement and expertise knowledge of wide range of participants and stakeholders throughout the adaptive reuse design, construction, completion and use, to manage the risks of the process and to get expected outcomes (Bond, 2011). Therefore, Wilkinson et al. (2014) stated that designers of the adaptive reuse buildings should have proper understand about the long term impacts of their decisions. Similarly, Langston et al. (2008) pointed out that it is important to have good understanding about potential values and risks of adaptive reuse intervention to the stakeholders of adaptive reuse of buildings. Addition to, Remoy and van der Voordt (2014) stated that the persons who involves to the process of adaptive reuse should have good knowledge on opportunities and risk factors of building conservation and adaptive reuse. Indeed, the risk and opportunity management improve the effectiveness of an organization (Olsson, 2008) and it is beneficial to have a proper risk management procedure for adaptive reuse of buildings. The process of risk management consists of several stages. According to a study by Fan et al. (2017), the main steps of the risk management process include risk identification, risk analysis, risk assessment and risk control. Hence, the steps of risk identification, risk analysis, risk assessment and risk control were considered in this study.

Risks associated to adaptive reuse of historic buildings

Risk identification is the first step of risk management process. There are several categories of risk factors related to adaptive reuse. The risks associated to adaptive reuse were identified from the literature review. Consequently, twenty four (24) risk factors were encountered by reviewing 10 key research works of literature (Table 1).

Table 1 Risk factors associated to adaptive reuse.

Category	Risk factors	Source of reference									
		1	2	3	4	5	6	7	8	9	10
Physical risk	Structural integrity	√	√	√			√		√	√	√
	Material durability issues	√		√							
	Maintainability issues	√							√		
	Design complexity	√	√				√	√	√	√	
Legal risk	Building codes and practices	√	√		√	√			√		
	Fire protection implementing issues	√		√					√		√
	Disability access implementing issues	√	√	√							
	Conservation guidelines		√	√							
	Occupational health and safety issues				√				√		
Economic risk	High maintenance cost	√									
	Unexpected costs		√	√	√	√	√		√		
	Market complexity		√	√	√	√		√	√		
Functional risk	Planning constraints			√	√	√	√		√		
	Inflexibility	√	√		√	√	√				
	Inconvertibility	√									
	Insufficient workforce					√				√	
Technical risk	Insulation and acoustic issues	√			√					√	
	Indoor environmental quality issues	√		√		√					
	Natural light and ventilation issues			√	√					√	√
	Low quality technologies							√		√	
Social risk	Less awareness on adaptive reuse							√			
	Social reluctance to change building use	√			√			√	√		
	Use historic value for business purpose					√		√	√		√
	Absence of transport and accessibility	√								√	

[**Source: 1-(**Wilkinson et al., 2014); **2-(**Shipley et al., 2006); **3-(**Bullen and Love, 2011b); **4-(**Langston, 2010); **5-(**Remoy and van der Voordt, 2014); **6-(**Eyuce and Eyuce, 2010); **7-(**Shen and Langston, 2010), **8-(**Bullen and Love, 2011a), **9-(**Finch and Kurul, 2007); **10-(**Bond, 2011)]

According to the key literature reviewed physical risk category includes structural integrity, material durability issues, maintainability issues and design complexity while, building codes and practices, fire protection implementation issues, disability access implementing issues, conservation guidelines and occupational health and safety issues are the legal risk factors associated to adaptive reuse of historic buildings. Economic risk category includes, high maintenance cost, unexpected costs and market complexity risk factors and functional risk category includes, planning constraints, inflexibility, inconvertibility and insufficient work force as risk factors. Further, insulation and acoustic issues, indoor environmental quality issues, natural and ventilation issues and low quality technologies are the technical risk factors while, social risk factors are less awareness on adaptive reuse, social reluctance to change building use, use of historic value for business purpose and absence of transport and accessibility.

Additional eight (08) factors, such as design changes, design errors requirement of approvals, higher opportunity cost, not meeting benefits of adaptive reuse, productivity risk, unable to achieve expected performance and material supply and availability risk, were encountered through the preliminary survey of adaptive reuse of historic building projects in Sri Lanka. Aforementioned 32 risk factors were used to assess the risks associated to adaptive reuse of historic building projects in Sri Lanka. The methodology adopted is described in section 3.

RESEARCH METHODOLOGY

This research is carried out under quantitative research approach as aim of this research is to evaluate the risks associated to adaptive reuse of buildings in order to develop a risk responsive framework for adaptive reuse of historic buildings in Sri Lanka. Literature review, preliminary survey and main questionnaire survey were carried out to collect the data. Before conducting the main questionnaire survey, a preliminary survey was carried out to validate the risk factors which were identified through literature review and to get a supplementary for literature findings relating to the Sri Lankan context. It was carried out among five (05) industry professionals who have passionately and actively involved in adaptive reuse of historic buildings in Sri Lanka with more than 10 years of professional experience. The main questionnaire was distributed among 35 respondents who have industry experience more than 10 years, by considering time constraints. Hence, the sample consists of thirty five (35) respondents, including architects, engineers and facilities managers who have involved in adaptive reuse of historic building projects in Sri Lanka. Out of 35 distributed questionnaires, twenty four (24) questionnaires were returned. It represented approximately 70% response rate to the overall distribution. 70% response rate includes eighteen (18) architects, three (3) facilities managers and three (3) engineers. Collected data were analysed using the descriptive analysis and risk rating matrix since risk matrix is the most commonly used risk analysis tool as mentioned by Berg (2010). The mode value of each risk factor is then counted in analysis. The risk matrix was used to rank the risk factors by using 4x4 or 5x5 matrices having event consequences along the other axis.

The data analysis and key research findings are presented in section 4.

RESULTS AND DISCUSSION

The analysis and key findings are derived in two sub sections, namely, risk evaluation and risk rating matrix of adaptive reuse of historic buildings in Sri Lanka.

Risk analysis

The risk associated to adaptive reuse of historic buildings in Sri Lanka was evaluated under six main risk categories of physical, legal, economic, functional, technical and social. For the easiness of data analysis, each

risk factor was identified by a reference code. While the probability and impact of each risk factor are calculated by using mode value in statistical data analysis. The risk score indicates the severity of impact of each risk factor (Refer Table 2). Risk score of each risk factor calculated by multiplying the probability and impact of each risk factor.

Table 2 Risk score calculation.

Category	Risk factor		Probability	Impact	Risk score
Physical Risk	A1	Structural integrity	1	3	3
	A2	Material durability issues	3	4	12
	A3	Maintainability issues	3	3	9
	A4	Design complexity	4	4	16
	A5	Design changes	3	3	9
	A6	Design errors	2	3	6
Legal Risk	B1	Building codes and practices	2	3	6
	B2	Fire protection implementing issues	3	4	12
	B3	Disability access implementing issues	2	3	6
	B4	Conservation guidelines	4	4	16
	B5	Occupational health and safety issues	3	4	12
	B6	Requirement of approvals	3	3	9
Economic Risk	C1	High maintenance cost	4	4	16
	C2	Unexpected cost	5	4	20
	C3	Market complexity	2	2	4
	C4	Higher opportunity cost	3	4	12
Functional Risk	D1	Planning constraints	4	4	16
	D2	Inflexibility	2	2	4
	D3	Inconvertibility	2	3	6
	D4	Not meeting benefits of adaptive reuse	1	2	2
	D5	Productivity risks	3	3	9
	D6	Quality risks	2	2	4
	D7	Unable to achieve expected performance	1	3	3
Technical Risk	E1	Insulation and acoustic issues	2	3	6
	E2	Indoor environmental quality issues	2	2	4
	E3	Natural light and ventilation issues	1	1	1
	E4	Material supply and availability risk	4	3	12
	E5	Lack of expertise and man power	4	4	16
Social Risk	F1	Less awareness on adaptive reuse of buildings	3	1	3
	F2	Social reluctance to change building use	2	3	6
	F3	Use historic value for business purpose	3	2	6
	F4	Absence of transport and accessibility	4	2	8
	F1	Less awareness on adaptive reuse of buildings	3	1	3

According to the risk scores, design complexity (A4) is the most severe risk factor in the physical risk category, since adaptive reuse of historic buildings has complex design structures which belong to a historic era. Further, material durability issues (A2) indicated the next high severity level in this category. While, as per the calculated risk score, conservation guidelines (B4) indicated high severity level compared to other risk factors in legal category. Since, the conservation guidelines always effect to the buildings which have historical worth and have to get legal approvals when changing the building parts to ensure the preservation of the historic value of the building. Further, in economic risk category unexpected cost (C2) represented a high severity level compared to other risk factors in the economic risk category due its unanticipated

circumstances throughout the adaptive reuse process. Market complexity (C3) shows low severity level in the economic category. Planning constraints (D1) indicated high risk score as per the risk evaluation since in many cases there are constraints to continue the forecasted procedures for the adaptive reuse of historic buildings due to its historic features and structure. Whilst, not meeting benefits of adaptive reuse (D4) and unable to achieve expected performance (D7) presented less risk score. As per the evaluation, lack of expertise and man power (E5) denotes high risk score level compared to other risk factors. As the next stage of data analysis, the risk score of each risk factor (refer Table 2) was used to develop the risk rating matrix (refer Figure 1). The overall risk rating matrix for the adaptive reuse of historic buildings was developed. It represented all the risk categories such as, physical, legal, functional, technical, economic and social factors.

Figure 1 Risk rating matrix for Adaptive Reuse of Historic Buildings in Sri Lanka.

			Severity of impacts				
			Low	**Minor**	**Moderate**	**Significant**	**Severe**
		Rating	1	2	3	4	5
Probability	**Rare**	1	E3	D4	A1, D7		
	Unlikely	2		C3, D2, D6, E2	A6, B1, B3, D3, E1, F2		
	Possible	3	F1	F3, F4	A3, A5, B6, D5	A2, B2, B5, C4	
	Likely	4			E4	A4, B4, C1, D1, E5	
	Almost Certain	5				C2	

According to the developed risk rating matrix, low, moderate, high and extreme risks were identified as illustrated in Table 3.

Table 3 Risk levels of risk factors.

Risk Score	**Risk Level**	**Risk Factors**
1-3	Low Risk	A1, D7, D4, E3, F1
4-6	Moderate Risk	A6, B1, B3, D3, E1, F2, C3, D2, D6, E2, F3, F4
8-12	High Risk	A3, A5, B6, D5, A2, B2, B5, C4, E4
15-25	Extreme Risk	A4, B4, C1, D1, E5, C2

Table 4 Proposed risk responsive strategies.

Risk Category	Risk Factors	Risk Level	Risk Responsive Strategy	Proposed strategies
Physical Factors	Structural integrity	Low risk	Accept	Use expertise knowledge from structural engineers, mechanical and electrical engineers
				Take structural reports from the National Building Research Organization (NBRO) in SL
	Design errors	Moderate risk	Mitigate	Use expertise knowledge from experienced architectures and engineers
				Ensure better design
				Use proper construction practices
	Material durability issues	High risk	Mitigate/Transfer	Conduct a material quality test from NBRO in SL to ensure physical and technical protection of the materials
	Maintainability issues			Develop proper maintenance plan
				Obtain expertise knowledge from persons who have experience in adaptive reuse building's operation stage
				Get involvement of Facilities manger's at the initial stage
				Use maintenance manuals
	Design changes		Transfer	Use expertise knowledge
				Take approval for building design from the authorities, Urban Development Authority (UDA) etc
				Adhere to proper design practices
	Design complexity	Extreme risk	Avoidance	Obtain expertise knowledge from experience architects and structural engineers
				Changing the design to eliminate structural demolition
				Proper documentation (since no proper drawing for the some renovation projects)
				Attract well qualified and professional team to handle the project
Legal Factors	Building codes and practices	Moderate risk	Mitigate	Comply with building codes
	Disability access implementing issues			Prepare proper disability access implementation plan
				Get advises form Ministry of Social Welfare
	Fire protection implementing issues	High risk	Mitigate/Transfer	Prepare proper fire implementation plan
				Obtain recommendations from the fire department
				Insurance policies for building
	Occupational health and safety issues			Use engineering and administrative controls
				Insurance policies to staff
				Maintain accident and incident reports
	Requirement of approvals		Transfer	Obtain legal advises
				Proper coordination with stakeholder and contractors
				Less involvement with politicians
	Conservation guidelines	Extreme risk	Avoidance	Obtain legal advices and comply with conservation guidelines

Risk Category	Risk Factors	Risk Level	Risk Responsive Strategy	Proposed strategies
Economic Factors	Market complexity	Moderate risk	Mitigate	Conduct study on present market changes eg: SWOT analysis
	Higher opportunity cost	High risk	Transfer	Conduct feasibility study
				Get advices from the financial experts in decision making
	High maintenance cost	Extreme risk	Avoidance	Prepare proper maintenance budget
				Prepare proper planned preventive maintenance schedule and carry out
	Unexpected cost			Prepare contingency plan related to unexpected breakdowns/ failures
				Conduct periodic condition surveys
				Appropriate budgeting for unavoidable cost increases
Functional Factors	Not meeting benefits of adaptive reuse	Low risk	Accept	Conduct cost benefit analysis for the adaptive reuse project life cycle
				Establish benchmarks to evaluate the expected benefits and achieved benefits
	Unable to achieve expected performance			Conduct standard commissioning process
				Conduct study to clearly identify the reuse option/purpose
	Inflexibility	Moderate risk	Mitigate	Carried out a study to clearly understand the reuse option
	Inconvertibility			Analyse the structural aspects of the building before convert the use
	Quality risks			Use tested and certified materials
				Conduct quality tests according to NBRO considerations
				Establish benchmarks and effective process control
	Productivity risks	High risk	Transfer	Improve workplace planning strategies
				Create proper plan to maximize the productivity
				Introduce key risk indicators (KRI) to pre identify the productivity risks
	Planning constraints	Extreme risk	Avoidance	Conduct a proper initial study about the building before the process of adaptive reuse
				Carried out feasibility study/plan
Technical Factors	Natural light and ventilation	Low risk	Accept	Conduct lighting level testing such as lux level test to maintain proper lighting level
	Insulation and acoustic issues	Moderate risk	Mitigate	Use quality insulation materials
				Use new technologies without influence to the building's historic value
	Indoor environmental quality issues			Conduct air quality tests and get control measures Establish benchmarks to evaluate air quality of the building
	Material supply and availability risk	High risk	Mitigate/ Transfer	Maintain data base on approved material suppliers, maintain pool of suppliers to help on-time delivery
				Get advices from experienced architects and engineers
				Having standby/ spare parts
	Lack of expertise and man power	Extreme risk	Avoidance	Conduct awareness programs and continues programs on adaptive reuse new trends
				Choose best experienced persons for the adaptive reuse process

Risk Category	Risk Factors	Risk Level	Risk Responsive Strategy	Proposed strategies
Social Factors	Less awareness on adaptive reuse of buildings	Low risk	Accept	Conduct social awareness programs/workshops on adaptive reuse concept to the stakeholders
				Carryout advertising programs
				Conduct trainings and CPDs on adaptive reuse
	Social reluctance to change building use	Moderate risk	Mitigate	Conduct social awareness programs and create job opportunities to the job market
				Get ideas from stakeholders to give their ideas on adaptive reuse of historic buildings
				Communicate the purpose and benefits of adaptive reuse to stakeholders
	Use historic value for business purpose			Carried out advertising/publishing programs on successful adaptive reuse of historic buildings
	Absence of transport and accessibility			Conduct a feasibility study before start the adaptive reuse process to identify the availability of transport and accessibility
				Obtain advices from experienced professionals

As per the overall risk rating matrix, six risk factors are identified as extreme risks which affects to the adaptive reuse of historic buildings in Sri Lanka. Those are, design complexity, conservation guidelines, high maintenance cost, unexpected cost, planning constraints and lack of man power. According to the consequence level of risk factors, risk responsive strategies were determined as presented in Table 4.

CONCLUSION

Adaptive reuse can be identified as a process that changes existing structure to new purpose/use, which increases its capacity, performance, efficiency and offering environmental, social and economic benefits. It is a predominant method to conserve the historic value of the buildings as it enhances the existence of the historic preservation. Risk management is important for adaptive reuse as it ensure the expected performance levels of such ultimate purpose. As found in the research, design complexity, conservation guidelines, high maintenance cost, unexpected cost, planning constraints and lack of expertise and man power were the extreme risk factors that need to be avoided for successful project deliveries. Accordingly, low, medium and high risk factors were also derived in line with relevant responsive strategies. In Sri Lanka the adaptive reuse of historic buildings is in a developing stage and still there is a need of a proper framework for risk management. The risk responsive strategies proposed may ensure that the industry professionals can adopt a proper risk management plan for adaptive reuse of historic buildings. It offers guidance on how to response for the risks of the adaptive reuse of historic buildings, which may ensure their sufficient extermination. Further, the adoption of risk responsive strategies for adaptive reuse of historic and other types of buildings can be admirable in the context concerned and, in other developing nations.

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THE EXTENT OF USE OF RISK MANAGEMENT TECHNIQUES IN THE CONSTRUCTION INDUSTRY (IN SOUTH AFRICA)

Shoayb Loonat, Enumerate Consulting

ABSTRACT

This paper is drawn from a thesis submitted in partial fulfilment of the requirements for a master's degree in business leadership.

The purpose of the study was to determine if professional consultants have the relevant knowledge to implement risk management adequately and to determine whether risk management is actually implemented on their projects, and if not implemented ascertain as to the reasons why this may be such. The study focused on built environment professionals practicing throughout South Africa that are registered with any of the built environment professional councils.

This research followed a deductive approach as it was informed by existing theory. Quantitative data was collected utilizing an online self-administered questionnaire. A likert scale was used from which respondents chose one option that best aligned with their view. The researcher then analysed the data received.

The following findings were noted:

a) The process and benefits of risk management were identified.
b) The percentage of projects currently utilizing a risk management system was ascertained.
c) The factors that determine the appropriate risk response methods used were identified.
d) The barriers to implementing risk management was determined.
e) The measures that would have a positive impact on managing risks in a construction environment were identified.

The industry is aware of the various risks and are implementing mechanisms to manage these risks. However it is not a strict requirement on all projects to have a structured risk management system. It is highly dependent on the type of project, size of project, complexity and the type of client. The research highlights that there is much more that should be done to minimize risk in a construction project. Risk management is still a core principle of project management and must form part of the project manager's skill set.

KEYWORDS

Construction project management, risk analysis, risk identification, risk management techniques.

LITERATURE

Introduction

Construction projects are complex with multiple tasks having to be completed to achieve a project objective. Construction project managers must at all times deliver projects within the time, quality and cost parameters despite construction projects being complex in nature and faced with many uncertainties. Economies of many countries rely on implementing huge capital investment projects successfully to contribute to the gross domestic product of the country. It is essential that project managers possess the knowledge and skills to ensure that projects are completed according to the specification, within budget and within the stipulated time.

"The CHAOS Report" produced by the Standish Group in 1994 quoted a statistic that seventy five percent of projects fail in some way or the other. This statistic is further broken down in three categories (The Standish Group, 1995).

- 16,2% of projects were completed successfully on time, within budget and according to the predetermined specification.
- 52,7% of projects were completed but were either late, over budget, or both or did not meet the user requirements.
- 31,1% of projects were cancelled at some point during the project execution.

The construction industry has a very poor reputation for managing risk, with major projects failing to meet deadlines and cost targets (Mills, 2001). Overruns in relation to cost and time, and shortfalls in performance criteria are on the rise (MacNamee and Perara, 2013). Medupi Power station, as an example, encountered numerous delays and was over budget (Gernetzky, 2015). Projects are faced with multiple uncertainties which if not controlled and monitored will create a deviation from the initial stated project objectives (Raydugin, 2013). Risk management may be identified as a key contributor to achieving a projects objectives, reducing uncertainty and creating value.

Risk and risk management

Risk revolves around uncertainty. We live in a world of uncertainty where the knowledge of future events remains an unknown. There are various definitions of risk with some only focusing on the negatives and others including the positives. The PMI refers to risk as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective (PMI, 2013). The Association of Project Management (APM) defines risk as the potential of an action or event to impact on the achievement of the objectives (APM, 2015). The PMBOK defines project risk as the cumulative effect of the chances of uncertain occurrences adversely affecting project objectives (PMI, 2013). Kendrick (2015) states that risks have a probability of occurrence and an expected consequence, which allows project managers to categorise the various risks. This is also referred to as "likelihood and loss". There is a likelihood that an uncertain event may occur and if it does occur there is a potential loss that may be suffered.

Project managers have to cope with several types of risks including technological, financial, insurance-related, environmental safety and regulatory risk (Zwikael and Ahn, 2011). Other factors affecting projects are force majeure conditions, natural disasters, changing legislation, socio-economic factors and economic stability. All of these may have an effect on the scope of the project, cost of the project and duration for completion. Uncertainty is high at the beginning of the project and decreases as time elapses and the final product is completed (Meredith & Mantel, 2012).

The effect of an uncertain event may be positive or negative and is a clear deviation from what was planned. It may be attributed to a specific event or change in circumstances. So there are things that are controllable (certain) as we are aware of them. However there are some uncontrollable (uncertain) things. It is these uncontrollable events that have an impact on project outcomes (Raydugin, 2013). Project managers should plan so that if these uncontrollable events do occur they have a mechanism to minimise the impact on the project objectives.

The Project Management Institute (PMI) regards risk management as a knowledge area within project management, requiring project managers to have the necessary skills, knowledge and experience in project risk management. Risk can affect productivity, performance, quality and the budget of a project (Mills, 2001). Chileshe and Kikwasi (2014) ranked awareness of risk management processes as one of the three highly ranked critical success factors for construction projects.

It is not possible to remove all risks and uncertainty. Thus the emphasis on being proactive rather than reactive. It is essential that professional consultants try and understand the uncertainty and put measures in place to eliminate, reduce, transfer or mitigate the impact. However risks are often ignored or are not systematically controlled.

The risk management process

The process of risk management according to the PMBOK is similar to that of ISO 31000. It commences with risk management planning which is the procedure of determining the methodology for the management of risks for a project. This entails determining the organisations risk strategy, risk tolerances and defining the roles and responsibilities of the various individuals. The project teams should hold planning meetings and develop the risk management plan. Once the plan is in place all risks that might affect the project must be identified along with their characteristics. This would require the involvement of the full project team and may also utilise external experts. The identified risks must then be analysed qualitatively or quantitatively and a risk response plan must be designed to determine if the risk can be avoided, transferred, mitigated or accepted. Thereafter the process continues with risk monitoring and control.

Project risk management is a formal process whereby risks are systematically identified, assessed and provided for (Wideman, 1992). Risk management is an important component of the project management body of knowledge but is sometimes over looked either because the project manager cannot properly identify the risks or when the project manager opts for an informal approach to managing risks (Kishan, Bhatt & Bhavsar, 2014). Risks are either ignored, or dealt with in a completely arbitrary way by simply adding a ten per cent contingency onto the estimated cost of a project (Mills, 2001). Good risk management must be done systematically from the beginning of the project and requires knowledge and experience (Serpella, Ferrada, Howard & Rubio, 2014). Project managers have a duty to protect their clients from potential risks that the project may be exposed to.

According to Raydugin (2013) there are three main components of a risk management system. First is the organizational framework taking into consideration the type of project and organization. It defines the responsibilities of members of the project team in the risk management process. It also defines the types and frequencies of risk review activities as well as establishing the requirements for risk reporting and escalation.

Secondly is the risk management process, which aims to systematically determine possible deviations from project objectives and assessing their probability along with the level of impact. It is important to identify all types of uncertainties that may affect a project. This identification may be done by undertaking a risk workshop, having a team meeting, conducting one-on-one interviews or having brainstorming sessions. If a risk is unidentified it becomes a weak point of the risk management system. All identified risks must be screened to determine if it is relevant to the project and the organization. Risks which are not relevant must be rejected and recorded as such. All remaining risk items should be assessed and ranked. A response plan must be made and implemented. There must be continuous monitoring of the plan.

Thirdly risk management tools are required to support the organizational framework and the risk management process. This entails the usage of risk registers and/or software packages.

The risk management plan must be prepared by the project manager with full co-operation of all other members of the consulting team (Architect, Engineers, Quantity Surveyors, Procurement, etc.) it must even include the contractor once he has been appointed. It is important to engage with all the parties involved. The risk management plan aims to identify, assess and address any deviations from the baselines. In some projects there is no formal risk management plan but it does not imply that the project manager does not manage risks. Risk management culture must also be considered as an important tool for good risk management (Raydugin, 2013). All team members must see the value of implementing a risk management plan.

Risk management planning

Risk management planning is to be carried out at the onset with emphasis on the approach to be adopted. Chapman & Ward (2003) refer to this as scoping the process and planning the process. The risk management plan outlines the methodology for the management of risks for a project, which focuses on determining the organisations overall risk strategy, risk tolerance levels and defining the roles and responsibilities of the various individuals. The project team should hold planning meetings and develop the risk management plan collectively.

More established organisation would have standard templates to assist with the project planning, information gathering and risk assessments (Kendrick, 2015). A risk breakdown structure is another tool used which illustrates the hierarchy of risks according to their risk categories and is a starting point for risk management.

Risk identification

Risk identification involves the determination of various risks associated with the projects through brainstorming, checklists, cause and effect diagrams or focus groups. The aim is to identify the gaps and potential problems, and list them. What are the uncertainties and how does it affect the project? These risks could be categorised in different types: financial, resources, technical, economic, environmental, operational, political, relationships, security and legal.

The project manager would use various documents to identify potential risks (Tadayon, Jaafar & Nasri, 2012):

- Work Breakdown Structure (WBS) to review every task for potential failure.
- Specification document prepared by the designers
- Cost estimates
- Time schedules and
- Resource plan (if already defined)

Tadayon, Jaafar & Nasri (2012) highlight the use of four techniques of risk identification in construction projects:

- Checklists prepared by a document specialist with key failure points from previous projects,
- Interviews with members of the professional team,
- Examining historical data from previous similar projects and
- Brainstorming with the project team.

Brainstorming is a process where the entire project team comes together to brainstorm potential problems, uncertainties and risks a project may be faced with. The facilitator may be the project manager or an external party. The facilitator must allow every member to participate and must record every risk. He must allow for discussion and debate to thoroughly assess the items recorded. The result is a list of risks. Previous experience may also be utilised. The project manager may also interview an expert to benefit from their experience on similar projects.

The PESTEL technique can also be used to identify risks (Rastogi & Trivedi, 2016). It would analyse the projects interaction with the political, economic, social, technological, environmental and legal areas.

A risk breakdown structure (RBS) is a pre-established hierarchy describing typical categories of risks. The project manager works through the hierarchy to determine which items apply to the specific project at hand.

Critical Path method utilises a time schedule to calculate the critical path which is the longest path of activities planned in a project. Any delay to a task on this path would result in a project delay. So the critical tasks are identified. The work breakdown structure is utilised to create a Gantt Chart an often used time schedule. The Gantt Chart details the time and duration of each task as well as the dependencies.

Cause and effect diagrams or root cause analysis is a technique to identify the source of the risks and is particularly appropriate if a risk has more than one cause. This process works backwards by first starting with the identified risk and then identifying the main factors which may make the risk occur. Thereafter for each factor more detail is to be identified and if possible it must be continued to reveal even more detail. This should continue until the cause is as detailed as possible.

The Delphi Technique is an iterative process used to estimate the likelihood and outcome of future events. Utilising a facilitator a workshop is held where the project team exchanges views and each independently gives estimates and assumptions about the various risks to the facilitator. Carefully designed questionnaires may be utilised. Participants are not required to be challenged. The facilitator then reviews the data and issues a summary report of the identified risks, to be reviewed by the project team who provide updated forecasts for further review. This process continues until all team members reach a consensus.

The Delphi technique workshop aims to minimize the influence between participants. Important discussion points are noted down without any discussion or debate. There is a possibility that each opinion could be biased but by the analysis of collected information by the facilitator the impact of the bias is averaged out (Raydugin, 2013).

Specialist consultants who specialise in risk management may also be utilised as a means to identify, analyse and manage risks. They would have knowledge is risk management for construction projects and be exposed to other projects to be used as benchmarks for current projects.

Risk assessment methods

Risk matrix

A risk matrix is a tool used to conduct qualitative and quantitative risk assessment. It evaluates the probability of occurrence and the severity of the impact. A grid system is utilised to tabulate the two elements mentioned. The level of risk increases diagonally from the bottom left to the top right. Risk items in the bottom left corner would have an acceptable level of risk. Risk items in the middle should avoided or mitigated. Risks in the top right must be eliminated or transferred. The scales used in a risk matrix can be adjusted to relate to a specific project.

Qualitative risk analysis methods divide the choices into ranges of probability and project team members are required to assign each risk to one of the pre-defined ranges (Kendrick, 2015). These ranges of probability may be very high, high, moderate, low and very low. Finding the optimum number of ranges makes it easier to find consensus amongst team members. For a qualitative risk analysis experience, polling, interviews and rough analysis may be used (Kendrick, 2015).

For the classification of impact, qualitative methods use ranges also based on the size and level of the impact.

- High Impact: the project objective is at risk (a change to the scope, schedule, or resources is required).
- Medium Impact: the project objectives may still be met, but significant re-planning is required.

- Low Impact: no major plan changes; the risk is more of an inconvenience and can be easily contained.

An alternative method using 5 ranges:
- Very low impact: Less than 1 percent impact on scope, schedule, cost, or quality
- Low impact: Less than 5 percent impact on scope, schedule, cost, or quality
- Moderate impact: Less than 10 percent impact on scope, schedule, cost, or quality
- High impact: Less than 20 percent impact on scope, schedule, cost, or quality
- Very high impact: 20 percent or more impact on scope, schedule, cost, or quality

Risks need to be assigned using these categories.

Qualitative risk analysis is used by tabulating a Risk Matrix. The matrix by Meredith & Mantel (2012) outlines the different risks, underlying cause, its probability of occurrence and the impact thereof, including the categorizing of the risks into critical, minor and insignificant.

Figure 2.8 A qualitative risk matrix

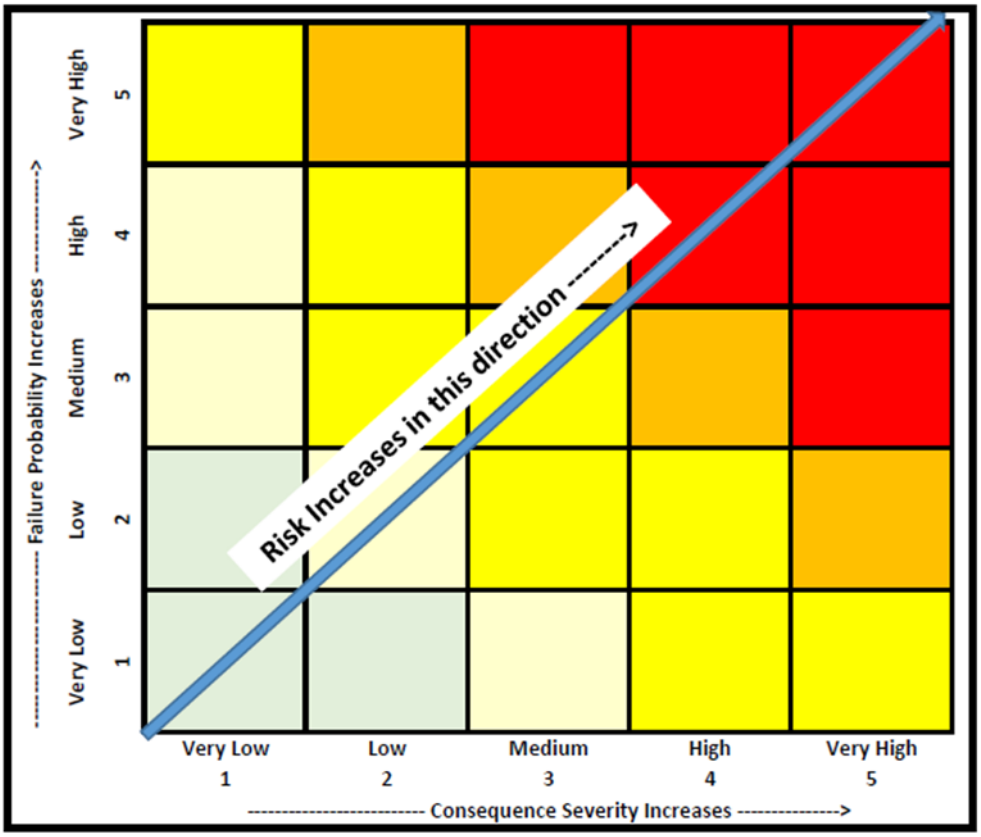


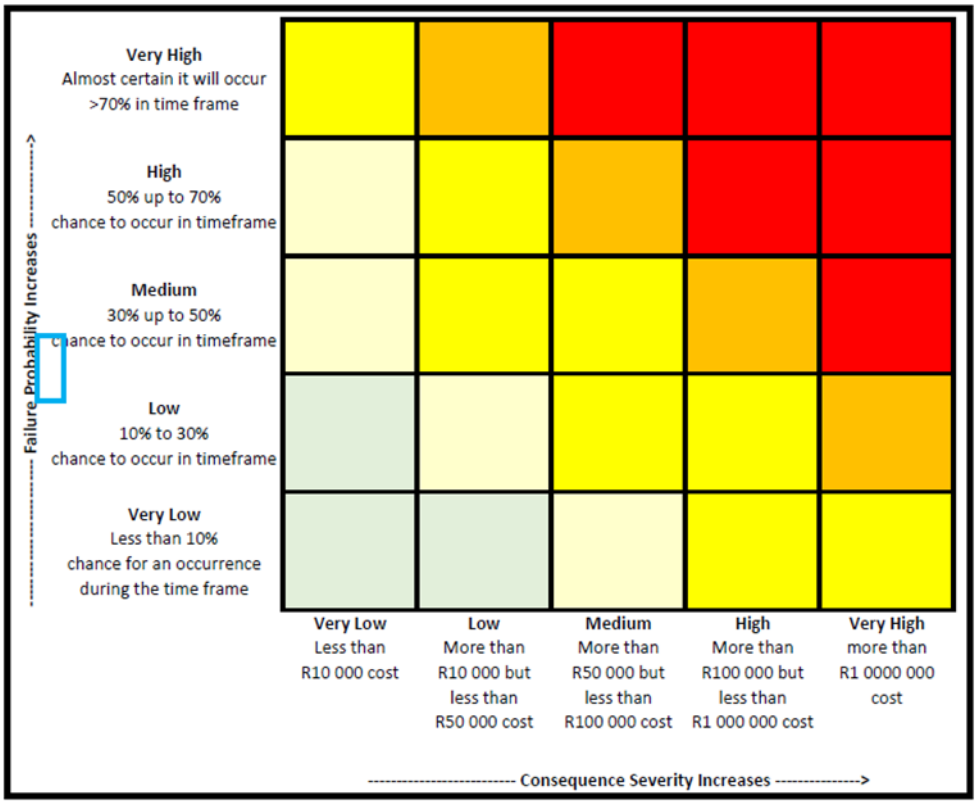
Figure 2.8 is referred to as a 5 x 5 matrix as it has five levels of probability and 5 levels of impact. The scales can be changed to accommodate the project environment. Risk increases diagonally from the bottom left to the top right of the table. A score can be calculated by multiplying the score of probability with the score of severity. The maximum score is 25. Risks in the upper right corner would require more attention.

Quantitative risk analysis methods assigns each risk a specific fraction between zero and one (or between 0 and a 100 percent) (Kendrick, 2015). For example there could be three ranges of probabilities:
- High (likely): 50% or greater chance of occurring

- Medium (unlikely): 10% to 50% change of occurring
- Low (very unlikely): 10% or lower chance of occurring

Quantitative assessment of risk impact relies on the calculation of the estimated impact on the budget and the calculated delay on the project completion.

Figure 2.9 A Quantitative risk matrix



Quantitative risk analysis follows after qualitative risk analysis, once the critical risk factors have been identified. Some of these methods would be Decision tree analysis, Sensitivity analysis, Delphi Method and Monte Carlo Simulation. The use of specialist software is also an option.

For the classification of impact, quantitative methods use estimates using units such as days delayed or monetary allowance.

Risk register

Once all the risks have been identified it should be compiled into a risk register and move forward to analysis. It is usually a table on a spreadsheet and should have the following information (Kendrick, 2015):

- A clear description of the identified risk
- An assessment of its probability
- A description of the potential impact, including when the risk would most likely occur
- An estimate of the potential impact
- Each risk must have an overall rating
- A risk owner must be stated for each identified risk
- List all potential triggers or other indicators that signal the occurrence of the risk
- A response summary
- A contingency or recovery plans

Other methods

Monte carlo simulation is a statistical technique by which a quantity is calculated repeatedly, using randomly selected "what-if" scenarios for each calculation. It is a computerized mathematically technique. The Monte Carlo method is multiple sampling of uncertainties as inputs to the mathematical models to get information about possible overall project cost and schedule uncertainty (Raydugin, 2013). Monte Carlo simulation provides the project manager with a range of possible outcomes and the probabilities they will occur for any choice of action.

Risk response planning

Risk response planning is required to assign a strategy to each of the identified risks. There are different approaches available for dealing with risks:

- Risk avoidance: making a change to the project plan or schedule to eliminate the risk entirely.
- Risk transfer: transfer the risk onto the other contracting party or other stakeholders such as an insurance company. This will not reduce the risk but reduce the financial impact should the risk occur.
- Risk sharing: sharing the exposure of the risk.
- Risk financing: taking our insurance thus transferring the financial loss on to the entity providing the insurance in exchange of a premium.
- Mitigate: does not remove the risk but aims to reduce it by make changes to the design, resources, etc. Actions to reduce the probability and or the impact.
- Acceptance: accept the risk and if required make a contingency allowance to cover the financial loss. If it is a minor risk and too insignificant to consider.
- Exploit opportunities: if the risk is positive then take advantage of the opportunity.

A risk response does not have to be limited to one single response but may include a combination of risk responses.

Decision tree analysis can be used to determine the appropriate risk response taking into considerations the probability of occurrence, the severity of the impact and the cost for the chosen response.

Risk monitoring and controlling

Once the response has been determined the residual risk must be monitored and any new risks must be identified. This is referred to as Risk Monitoring and Control. The Risk Management Register keeps a record of the risks and the control thereof.

Benefits of project risk management

Some benefits of project risk management (Chapman, 2011)

- increasing the likelihood of a project achieving its objectives;
- forcing a project's objectives to be made explicit and prioritised;
- ensuring that realistic monetary contingencies are provided;
- ensuring that the procurement route, form of contract and contract conditions reflect the sponsor's risk appetite and project objectives;
- forces the team to think collectively and collaboratively;
- engenders a proactive management culture – "tackling tomorrow's problems today";
- validates the funding requirements;
- enhances value for money;
- protects the organisation's reputation and increases stakeholder confidence;
- improves accountability, decision making and transparency;
- facilitating change to be executed more effectively and efficiently and improving project management;

- provides a better understanding of and compliance with relevant legal and regulatory requirements; and
- improves integration of the project into the organisation's operations.

If risk management is implemented, monitored and controlled in accordance with ISO31000 or PMBOK an organization would benefit from an increasing likelihood of achieving project objectives with proactive project management. There would be improved control with better communication, more reliable decision making and fewer surprises. Risk management improves the chances of project success, identifies infeasible projects, reduces crisis management, lowers the overall cost and improves planning. It also provides a means of establishing realistic time and cost reserves (Kendrick, 2015). Managing risks requires time and effort from the client, project manager and the consulting team. Both time and effort come at a cost. Clients and members of the consulting team should understand the benefits that coherent and reliable risk management can bring and should endeavour to implement it from inception of the project.

RESEARCH METHODOLOGY

This research followed a deductive approach as it was informed by existing theory. Quantitative data was collected utilising a structured approach and the researcher attempted to identify patterns in the data. A quantitative research, according to Creswell (2012), means the testing theories by examining the relationship among variables, with the aim to explain, predict, investigate relationships and describe current conditions or to examine possible impacts or influences on designated outcomes.

A self-administered questionnaire was used to collect the data. A self-administered survey is an instrument delivered to the participants via personal (intercept) or non-personal (computer – delivered, mail delivered) means that is completed by the participant without additional conduct with an interviewer (Cooper & Schindler, 2014). A questionnaire allows the researcher to count the frequency of occurrence of opinions, attitudes, experiences, processes, behaviours, or predictions (Rowley, 2014). Self-administered survey were used to gather information from the participants through e-surveys and mail surveys.

Questionnaires were distributed via email to the sample population with clear instructions on how to answer the questions and asking for e-mailed responses. The respondents were be given a period of six weeks to answer the question thus it's a cross sectional survey. It was issued for a defined population at a single point in time over a short time period (Salkind, 2014). A second email was also sent out after two weeks to act as a reminder for those that had not yet submitted and to thank those that have submitted. A total of 630 questionnaires were emailed. The initial response was very low so to improve the number of respondents received, links to the questionnaire were also placed on the Association of South African Quantity Surveyors (ASAQS) newsletter, which has 11 000 subscribers as well as on the Linkedin group Construction in South Africa which has a membership of 2 156 people

When designing the response scales for the self-administered questionnaires, the researcher has considered the number of categories to offer, the labelling of the categories and the visual display of the scale (Melani, Parsons & Dillman, 2009). The Likert scale (named after Rensis Likert) is appropriate as the researcher would like to identify attitudes, feelings and opinions about a certain issue. A Likert scale is an ordered scale from which respondents choose one option that best aligns with their view. The Likert scale was used to allow the respondents to express their view as well as the strength of their opinion about the topic being researched. Likert scales are widely used as they are simple to develop (Salkind, 2014).

It is important to note that there is a debate around the appropriate number of scale points to be use. A typical scale would have an equal number of positive and negative response options and may include a neutral option as well. The mid-point is usually a neutral point on the scale and does note ensure that respondents make a specific choice. Garland (1991) noted that if a rating scale with 5 points is used then there is evidence of social desirability bias, which arises form the respondent's bias to please the interviewer and for the respondent's answers not to be perceived as being socially unacceptable. Garland suggests that to minimise social desirability bias the mid-point of the scale must be eliminated. However if the mid-point is eliminated then the researcher must ensure that the results are not being distorted as a result thereof. As there may be respondents that truly feel neutral about the topic and would be forced to make a choice. Brinkman (2009) highlights the interpretation of a neutral point by some respondents in a Likert Scale as problematic and suggest the use of a separate option with "no opinion" or 'not applicable" and ignoring the data when performing the analyses. Thus it would be best for the researcher to determine whether the topic being researched would benefit from having a mid-point on the scale. Likert scales are ordinal data showing that one score is higher than the other and it does not show the distance between the points.

The researcher utilised statements with 5 response scales typically ranging from extremely important, important, neutral, not important, to extremely not important, or strongly agree, agree, neutral, disagree to strongly disagree. Respondents are asked to select the answer that best represents their attitude or behaviour. A mid-point is maintained to ensure that no respondent is forced to make a choice.

All questionnaires returned were analysed and the data was captured on a spreadsheet utilising Microsoft Excel for analysis. The capturing on a spreadsheet enables the researcher to record and sort all data. Particular care was taken to capture the data accurately. The reliability and validity of the data was measured using Cronbach alpha and exploratory factor analysis respectively. Cronbach's alpha reliability coefficient usually ranges between 0 and 1. However, there is actually no lower limit to the coefficient. The closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. For good internal consistency values of .7 and greater are required.

A total of 630 questionnaires were emailed and links to the questionnaire were also placed on the Association of South African Quantity Surveyors (ASAQS) newsletter, which has 11 000 subscribers as well as on the Linkedin group Construction in South Africa which has a membership of 2 156 people. A total of 66 responses were received. This represents an extremely low response rate. From the 66 that responded only 55 questionnaires were completed in full and met the sampling criteria.

RESULTS AND DISCUSSION

The purpose of this study was to determine if professional consultants have the relevant knowledge to implement risk management and to determine whether risk management is actually implemented on their projects, and if not implemented ascertain as to the reasons why this may be such.

Job function of respondents

The respondents were all members of the professional team on construction projects executed within South Africa. They had various years of experience on different types of projects with differing project values. 40% of the respondents were quantity surveyors, 25.54% were architects, 20% were project managers, 9.09% were consulting engineers and the remaining 5.45% were development managers. This is a fair representation of the desired population. It was expected that the Project Manager, Architect and Quantity Surveyor would be the three highest respondents. The majority of 81.82% had experience of more than 5 years in the built environment. This shows that the majority of respondents were actively involved in the industry for more than 5 years.

Location and size of projects being executed

74.55% of the respondents undertook projects mainly in Gauteng, with the remainder 25.45% in the other regions in South Africa. Gauteng is the region with the highest gross domestic product and does have a higher concentration of professionals when compared to other provinces. This may be seen as a limitation as there is a high concentration in one region (Gauteng). Majority (89%) of the respondents were executing project with a construction value greater than R10million.

Benefits of risk management

All respondents (100%) agreed that project risk management has the potential to increase overall project success. 87.27% of respondents agreed that project risk management would reduce time delays. 78.18% of respondents agreed that project risk management would improve quality. 65.45% of respondents agreed that project risk management would lower total cost. The majority of respondents agreed that there are definite direct benefits to project risk management.

Utilising a risk management system

Respondents confirmed that only 10% to 30% of projects currently utilise a risk management system. 80% of respondents confirmed that the project manager should have the main responsibility of risk management. This confirms the importance of the project manager to have the relevant knowledge with regards to risk management.

General project risk management practices

Less than half of the respondents agreed that risk management was adequately implemented in the design and constructions phases of the project. 62 % of respondents were satisfied that once the risks were identified they were adequately monitored throughout the design and construction phase of the project. 40% of respondents confirmed that risk management was as an integrative part of the project plan. 58% of respondents confirmed that project success was enhanced as a result of proactively managing risk and that there was an increase in the use of risk management. Risk management on projects has been adequately implemented, monitored and controlled throughout the planning and construction phase of the project, but there is room for improvement.

Risk identification tools and risk quantification methods

Previous experience was the main risk identification tool being used with project managers also using brainstorming and checklists as well. Previous experience, ranking, risk assessments and risk matrix were the four main risk quantification methods being utilised.

Risk response methods

Majority of respondents agree that risk response methods need to take into consideration:

- The cost of the project,
- The size of the project,
- The type of project,
- The type of risks identified and
- Previous experience.

Contingency plans are the most used risk response method, while the other risk responses (risk reduction, risk transfer, etc.) are also being utilised on projects.

Barriers to implementing risk management

The barriers to implementing risk management were mainly communication, insufficient knowledge/understanding of the risk management process and lack of experience. The cost to implement was also identified as a barrier to implement risk management.

Measures that would have a positive impact on managing risks in a construction environment

Respondents identified measures that would have a positive impact on managing risks in a construction environment were mainly:

- Additional coursework,
- Additional time at planning stage to identify potential risks,
- Utilising a specialised risk consultant
- Incentivising the project manager to implement risk management,
- Inclusion in course work at tertiary level and
- Mentoring.

Future Research

The following recommendations are made for future research:

- To research the practices of Quantity Surveyors to understand how the various risks are taken into account when preparing initial cost estimates and bills of quantities. To better understand how contingencies are calculated and allowed for in the various cost estimates and bills of quantities.
- Investigate the potential additional professional fees required for a specialised risk consultant on a construction project and the impact thereof on the projects return.
- Finding methods to incentivise project managers to implement risk management.

CONCLUSION

This research focussed on understanding what project risk management is and the potential benefits of project risk management. The risk management process was clarified as risk planning, risk identification, risk analysis, risk response methods and continuous monitoring and control. The various risk identification and quantification tools were also analysed along with the various different risk responses. The project manager was identified as the responsible individual to implement and manage the project risks. Thus the importance for the project manager to have the necessary knowledge, skills and experience to implement a project risk management system. The industry is aware of the various risks and are implementing mechanisms to manage these risks. However it is not a strict requirement on all projects to have a structure risk management system. It is highly dependent on the type of project, size of project, complexity and the type of client. The use of contingency plans (monetary allowances and the acceptance of risks is the most used risk response methods.

The research confirms that the responsibility of risk management still rests with the project manager. Previous experience, brainstorming and checklists are the three main risk identification tools being utilised. Previous experience, ranking, risk assessments and risk matrix were the four main risk quantification methods being utilised. The type of risk response methods being chosen are dependent on the cost, size and complexity of the project. Contingency plans are the most used risk response method, while the other risk responses (risk reduction, risk transfer, etc.) are also being utilised on projects.

Recommendations to improve project risk management on construction projects are to provide more detailed coursework on project risk management at tertiary level. Project managers must also be incentivised to implement project risk management. On larger projects specialised risk consultants may also be appointed to carry the responsibility of risk management

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THE GLOBAL PROJECT COST MANAGEMENT PROFESSION

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ABSTRACT

This paper examines the global development of the project cost management profession and explores the opportunities that the profession might benefit from by implementing over-arching global strategies to raise professional recognition and standards on a global scale. For the purposes of this paper Project Cost Management is used as the single descriptor for the professional roles of cost engineering, quantity surveying, project management and project controls. The paper commences with an analysis of the various terminologies used to describe the profession around the world and the major global and regional associations representing the profession. This is followed by a comparison of the major regional differences in registration/certification requirements for the profession. The purpose of the paper is examine how the identified differences affect the transportability of professional project cost management services between countries and the effect that they have on global recognition of the profession. The research method underpinning this study comprises interviews with professional cost management associations that are members of the Pacific Association of Quantity Surveyors (PAQS) and the International Cost Engineering Council (ICEC). The research results reveal that whilst there are differences in practices, standards and registration/certification requirements, the fundamental principles and procedures of project cost management practice are the same throughout the world. The paper concludes with a range of recommendations and strategies to help unify the profession. It will put forward the proposition that collaboration between the various cost management professional associations around the world is the key. The catalyst for change lies with the current International Cost Management Standards (ICMS) initiative that has been developed by a coalition of over 40 professional cost management associations from around the world to implement international standards for benchmarking, measuring and reporting construction project cost. This global coalition provides tremendous opportunities to go well beyond the ICMS project to further develop the profession on a global scale and establish a greater global identity.

Keywords: Project Cost Management, International Standards.

INTRODUCTION

The main professional disciplines providing specialist project cost management services around the world are cost engineers, quantity surveyors, construction economists, project managers and project controls professionals. Quantity Surveying is a profession with origins in the United Kingdom and is a professional title recognised mainly in Commonwealth countries. Cost Engineering is the term mainly used in North and South America, China and some parts of Europe. Construction Economist is used in some European countries and in other parts of the world as an alternate descriptor for the service. In other regions, particularly in Europe, these three professional titles are not recognised with cost management services largely carried out by Project Managers as part of their suite of services. A relatively new professional discipline of Project Controls has also emerged as a more encompassing descriptor of the role of the cost manager. The fundamental cost management principles and practices of these professions are the same.

Additionally cost management is not the exclusive preserve of these professionals and there are few countries that require official registration to practice as a professional in the project cost management field. Accordingly cost management is commonly carried out by a range of other professionals that may well lack the specialist technical competencies and expertise that is required for effective cost management.

Accordingly the professional discipline of project cost management suffers from the lack of a single descriptor/title that is recognized globally (such as an architect and engineer). There is also a lack of common professional standards and competencies (such as an ISO standard) that are typically found in other professional fields such as accountancy.

This paper examines the need for the unification of the profession on a global scale. This will include a comparison of the major regional differences in competency standards, education and registration/certification requirements for the profession. It will conclude with a range of recommendations and strategies to help address these needs.

LITERATURE REVIEW

Global/Regional Representation for the Profession

Professional associations provide important representation for the profession and the development/maintenance of professional standards. There are now a number of global/regional professional associations that represent the interests of project cost management professionals. The key associations are the International Cost Engineering Council (ICEC), the Royal Institution of Chartered Surveyors (RICS), the Association for the Advancement of Cost Engineering International (AACE International), the International Project Management Association (IPMA), the International Federation of Surveyors (FIG), the African Association of Quantity Surveyors (AAQS, the Pacific Association of Quantity Surveyors (PAQS) and the European Council of Construction Economists (CEEC).

ICEC arguably provides the main global identity for the profession. It acts as an umbrella organisation for cost engineering, quantity surveying and project management associations around the world with a membership base of 40 national associations located in nearly 40 countries and representing over 300,000 cost management professionals working in over 120 different countries (ICEC 2018).

The RICS are a large global organization with over 125,000 qualified members and over 30,000 student members in 146 countries. It represents professionals working in property, land and the built environment with 17 professional groups across these fields. The groups specific to cost management are the Quantity Surveying & Construction Group the Project Control Group (RICS 2018).

The AACE International (formerly the American Association of Cost Engineering) was formed in 1956 and was originally nationally focused but it is now a global organisation with over 7,000 members world-wide. They have members in over 100 countries with over 80 local and international sections (AACE 2018).

IPMA represents the professional disciplines of project, programme and portfolio management. Cost management is a core activity of the project manager so there is a lot of correlation between IPMA and cost management associations. IPMA has approximately 70 member associations spread from Europe to Asia, Africa, the Middle East, Australia, and North/South America (IPMA 2018).

FIG is the main organisation representing the surveying profession around the world with 103 member associations. They also have 84 Academic Member organisations, 43 Affiliate Member associations and 27 Corporate Member organisations. Collectively 115 countries are represented in FIG. The field of Quantity Surveying/Cost Management/Construction Economics is represented by FIG's Commission 10 – Construction Economics (FIG 2018).

A range of regional associations also represent the profession.

The AAQS provide regional representation for the quantity surveying profession in Africa. Membership primarily comprises quantity surveying professional associations in Africa but recently membership was opened to professional firms. The AAQS has 17 member associations from across Africa (AAQS 2018).

PAQS represents the quantity surveying/cost engineering profession in the Asia-Pacific region with 14 member associations and 1 observor association drawn from the region (PAQS 2018).

The CEEC represents the field of construction economics in Europe and promotes the profession at the European level. Membership primarily comprises professional associations or groups within a European country and individual members in countries where relevant professional associations don't exist. They currently have 14 member associations (CEEC 2018).

However, there is a lack of national Quantity Surveying and Cost Engineering national associations in the Middle East regions. At the moment the professions are represented in the regions by local chapters/sections of associations such as the AIQS, RICS and AACE International.

Education & Qualification

Nalewaik & Bennett (2012) found that Cost Engineering and Quantity Surveying differ primarily in the route taken to professional qualification rather than any substantive difference in services provided by the two professions. It was found that the Cost Engineering profession suffers from a lack of formal training programmes at universities. There are few formal university degrees in Cost Engineering and education in the cost engineering fields of cost management, estimating, and scheduling are typically included as coursework in civil engineering, construction management, and project management courses.

However, specific cost engineering degree programs have now emerged in China (Sue 2016). Registration or certification as a cost engineer is generally not required except in countries such as China. Nevertheless a range of cost engineering certification programs have been developed around the world with the most prominent being those produced by the AACE, the Association of Cost Engineers in the UK and the China Engineering Cost Association (CECA).

Conversely, Bennett & Maddalena (2010) found that university degrees in Quantity Surveying were common in mostly Commonwealth countries (albeit often as elements of construction management degrees) and that has assisted in providing professional recognition for the quantity surveying profession. They found that university degrees provided the primary path to the profession. However, formal recognition is largely achieved by corporate membership of a quantity surveying related professional association through assessment of professional competency based on industry experience.

Nalewaik & Bennett (2012) found that university degrees are provided in project management and construction widely around the world. Construction management degrees are provided at both undergraduate and postgraduate levels whilst project management courses tend to be offered primarily at postgraduate level although the number of undergraduate project management courses has been increasing. As with quantity surveying, formal recognition is largely achieved through corporate membership of a project management related professional association through assessment of professional competency based on industry experience.

Certification & Registration

There are generally no legal requirements for project cost management professionals to have formal qualifications or certification/registration requirements except for a limited number of countries such as in Malaysia, China and Hong Kong. Some employers and clients do require qualification/certification, but there is generally no statutory requirement in most countries, such as for registered professional engineers, architects, or lawyers.

A variety of certification programs have been developed in the cost engineering field. The following provides a list of some of the main globally recognised cost engineering related certification programs:

<u>AACE International (United States)</u>
Certified Cost Technician (CCT)
Certified Scheduling Technician (CST)
Certified Cost Professional (CCP)
Certified Estimating Professional (CEP)
Earned Value Professional (EVP)
Planning & Scheduling Professional (PSP)
Certified Forensic Claims Consultant (CFCC)
Decision & Risk Management Professional (DRMP)

<u>Dutch Association of Cost Engineers (DACE)</u>
Certified Cost Engineer (CCE)

<u>Association of Cost Engineers (United Kingdom)</u>
Certified Cost Engineer (CCE)

<u>Brazilian Institute of Cost Engineers (Brazil)</u>
Certificador Professional Certification Program

<u>Italian Association for Total Cost Management (AICE)</u>
Esperto in Ingegneria Economica Certification (Expert in Economic Engineering Certification)

The Quantity Surveying profession generally adopts a different path to professional recognition. This recognition is largely derived through completion of a university degree in the field and the completion of an assessment of professional competency (based on industry experience) to become a corporate member of a professional quantity surveying association.

An example is the Royal Institution of Chartered Surveyors (RICS) who have an Assessment of Professional Competency Program that, upon successful completion, leads to full corporate member and chartered surveyor status. Most quantity surveying associations have a similar assessment of competency program leading to full membership status. This is typically complemented by annual Continuing Professional Development requirements.

Most countries do not require Cost Engineers/Quantity Surveyors to be certified or registered to practice (as is typically required for architects and engineers). However, some countries require registration by law. Examples include:

Malaysia
The professional association in Malaysia is the Royal Institution of Surveyors Malaysia (RISM) but to practice quantity surveyors must be registered through the Board of Quantity of Surveyors, Malaysia.

Nigeria
In Nigeria, quantity surveyors are required to be registered through the Quantity Surveyors Registration Board. The peak association is the Nigerian Institute of Quantity Surveyors.

Hong Kong
Quantity Surveyors are required to be registered through the Surveyors Registration Board. The Hong Kong Institution of Surveyors is the professional association representing the profession.

China
China has a certification/registration program for cost engineers and cost engineering firms. Cost engineering work can only be undertaken by certified individuals/firms.

A number of other countries promote certification/registration albeit without statutory legal requirements. Examples include:

Australia
The Australian Institute of Quantity Surveyors (AIQS) has recently introduced a Certified Quantity Surveyor (CQS) program.

New Zealand
The New Zealand Institute of Quantity Surveyors (NZIQS) introduced a Registered Quantity Surveyor Scheme in 1999.

South Africa
The South African Association of Quantity Surveyors (ASAQS) helped develop a quantity surveying registration scheme through the South African Council for the Quantity Surveying Profession (SACQSP).

Global Standards – Quantity Surveying and Cost Engineering

The International Organization for Standardization (ISO) is the leading authority on global standards. They describe a standard as *'a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose'*. More pointedly they note that *'for business, (standards) are strategic tools that reduce costs by minimizing waste and errors, and increasing productivity. They help companies to access new markets, level the playing field for developing countries and facilitate free and fair global trade'* (ISO 2015, p.1). The ISO have a membership of over 164 national standard bodies throughout the world and publish over 19,500 standards.

The Organization for Economic Cooperation and Development and the US Department of Commerce has estimated that standards and related conformity assessment (checking that products and services measure up to standards) have an impact on 80% of the world's trade in commodities (ISO 2015). Major global entities such as the World Trade Organisation (WTO) require their members to use international standards where available. This helps to avoid the technical barriers to trade that can be caused by differing national or regional standards.

It is notable that there is no ISO Standard or any other global standards that relate directly to the core processes/services of the project cost management profession. Whilst ISO standards exist in allied fields such as Risk Management, Quality Management, Environmental Management and Project Management there are none that relate specifically to project cost management.

The accounting profession provides a good example of global professional standards that have been developed and now form the basis for financial reporting in most countries around the world. The development of these standards importantly had the support of major global organisations such as the G20, World Bank, International Monetary Fund, the IOSCO, and IFAC (IFRS 2018).

The objective of the financial standards is to provide a common global language for business affairs so that company accounts are understandable and comparable across international boundaries. Most countries are now adopting these international standards in lieu of their own national standard. They enable accountants to prepare accounts using a common international framework that can be understood across international boundaries (IFRS 2018). These standards have the added benefit of uniting the accounting profession through common goals and frameworks.

The accounting profession has also developed a Chartered Global Management Accountant™ (CGMA®) designation for management accountants. CGMAs qualify through rigorous education, exam and experience requirements. More than 150,000 accounting and finance professionals hold the CGMA making it the most widely held management accounting designation in the world (CGMA 2018).

A key issue regarding global standards for the project cost management profession is the differences in Quantity Surveying and Cost Engineering methods and procedures in relation to measurement and general cost management practices and procedures. It can be generalised as the differences in the 'British approach' (Quantity Surveying) and the 'American approach' (Cost Engineering).

Quantity Surveyors generally adopt a Standard Method of Measurement that has been developed for their particular country, region or market sector. These standards are commonly then adapted by Quantity Surveyors to suit their particular measurement approaches and or client/market requirements. An example is the adaptation of a standard method of measurement to a more concise/abbreviated form.

The Cost Engineering approach generally allows contractors to base their estimate on their individual methods of measurement and pricing – this often forms a distinct competitive advantage for contractors when bidding on projects.

Accordingly, the development of global standards would need to address these fundamental differences in practices and procedures. The challenge is to develop a global standard that incorporates aspects of both approaches – minimum standards that can then be adapted to suit the particular requirements in various countries, regions and market sectors.

RESEARCH METHODOLOGY

The literature review revealed a range of issues and problems for the profession. The author investigated these identified issues and problems in more depth through a series of discussions and meetings spanning the period 2014 to 2018 with representatives of all the main professional associations outlined in the previous section. The primary discussions were conducted through the International Cost Engineering Council (ICEC) and a number of their key member associations from the United States, the United Kingdom, Europe, Brazil, Africa and the Asia Pacific. Discussions and meetings were also held with representatives of the Royal Institution of Chartered Surveyors (RICS), the International Project Management Association (IPMA), the International Federation of Surveyors (FIG), the African Association of Quantity Surveyors (AAQS, the Pacific Association of Quantity Surveyors (PAQS) and the European Council of Construction Economists (CEEC).

This enabled the author to canvass issues across the globe and also at regional levels, to investigate initiatives being undertaken and to identify future needs. The following section outlines the main findings derived from these meetings and discussions.

RESEARCH RESULTS

Single Professional Title & Global Leadership

Global recognition requires a single professional title. Whilst it is important for titles such as Quantity Surveyor, Cost Engineer or Construction Economist to still be used by firms and associations in individual countries as appropriate, a global identity requires a single title. This could well be Project Cost Management or other more encompassing title.

Global leadership is also needed to move the profession forward. This can be provided by a single global association that represents all cost management professionals such as provided by the International Project Management Association (IPMA) for the project management profession. The International Cost Engineering Council (ICEC) currently provides this global representation. ICEC facilitates the networking and sharing of global information and knowledge to assist in the development of the profession and professional cost management standards across the globe. However ICEC operates on a very limited budget with no employees. Additionally the title of Cost Engineering may not be the best global descriptor.

Accordingly the development of an International Project Cost Management Association with appropriate funding and support from professional associations and firms across the globe would go a long way to developing the global identity of the profession. This may involve the restructuring of ICEC or the establishment of a new organization.

Global Professional Standards & Certification

The profession needs to develop common global standards, common bodies of knowledge and standard definitions/terminology. These standards could provide an over-arching platform that could then be adapted to suit local and regional requirements. Large global entities typically require

International Standards, International Certification and International Accreditation. Excellent standards already exist in many parts of the world (such as the AACE Total Cost Management Framework, the PAQS Competency Standards and the RICS International Standards). These could form the foundation for the development of global standards.

However a major challenge is developing global standard that incorporate the different approaches used by quantity surveyors and cost engineers. This may require minimum standards that can then be adapted to suit the particular requirements in various countries, regions and market sectors.

Measurement Standards for the Construction/Property Sectors

The most common standards developed for the project cost management profession are Standard Methods of Measurement for building work. Standard methods or measurement are also commonly prepared in many countries for civil engineering works. Cost management professionals generally adopt a Standard Method of Measurement that has been developed for their particular country, region or market sector or develop their own informal 'in-house' methods that meet their clients' needs. These standards are commonly adapted to suit particular measurement approaches and or client/market requirements. An example is the adaptation of a standard method of measurement to a more concise/abbreviated form.

The first Standard Method of Measurement (SMM) of building works dates back to 1922. This was prepared by the Royal Institution of Chartered Surveyors (RICS) in the United Kingdom. The RICS have subsequently developed numerous versions of this standard. The RICS standards have been widely adopted by the quantity profession in Commonwealth countries. Mills et al. (2006) found that the RICS SMMs are the most widely used around the world for the building sector. Nanil et al. (2008) reported on research that has shown that the use of SMMs is widespread. A global survey by the Building Cost Information Service (BCIS) identified 32 different SMMs in various countries (RICS, 2003) while Mills et al. (2006) identified 44 SMMs used in 32 countries. This research also found that many SMMs are amended versions of the RICS SMMs.

There has also been measurement standards developed on a regional basis. This includes a European Code of Measure developed by the European Council of Construction Economists and the Africa Standard Method of Measuring Building Work developed by the Africa Association of Quantity Surveyors. The Association for the Advancement of Cost Engineering International (AACE) have developed a Total Cost Management Framework (TCM) that is being increasingly used in many countries. The AACE are based in the United States but have sections in many countries around the world. Whilst not strictly a measurement standard it provides a standard for the whole cost management process.

However, research undertaken by the BCIS (2009) found substantial variations in the costs derived from various methods of measurement. Their research, undertaken in collaboration with the European Committee for Construction Economics (CEEC), found that costs varied by as much as 160% and costs per m2 varied by 140% with no clear correlation between the two. They commented that 'even though there had been a long held suspicion that comparing costs between countries was dangerous, the results came as a bit of a shock, particularly as cost per m2 tended to be the lingua franca in any discussions about costs in different countries. It was clear that, in arriving at cost per m2, different countries were including different costs and dividing them by different floor areas' (BCIS 2009, p.5).

Building on these research findings, the BCIS (2009) undertook an extensive international survey of measurement standards used around the world and found a range of important issues. The survey covered 40 countries. Key findings were that:

- 19 out of the 40 countries did not claim any published standard method of measurement or standard elemental classification of building parts.
- in the absence of locally agreed standards, professionals frequently adopt 'foreign' standards or ad hoc in-house developed standards
- there was no common way of expressing cost per m2, both in terms of the cost definition and the floor area
- there were many countries where the quality of cost information and data classification falls short of what local professionals might wish.

BCIS (2009, p. 4) concluded that *'although there are countries with quite complete cost related standards and information sources, there appear to be many more where the quality of published guidance and cost information falls short of what local professionals might wish'*.

The Problem – The Need for Global Measurement Standards

Business activity is increasingly global in nature with a concomitant increase in demand for consistent global standards and rules. The International Financial Reporting Standards are a prime example of this. The property and construction industries are certainly global with multi-national investment in property development and international partnering in large scale building and infrastructure projects. Muse (2015) contends that as 70% of global wealth is held in land and property the need for global standards in the construction/property industries is paramount.

PWC (2014) predict that global investable real estate will increase by more than 55% compared to 2012 and then expand by a similar proportion in the following decade. This will be dominated by emerging/developing markets. Muse (2015) argues that this rapid change in global investment with more focus on emerging/developing economies adds even more strength to the argument for global standards – emerging/developing real estate/construction markets generally have standards lagging well behind more developed countries.

Muse (2015, p.6) articulates the problem as follows. *'One factor which is hampering the efficiency of the market revolves around a lack of consistency about how costs and measurements are defined throughout different parts of the world. Imagine, for example, we were to say that a commercial building in Sydney costs $A3,000 per square metre to design and construct whereas one in New York costs $US2,500. As things stand at the moment, such a comparison would be affected not only by exchange rates but also by whether or not the 'cost' in each case includes or excludes finance costs or amounts paid for professional fees and whether or not the floor area in both cases includes or excludes space associated with balconies, car-parks or elevator shafts. In short, we have no straightforward way of comparing costs across international jurisdictions on a like-for-like basis'*.

Uncertainty and risks are a major inhibitor to investment in construction and infrastructure, often caused by a lack of comparable, consistent and collaborative standards. This lack of measurement standards means that construction projects, their inherent works elements and the resultant assets are incomparable from one geographical market to another. In addition, robust global benchmarks for cost, time, quality, risk and technology are not available.

Extensive research by Meikle and Gruneberg (2014, p. 126) found that *'consistent approaches are required as to what is included in, or excluded from, construction activity, and how variables should be measured and presented. This needs to take account of the data requirements of statisticians, policy makers, international bodies, industry, researchers and others. It is an international issue and needs to be addressed at that level; construction is too important a sector of the economy to be measured so poorly'*.

The lack of international measurement standards means that comparison of construction works between countries is typically inefficient, inconsistent and misleading for the unwary investor. This scenario creates a barrier to well-informed investment decisions, from commercial real estate portfolios, through to the individual dwellings and land rights of the poorest sections of society.
The Global Alliance for Buildings & Construction further the argument for the need for global measurement standards. *'Real estate markets are increasingly global. Whether constructing, buying, leasing or occupying property assets, global investment decisions crucially depend on transparency and comparability, regardless of where the investment originates from. Without it, markets are inherently risky and unsustainable. 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'* (GABC 2015, p.8)

Case Example - International Property Measurement Standards

These measurement problems have long been identified in the property sector. The IPMS (2018) comment that the way property assets are currently measured varies dramatically. For example, in some parts of the world it is established practice to include common space (lift shafts; communal hallways etc) in floor area measurements; in others off-site parking might be included or even swimming pools. With so many different methods of measurement in use, it makes it difficult for property users, investors, occupiers and developers to accurately compare space. IPMS (2018) cite research by global property firm JLL that showed that a property's floor area can deviate by as much as 24% depending on the measurement method used.

This led to a major global initiative to address this problem. Professional associations representing the property sector began joining forces in 2013 in collaboration with and the support of major global organisations such as the World Bank and the International Monetary Fund. They formed an International Property Measurement Standards Coalition (IPMSC) with a clear focus on global collaboration amongst professional associations.

It was very apparent that this initiative would not have been successful if it was developed by a small number of organisations – this would limit the global 'take-up' of the standards and would open up the standards to criticism/cynicism due to perceptions that they were influenced by the vested interests of these organisations. Focusing on global collaboration and ensuring that the coalition drove the standards development, rather than individual organisations, has seen the IPMS flourish in a very short space of time. A fundamental feature of the coalition was equal voting rights for each of the coalition members to help ensure that the standards are truly global rather than just cater to the needs of major organisations.

The IPMSC selected real estate experts from around the world to form its Standards Setting Committee (SSC) – the core group who would develop global standards for property measurement. Momentum built quickly and the International Property Measurement Standards Coalition (IPMSC) now comprises more than 80 professional and not-for-profit organisations from around the world (from a base of 34 foundation members) working together to develop and implement international standards for measuring property.

The first property measurement standard for offices was published in 2014. Importantly, this standard has been quickly endorsed and adopted by governments and clients in many countries. Further standards are currently being developed for the residential, industrial and retail sectors (IPMS 2018).

The International Construction Measurement Standard (ICMS)

The success of the International Property Measurement Standards (IPMS) initiative spawned the development of International Construction Measurement Standards (ICMS) with input and support from project cost management organisations around the world.

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 following outlines the development of this standard based on the author's involvement and the internal meetings and internal documentation/reports that have been prepared by the working groups (ICMS 2018).

The first formal meeting for the development of the standard was held in June 2015 at the International Monetary Fund (IMF) head office in Washington DC in the United States. The IMF and the World Bank were two early supporters of the initiative and continue to be so. The meeting resulted in the formation of the International Construction Measurement Standard Coalition (ICMSC) with 17 project cost management associations signing up as foundation members.

The IPMS development model was adopted for the ICMS. The purpose was to develop international standards that are recognized by world bodies and national governments. This would be ideally similar in character to the International Financial Reporting Standards (IFRS) outlined earlier that is universally adopted by the accounting profession and recognized by all major corporations and governments around the world. The objective is for professional associations to lead the development of common, internationally agreed standards. Working as a coalition of equals, it is planned that these professional bodies will have the authority and ability to drive forward common rules of engagement which practitioners will be responsible for delivering around the world (ICMS 2018).

Each professional association in the ICMS coalition appointed a trustee to represent them and the trustees then elected a trustee board. In line with the IPMS model, each trustee (i.e. each association) has one vote per body to help ensure real global participation and approval (and help offset perceptions that the initiative would be driven by the larger organisations). The trustees then set about appointing a Standard Setting Committee (SSC) comprising expert measurement professionals from around the world nominated by coalition members. They were tasked with developing the standards with a key criteria that they were not writing a standard representing their country, body or jurisdiction - conversely they were writing an international standard for the benefit of all stakeholders.

The ICMS coalition and support for the measurement standards grew quickly. The coalition has now grown from a foundation membership base of 17 professional associations in mid-2015 to a membership of over 40 associations by mid-2018. It was widely acknowledged that the development of a construction measurement standard would be more complex and difficult than the property measurement standard (which focused largely on floor areas) but these difficulties have been worked through.

One of the first things that the SCC recognised was that there was a need to cover both infrastructure and building works. Given the inherent differences between the two sectors the SCC decided to develop separate standards for these two sectors.

Key requirements for the standards were that they be:
- high-level, over-arching and principles-based
- cover both capital cost and whole life cost
-define construction cost (adopt universal definitions of construction costs and the associated variables)
- be consistent with the International Property Measurement Standards (IPMS) in terms of expressing cost per m2, but acknowledging the construction process
- provide consistent cost comparisons on a per m2 basis through consistency with the International Property Measurement Standard
- create a single classification system for building and civil engineering projects for use with digital tools such as BIM
- recommend a consistent data framework for the collation of national statistics
-be as simple as possible, commensurate with allowing robust comparisons to be made
- articulate with local measurement standards wherever possible
- recommend a standard reporting format
- allow global cost comparisons and benchmarking for global investors, corporate bodies and contractors
- provide a checklist for international best practice
- provide consistent language and terminologies for the worldwide and increasingly mobile profession
- accommodate the need for continuous refinement, updating and change.

The ICMS was launched in July 2017 and has also been translated into Chinese and Spanish. Further translations are now being developed. The coalition continues to work together to further develop the current standards and to also implement further international standards for benchmarking, measuring and reporting construction project cost.

The ICMS will enable governments and international bodies to compare the costs of construction of building and civil engineering works so that national costs can be benchmarked, the causes of differences in costs can be identified, properly informed decisions on the location of construction projects can be made, and the relative performance of the construction industry in different countries can be more readily determined.

Further Global Measurement Standards - BIM Measurement & Environmental Measurement

The variance in Building Information 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 but this is a small piecemeal approach to an industry wide problem.

The development of global BIM modelling standards for project cost managers has the potential to have project cost managers strategically placed to not only more effectively implement BIM and allied digital technologies on projects but to also be key members of the digital project team.

As mentioned previously, the Global Alliance for Buildings & Construction highlighted the need for global measurement standards for the environmental performance of buildings. This is another key area that the profession should be involved in and become key players in the environmental assessment of buildings through standardised measures.

The ICMS coalition provides the ideal platform to develop these global BIM Measurement and Environmental Measurement Standards as well as other standards for the profession.

ISO Cost Management Standard

A global standard would further provide significant recognition for the profession and would provide the basis for institutionalising the benchmarks for the profession based on mutually recognised international standards and best practices. The global project management community embarked on the development of an ISO Project Management Standard in 2007 and the ISO 21500:2012 Guidance on Project Management was finally published in September 2012. The process is not simple as demonstrated by the 5 years of development and this is only the first stage in developing a suite of portfolio, program and project management standards.

Project Cost Management Terminology & Baseline Body of Knowledge

The development of a global multi-lingual glossary for Quantity Surveying / Cost Engineering terminology and a Baseline Body of Knowledge for the profession would also help with the development of global standards for the profession.

A number of national associations have produced standard terminology and also baseline bodies of knowledge for their particular regions. These could provide the starting point for global publications. ICEC currently are working on a project to produce this global terminology and body of knowledge. This could then be further developed by the ICMS coalition.

Project Cost Management Certification Programs

The need for the development of Project Cost Management Certification programs vary amongst the various global regions. For example the certification, educational and Continuing Professional Development (CPD) programs of many cost management associations are well established with efficient systems and procedures. Particular needs for certification programs have been identified in Europe, the Middle East, India and countries where the profession has not been traditionally recognized.

ICEC is currently examining the feasibility of developing a certification program for the European region. Given the prominence of the project management profession in the region this will include collaboration with the International Project Management Association (IPMA) to examine the possibility of linking in with IPMA's well established global project management certification programs. It will also include working in collaboration with the ACostE and the AACE to see if their certification programs could be adapted for use in the European region. A longer term goal is to get professional project cost management qualifications officially recognised within the European Union (EU) to facilitate greater movement of cost professionals in the region.

However the development of a global certification program is worth considering. A good example of what is possible is the Chartered Global Management Accountant (CPMA) certification program. This program was introduced in 2012 by a joint partnership between the American Institute of Certified Public Accountants (AICPA) and the Chartered Institute of Management Accountants (CIMA). This provides a global CPMA designation for members who successfully complete the certification program (CGMA 2018).

A global certification program that provided a global chartered/certified project cost management designation would create numerous benefits and opportunities for the profession.

Engagement With Key Global Organisations

Effective engagement with major global organizations such as the United Nations (UN), the World Bank, the World Trade Organisation and the International Monetary Fund (IMF) are important steps for the development of the profession. This can be facilitated by high level global leadership outlined earlier. The United Nations is a particularly important organization. The UN Economic and Social Council (ECOSOC) coordinates the economic and social work of the UN and its family of organisations.

It plays a key role in fostering international cooperation for development, consults with Non Government Organisations (NGOs) thus maintaining a vital link between the UN and civil society. ECOSOC is the central forum for discussing international economic and social issues and for formulating policy recommendations. ECOSOC oversees several programs, funds and other bodies within the UN. UN programs, funds and agencies have regional/sub-regional and in several cases national offices all over the world. Some of the bodies relevant to the project cost management profession are: UN-HABITAT - United Nations Human Settlements Programme, UNEP - United Nations Environment Programme, UNDP - United Nations Development Programme, UNCTAD - United Nations Conference on Trade and Development and the ITC - International Trade Centre (UNCTAD/WTO). The UN ECOSOC also works with the World Bank, the International Monetary Fund, the United Nations Industrial Development Organization and the World Trade Organization.

CONCLUSION

Ultimately common standards, terminology and certification programs and international recognition will assist in the transportability of professional cost management services and raise professional standards across the globe. The development of global project cost management certification programs and global standards would provide the greatest scope for this.

The key to achieving this is collaboration between the project cost management profession and their representative professional associations on a global scale. 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.

The International Cost Management Standard (ICMS) initiative is bringing the profession (be they quantity surveyors, cost engineers or other project cost management professionals) together to develop 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 lack of global standards inhibits the development and identity of a profession. The ICMS initiative has much potential to provide the first step in the development of a range of much needed global standards. Recommendations for further study would therefore include research into other project cost management fields that would benefit from global standards such as BIM and environmental measurement standards.

The 'global passport' provided by achievement of the ' Chartered Global Management Accountant™' designation provides a good example of what is possible. The profession needs to come together for common good. Collaboration between the various project cost management associations around the world is the key for the global development of the profession

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THE IMPACT OF BIM ON QUANTITY SURVEYOR'S ROLE - THE CONTRACTOR PERSPECTIVE

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ABSTRACT

Purpose - This paper aims to identify the impact of Building Information Modeling (BIM) on contractors' Quantity Surveyor (QS)'s role and how the latest BIM tools affect QS functions in construction projects in Hong Kong.

Design/methodology/Approach - First, a comprehensive literature review was carried out to explore the antecedents of BIM and identify contractors' QS functions both in traditional and BIM-based environments. Latest BIM tools, which are adopted in performing QS functions, were then investigated. By conducting a questionnaire survey, types of BIM tools currently used for each QS function and learning sources of BIM were identified in the context of Hong Kong (HK) construction industry. The collected data was analyzed using descriptive and frequency analysis techniques by SPSS software.

Findings - Findings from the study suggest that QS's role has been shaped due to BIM implementation in construction. Improvements to current BIM education and the training of BIM tools are necessary. Thus, this research seeks to address the research gap by recommending academic and professional institutions to revamp the undergraduate programs, CPDs, and other relevant QS courses accordingly.

Originality/Value - Limited research has been undertaken regarding the impact of BIM on contractors' QS's role in construction. Especially, how project performance can be improved by contractors' QS's involvement in BIM-based environment has not been thoroughly examined. Further, contractors in Hong Kong are expected to adopt BIM models in most of the major construction projects as BIM implementation is being considered as a client's requirement for the award of tender. Therefore, it is necessary to investigate the impact of BIM on contractor QS's role as the QS's involvement is vital for performing major functions (i.e. quantification of works, cost monitoring and control, payment application preparation) of a construction project.

Keywords: BIM, BIM Education, BIM Tools, QS Functions, Quantity Surveyor

INTRODUCTION

The construction industry is one of the vital contributors to the national economy of any country (Blayse and Manley, 2004). Yet, the industry has faced several changes such as globalization, technological evolution and increased regulation which has led to a competitive environment (Horta and Camanho, 2014). In order to keep pace with this dynamic nature, the construction industry requires to be more innovative and informative (Aouad *et al*., 2010). However, compared to other industries, the construction industry has been criticized for being inefficient due to its excessive use of energy and natural resources as inputs and generation of extensive amounts of waste and greenhouse gases (Abanda *et al*., 2017, Winch, 2003, Xu, 2017).

In order to address the issue of inefficiency in the construction industry, Building Information Modeling (BIM) has been introduced. Several definitions are found interpreting BIM as a tool of communication, project management, cost management and information technology (NBIMS, 2015, Mordue *et al*., 2015). Among those, Mordue *et al*. (2015, p.16), defined the concept of BIM as "a process of combining information and technology to digitalize a project which integrates data and

information about the project from several sources and that model evolves with the complete timeline of the actual project". Kim and Park (2016) described that BIM tools enhance the productivity and fragmented practice in the construction industry. BIM has shaped the traditional role of construction professionals which was shaped by the traditional construction procedures (Liu *et al*., 2017). Thus, making holistic insights into refined job roles requiring upgraded skills and competencies become significant.

Quantity Surveyor (QS) is a key professional in a construction project, whose primary responsibilities are to perform cost management, procurement and involve in contractual issues during complete project life cycle (Olanrewaju and Anahve, 2015). RICS (2017) has defined the QS as an expert in the art of costing a building at it all stages. It further elaborates that a chartered quantity surveyor (CQS) is a well-trained professional who can advise on construction costs. The 'Charter' is a professional qualification which is obtained after qualifying under quantity surveying and construction APC (Assessment of Professional Competence) path way (RICS, 2017). The QS profession is recognized under two categories (Professional QS and Contractors' QS). Professional QS (PQS) is defined as the cost consultant to the client in a construction project and PQS involves in all stages in construction project from pre-contract cost advice to preparation and issuance of final accounts (Towey, 2012). The contractors' QS is different from PQS since pre-contract stage is excluded and bear the responsibilities of cost reporting, providing a flow of information to a contractor's supply chain, preparing payment applications and so on (Towey, 2012). The construction industry is changing with the development of technology, process and people (Olatunji *et al*., 2010) and BIM is one of the reasons for this changing nature (Arayici *et al*., 2011). Hence, exploring the QSs role in a BIM-based environment may help to identify how it can enhance the efficiency and effectiveness of the QS.

Hong Kong is one of few regions in which BIM is practiced. Hong Kong is also titled as the pioneer to embrace BIM in the region of Asia (HKCIC, 2014). Therefore, BIM development in Hong Kong has been a major research topic among practitioners and academia in the region. When considering the recent research carried out in the context of Hong Kong construction industry, significant number of studies have focused on BIM. Chan (2014) has investigated the barriers to implement BIM from the designers' perspective. The empirical results have shown that application of BIM is limited among designers due to several barriers such as lack of qualified in-house staff, lack of training/education, lack of standards and lack of client demand. Likewise, Wong *et al*. (2011) have studied the approaches used to educate BIM for tertiary construction students in Hong Kong and recommended the strategies required for the development of BIM education. A study by Lu, Chen, Wang and Zue (2017) has proposed a model for BIM open access library for ordinary users to enhance BIM implementation.

Moreover, having considered the BIM implementation in the perspective of construction industry professionals, Chan, Liu, and Chen (2018) have studied the QSs' ability to adopt with 5D-BIM. Other than that, no significant research was found on QSs' perspective on BIM in Hong Kong. Therefore, this study is aimed at investigating the impact of BIM on QSs' role in the Hong Kong construction industry. However, the research is narrowed down to contractors' QS' perspective considering the mandatory involvement of contractors on BIM implementation and development. For example, HKSAR government intends to adopt BIM in public sector construction projects and clients such as Housing Authority, MTRC and Airport Authority prefer to do their designs and constructions incorporating BIM (HKCIC, 2014). Therefore, contractors need to be competent with BIM if they are to survive and to adapt to evolving industry requirements. Hence, studying the impact of BIM on contractors' QS becomes a necessity. Based on this argument, the research question is formulated as "What contractors' QS functions are affected by adopting BIM in construction?"

The findings of this research are expected to use to explore the impact of BIM on QSs' role in relation to the QS functions in BIM-based environments. In addition, recommendations are given to contractors, academia and the government to enhance the efficiency of contractors' QS functions by expanding the adoption of BIM tools. Ultimately, this research is contributed to the development of

BIM in the Hong Kong construction industry. However, the recommendations made can be applied to different construction industries with necessary adjustments.

LITERATURE FINDINGS

Building Information Modeling (BIM)

A variety of definitions can be found for BIM with regarding its functions and purposes. Among those definitions, Succar (2009) identified BIM as a collection of interacting policies, processes and technologies which generate a methodology to manage a building throughout its life cycle using its data in digitalized format. Furthermore, Mordue *et al*. (2015), defined the concept of BIM as a process of combining information and technology to digitalize a project which integrates data and information about the project from several sources and that model evolves with the complete timeline of the actual project. Having considered both definitions, it is understood that BIM is a collection of information, policies, processes and technologies that can be used in managing a building throughout its complete lifecycle in a digitalized manner.

BIM is described as a socio-technical system since it contains technical components such as 3D modeling and social components such as process re-engineering (Liu *et al*., 2017). In addition, Ghaffarianhoseini *et al*. (2017) explained that BIM aims to enhance the collaboration within construction organizations which will increase the productivity while improving the design, construction and maintenance of construction projects.

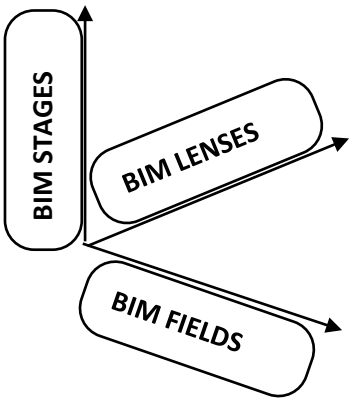
The idea of BIM initialized in the 1970s and, the Autodesk company brought the proposal for fostering BIM in 2002 (Xu, 2017). Since then, it gradually developed up to 5D BIM. According to Kymmell (2007), there are several functions of BIM such as planning and design (conceptual design, schematic design, cost analysis), development of 3D model, constructability analysis, construction scheduling, project management, project team management, construction process management and facilities and operation management.

When analyzing the above definitions and opinions, it is clear that BIM is directly attached to the projects in the construction industry. Therefore, understanding the construction industry and how BIM is adopted in construction projects is vital.

BIM Implementation

Several authors introduced models and frameworks indicating the BIM implementation process. Among them, Succar (2009) introduces a triaxial knowledge model as BIM framework (see figure 1). Those axes are BIM fields (technology, process and policy), BIM stages (modeling, collaboration and integration) and BIM lenses. Similarly, Khosrowshahi and Arayici (2012) also used the same concept to develop a roadmap for implementing BIM in the UK construction industry.

Figure 1 BIM Framework: Fields, Stages and Lenses — tri-axial model



Source: (Succar, 2009)

BIM and the Hong Kong Construction Industry

The construction organizations in Hong Kong adopt BIM in two ways as follows.

1. Clients such as MTRC, Hong Kong international airport and Hong Kong Disneyland handover their BIM models to the contractors upon the award of contract or tender for further development.
2. Some clients prefer to use BIM in the construction stage. They hand over their 2D drawings to the contractors and ask them to make the 3D model based on those drawings (HKCIC, 2014)

According to HKCIC (2014), the Hong Kong construction industry has adopted maturity level concept for implementing BIM. Further, HKCIC has proposed a detailed plan for BIM implementation.

In the Hong Kong construction industry, BIM is at an early stage in the adoption process. However, several practitioners are preparing themselves to adopt BIM in to their organizations while others closely observe pros and cons of BIM before considering the adoption (HKCIC, 2014). The initial step was taken by Hong Kong Housing Authority in 2009 by setting a target to apply BIM for all new projects by 2014. Then Hong Kong Institute of Building Information Modeling (HKBIM) issued a BIM standard to define the scope in 2011. Later in 2013, Architectural Services Department started a BIM training program for their staff and later several organizations started seminars and courses to educate BIM to the local industry. In 2014 and 2015, HKCIC developed a roadmap for BIM implementation (Ng and Lai, 2016).

The recent significant move from Hong Kong Special Administrative Region (HKSAR) government is publishing the circular for BIM adoption. According to Development Bureau (2017), HKSAR government set out policies for adopting BIM through the technical circular (Works) No. 7/2017 for capital works. As illustrated in the policy, capital works projects with the estimate over $30 million shall use BIM technology. In investigation, feasibility or planning stage, BIM adoption is optional and in designing and constructions stage, it is a mandatory requirement to adopt BIM. Therefore, it is certain that Hong Kong is rapidly adopting to BIM and most government and non-government institutes (i.e., Housing Authority, Buildings Department, Architectural Services Department, Airport Authority, MTR Corporation) use BIM for their projects.

BIM Tools

BIM tools are identified as BIM software applications which are used to generate, structure and manage design information (Escobar *et al*., 2012). These BIM tools also have interfaces for other functions such as rendering, energy analysis or cost estimation. According to Jason and Umit (2009), BIM tools are classified as follows:

1. Preliminary Tools: Preliminary space planning tools, preliminary massing and sketching tools, preliminary environmental analysis tools, Preliminary cost estimating tools.
2. BIM Design Tools
3. Structural Design Tools
4. BIM Construction Tools
5. Fabrication Tools
6. Environmental Analysis Tools
7. Construction Management Tools
8. Cost Estimation Tools
9. Specification Tools
10. Facility Management Tools
11. Mechanical Tools

Luciani *et al*. (2012) stated BIM has strongly supported software tools and many developments in software sector have come with a set of various rich functions that allows design activities to improve regarding quality, reliability, optimized scheduling, error and cost reduction and document management. When considering these definitions and opinions, it is understood that BIM tools are software applications incorporated with BIM to perform various functions within BIM environment.

Contractor Quantity Surveyor

QS Functions in Non-BIM Based/Traditional Environment

Contractors' QS performs jobs related to cost and the estimates on behalf of the contractor and agrees the estimated quantities with client's QS (Wao and Flood, 2016). Furthermore, authors agreed with the fact that contractor's QS performs different tasks compared to client's QS. Contractor's QS calculates the financial value of the work done and checks whether the contractor is paid accordingly. Additionally, they conduct site measurements, determine the site progress in interim payments and prepare project reports to support the smooth management of the project.

The Following table 1 illustrates the functions of contractors' QSs identified by different researchers.

QS Functions in BIM-based Environment

Construction industry is changing shape, and QSs have commenced exploring new potential roles for their services (Ashworth *et al*., 2013). The changing nature of construction industry can be identified as an evolutionary development as a function of technology, process and people (Olatunji *et al*., 2010) and BIM is one of the technologies adopted (Arayici *et al*., 2011).

Several functions of QS, which are performed in BIM-based environment are identified by many authors; i.e. (Wong *et al*., 2015, Ismail *et al*., 2016, Raphael and Priyanka, 2014). The following Table 1 illustrates which functions are benefitted/ affected by BIM environment, particularly relevant to contractors' QS. Seven out of thirteen Contractor's QS functions are affected by BIM. Therefore, QS professionals should fully aware the opportunities emerge through BIM in related to their current and future roles (Wu *et al*., 2014).

BIM tools used in Contractor QS Functions

BIM tools provide cost estimates more accurately with the use of available data in building geometry (Ismail *et al*., 2016). The following table 2 summarizes BIM tools used in performing contractor QS functions based on the empirical findings of pervious research.

In order to validate the literature findings and investigate the usage of BIM tools among contractor QSs, a questionnaire survey was then carried out.

Table 1 Traditional Contractors' QS functions

Traditional/BIM-based QS Functions	Non-BIM based/Traditional environment	BIM-based environment
F1: Quantification of works	RICS (2017); HKIS (2006); Mohd Shafiei and Said (2008); Fung *et al*. (2014); Oluwasuji and Onajite (2012)	Wong *et al*. (2015); Ismail *et al*. (2016); Raphael and Priyanka (2014); Kulasekara *et al*. (2013)
F2: Tender/ Bid Preparation	Olatunji *et al*. (2010)	-
F3: Cost monitoring and control	HKIS (2006); Lau (2012); Mohd Shafiei and Said (2008); Fung *et al*. (2014) Oluwasuji and Onajite (2012)	Ismail *et al*. (2016); Raphael and Priyanka (2014); Kulasekara *et al*. (2013)
F4: Project cash flow preparation	Olatunji *et al*. (2010); Tucker (1986)	-
F5: Value management	HKIS (2006) Lau (2012); Oluwasuji and Onajite (2012)	-
F6: Payment application preparation	HKIS (2006); Lau (2012); Mohd Shafiei and Said (2008); Fung *et al*. (2014); Cornick and Osbon (1994)	Wong *et al*. (2015); Raphael and Priyanka (2014); Kulasekara *et al*. (2013)
F7: Variations and claims preparation	Lau (2012); Fung *et al*. (2014); Cornick and Osbon (1994)	-
F8: Subcontractor Payment certificate preparation	Lau (2012); Cornick and Osbon (1994)	-
F9: Life cycle costing	RICS (2017); HKIS (2006); Lau (2012); Oluwasuji and Onajite (2012)	Ismail *et al*. (2016); Kulasekara *et al*. (2013)
F10: Risk Management	RICS (2017); HKIS (2006); Oluwasuji and Onajite (2012)	Zou *et al*. (2017); Musa *et al*. (2016)
F11: Financial reporting	Mohd Shafiei and Said (2008); Fung *et al*. (2014); Cornick and Osbon (1994)	Kulasekara *et al*. (2013)
F12: Progress reporting	Cornick and Osbon (1994)	Liberatore *et al*. (2001)
F13: Arbitration and dispute resolution	HKIS (2006); Mohd Shafiei and Said (2008); Oluwasuji and Onajite (2012)	-

Table 2 BIM tools for Contractors' QS functions

BIM tool/ Reference(s) QS Functions	BIM tool	Reference(s)
F1: Quantification of works	Autodesk QTO	(Kulasekara *et al*., 2013)
	BIM Measure	(Kulasekara *et al*., 2013)
	Autodesk Revit	(Olsen and Taylor, 2017); (Kim and Park, 2016)
	IES VE/ IMPACT[1]	(Olsen and Taylor, 2017); (Kim and Park, 2016)
	MasterBill QSCAD	(Liu *et al*., 2011)
	Tocoman	(Liu *et al*., 2011)
F3: Cost monitoring and control	Vico cost explorer	(Kulasekara *et al*., 2013)
F6: Payment application preparation	Bentley	(Kulasekara *et al*., 2013)
F9: Life Cycle Costing	IES Virtual Environment	(Kulasekara *et al*., 2013)
F10: Risk Management	Virtual Reality	(Zou *et al*., 2017)
	4D CAD	(Zou *et al*., 2017)
	GIS Seldom	(Zou *et al*., 2017)
F11: Financial reporting	Tocoman	(Liu *et al*., 2011)
	Vico office client	(Kulasekara *et al*., 2013)
F12: Progress Reporting	Primavera	(Liberatore *et al*., 2001)

RESEARCH METHODOLOGY

Quantitative approach is selected to proceed with this study to answer the research question "What contractors' QS functions are affected by adopting BIM in construction?". Survey method was adopted as the major research method. Having used the findings attained from the comprehensive literature review, the questionnaire survey was prepared and distributed via 'SurveyGizmo' online survey tool, and a priority has been given to the QS professionals who had worked in both traditional and BIM-based construction projects in Hong Kong.

1 Virtual Environment/ Integrated Material Profile and Costing Tool

The questionnaire survey consists of two parts. First is to explore the educational and professional background of each respondent. Respondents were asked to mention their position, experience in both non-BIM based and BIM-based environment, education level and the sources of BIM education obtained. Moreover, the adoptability of BIM-based in the sector (public, private or both) and project type (i.e., industrial, commercial, public housing, infrastructure) was questioned.

The second part was designed to identify the BIM tools used in performing different contractors' QS functions in Hong Kong construction industry. Respondents were asked to select the BIM tool (which were identified by the literature review) they are using for each function and rank their satisfaction regarding the BIM tool based on its performance. Moreover, all the contractors' QS functions identified in the literature review were listed out in the questionnaire to identify the functions which are performed without using BIM tools. Using those results, the recommendations are given to enhance the efficiency of contractors' QS functions by expanding the adoption of BIM tools.Responses to the questionnaire survey were analyzed using descriptive analysis and frequency analysis techniques using SPSS software. With the use of the responses received for the first part of the questionnaire, respondents level of BIM education and common sources for BIM education in Hong Kong were analyzed using frequency analysis. Next, the usage of BIM tools was identified, and descriptive analysis technique was adopted to analyze the respondent's satisfaction with each BIM tool.

DATA COLLECTION AND FINDINGS

Survey Responses and Profile of Respondents

Total 120 questionnaires were sent, and 24 e-mails were not delivered. Out of remaining 96, only 36 responses were received. These responses were a mix of participants who have BIM experience and non-BIM experience. Out of 36, 4 responses were partially completed, without responding any of the questions other than the type of job, years of experience and years of BIM experience. These 4 responses, therefore, were not considered for the analysis. Out of remaining 32 responses, 5 have been sent without having BIM experience. These 5 participants have not answered any of the Questions related to the impact of BIM tools on QS functions. However, they have answered the questions of 'most popular construction sector to adopt BIM' and 'most popular project type to adopt BIM'. To analyze these two parts, 33% (32 out of 96) of response rate is considered. To analyze the impact of BIM tools for each QS function, the response rate of 28% (27 out of 96) is considered. The following Table 3 summarizes the details of the responders.

Table 3 Details of the respondents

Job title	**Years of Experience (x)**			**Total**
	0<x<=5	**5<x<=10**	**x>=10**	
Quantity Surveyor	8	3	1	12
Senior Quantity Surveyor	0	3	1	4
Project Quantity Surveyor	1	1	0	2
Assistant Quantity Surveyor	2	0	0	2
Cost Manager	1	1	0	2
Cost Engineer	1	0	0	1
Project Manager	0	1	1	2
Engineer	1	1	0	2
Total	14	10	3	27

Having analyzed respondents' years of experience in BIM, only one respondent out of 27 have more than 5 years' experience where all the others were below five years. Even though almost half of the respondents (13 out of 27) are experienced in QS more than 5 years, experience in BIM is comparatively lesser.

Education Level

According to the survey results, 92% of respondents who have experience in BIM, have at least a bachelor degree.

Source of BIM Education

According to the survey results, the majority of 36% have gained the experience in BIM from the training given by the employer. 26% of respondents have named their source of learning as tertiary education. The third most significant mode of BIM education is web-based learning, mostly from tutorials and webinars which is 19% of the total.

Most Popular Construction Sector

Having analyzed the data using frequency analysis by SPSS software, both public and private construction sectors are popular in adopting BIM. Yet, out of both sectors, 31.3% of the respondents suggest that public sector projects gained more popularity in adopting BIM than the private sector in Hong Kong.

Most popular Construction Project Type

Public housing and office/commercial and infrastructure project types are highly popular to adopt BIM. Industrial, Institutional, hotels, Private residential, sports and recreational facilities and hospitals have comparatively lesser tendency to adopt BIM in the Hong Kong construction industry.

Impact of BIM Tools on Quantity Surveying Functions

Frequency analysis was performed for the responses on BIM tools for each QS function to identify the popularity of each BIM tool against each function. Figure 2 shows the response rate for each BIM tool for each QS function. Accordingly, 'Autodesk Revit' was selected by 70.4% as the highest rated BIM tool for F1: Quantification of works. The second highest rated BIM tool was 'Primavera' for F12: Progress reporting with 55.6% response rate. 'Virtual Environment' for F9: Life cycle costing, 'Bentley' for F6: Payment application preparation, 'Virtual Reality' for F10: Risk management and 'Vico Office Client' for F11: Financial reporting have obtained average popularity comparatively.

In contrast, 'Sketchup' for F1: Quantification of works, 'ArchiCAD' for F5: Value Management, 'Synchro-3D' for F12: Progress reporting, 'Autodesk Revit' for F13: Arbitration and dispute resolution and 'Bentley' for F12: Progress reporting have gained lesser response rate.

Results show that only few BIM tools (i.e., Autodesk Revit, Primavera) are largely being used in the Hong Kong construction industry. Also, the same BIM tool would not be equally efficient for a different QS function (i.e., Autodesk Revit for F1 and F13).

Figure 2 Summary of responses for each BIM tool

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
QS F1 - Autodesk Revit	19	70.4%	8	29.6%	27	100.0%
QS F1 - ArchiCAD	3	11.1%	24	88.9%	27	100.0%
QS F1 - Golden	4	14.8%	23	85.2%	27	100.0%
QS F1 - Sketchup	1	3.7%	26	96.3%	27	100.0%
QS F2 - Golden	3	11.1%	24	88.9%	27	100.0%
QS F3 - Vico Cost Explorer	2	7.4%	25	92.6%	27	100.0%
QS F5 - ArchiCAD	1	3.7%	26	96.3%	27	100.0%
QS F6 - Bentley	12	44.4%	15	55.6%	27	100.0%
QS F9 - Virtual Environment	13	48.1%	14	51.9%	27	100.0%
QS F10 - Virtual Reality	11	40.7%	16	59.3%	27	100.0%
QS F10 - 4D CAD	6	22.2%	21	77.8%	27	100.0%
QS F11 - Vico Office Client	10	37.0%	17	63.0%	27	100.0%
QS F12 - Primavera	15	55.6%	12	44.4%	27	100.0%
QS F12 - Synchro-3D	1	3.7%	26	96.3%	27	100.0%
QS F12 - Bentley	2	7.4%	25	92.6%	27	100.0%
QS F13 - Autodesk Revit	1	3.7%	26	96.3%	27	100.0%

a. Limited to first 100 cases.

Descriptive Analysis

In the questionnaire survey, participants were asked to select the level of satisfaction for each BIM tool for each QS function. It is assumed that only one BIM tool is/was being used for a particular QS function in construction organizations. i.e., Autodesk Revit to perform quantification of works.

The seven-point Likert scale was provided in the questionnaire survey against each QS function asked the respondents to rank the level of satisfaction of efficiency ranging from 'Completely dissatisfied' to 'Completely satisfied'.

The following Figure 3 illustrates the mean values and standard deviations of satisfactory level for each BIM tool against each QS function. The results were generated from SPSS software after performing descriptive analysis on the Likert scale responses received. For the analysis, an index value is given for each point of the Likert scale. The value allocation as 1 – completely dissatisfied, 2 – mostly dissatisfied, 3 – somewhat dissatisfied, 4 – neither satisfied or dissatisfied, 5 – somewhat satisfied, 6 – mostly satisfied and 7 – completely satisfied. Mean value is used to compare the level of satisfaction and the varied level of satisfaction from the mean value can be identified from the standard deviation.

Figure 3 Results of descriptive analysis of the impact of BIM tools on QS functions

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
QS F1 - Autodesk Revit	19	2.00	7.00	5.6842	1.10818
QS F1 - ArchiCAD	3	5.00	7.00	5.6667	1.15470
QS F1 - Golden	4	5.00	6.00	5.2500	.50000
QS F1 - Sketchup	1	6.00	6.00	6.0000	.
QS F2 - Golden	3	5.00	5.00	5.0000	.00000
QS F3 - Vico Cost Explorer	2	6.00	6.00	6.0000	.00000
QS F5 - ArchiCAD	1	5.00	5.00	5.0000	.
QS F6 - Bentley	12	4.00	6.00	5.3333	.65134
QS F9 - Virtual Environment	13	4.00	6.00	4.9231	.75955
QS F10 - Virtual Reality	11	4.00	7.00	5.0000	1.00000
QS F10 - 4D CAD	6	5.00	7.00	6.0000	.63246
QS F11 - Vico Office Client	10	4.00	7.00	5.1000	.87560
QS F12 - Primavera	15	4.00	7.00	5.6000	.82808
QS F12 - Synchro-3D	1	6.00	6.00	6.0000	.
QS F12 - Bentley	2	6.00	6.00	6.0000	.00000
QS F13 - Autodesk Revit	1	6.00	6.00	6.0000	.
Valid N (listwise)	1				

Considering the mean values, all the BIM tools were scored 5 or above 5 (somewhat satisfied or above) except 'Virtual Environment' for F9: Life cycle costing. Highest standard deviation of 1.1547 was recorded for 'ArchiCAD' against QS function F1: Quantification of works and second highest was for 'Autodesk Revit' for the same function. The standard deviation was 0 for 3 BIM tools and those are, Golden for F2: Tender/ Bid preparation, 'Vico Cost Explorer' for F3: Cost monitoring and control and 'Bentley' for F12: Progress reporting. No standard deviation was calculated for BIM tools which have only one response.

DISCUSSION OF THE FINDINGS

Table 4 Research findings on usage of BIM tools for QS functions

QS function	**BIM Tools**	
	From Literature findings	**From Questionnaire Survey**
F1: Quantification of works	Autodesk QTO, BIM Measure, Autodesk Revit, IES VE/IMPACT, MasterBill QSCAD, Tocoman	Autodesk Revit, ArchiCAD, Golden, Sketchup
F2: Tender/ Bid Preparation	-	Golden
F3: Cost monitoring and control	Vico cost explorer	Vico cost explorer

F4: Project cash flow preparation	-	-
F5: Value management	-	ArchiCAD
F6: Payment application preparation	Bentley	Bentley
F7: Variations and claims preparation	-	-
F8: Subcontractor Payment certificate preparation	-	-
F9: Life cycle costing	IES Virtual Environment	IES Virtual Environment
F10: Risk Management	Virtual Reality, 4D CAD, GIS Seldom	Virtual Reality, 4D CAD
F11: Financial reporting	Tocoman, Vico Office Client	Vico Office Client
F12: Progress reporting	Primavera	Primavera, Synchro-3D, Bentley
F13: Arbitration and dispute resolution	-	Autodesk Revit

As illustrated in Table 2, ten QS functions were recognized to use BIM tools in construction projects. Three QS functions: *Project cash flow preparation, Variations and claims preparation and Subcontractor payment certification preparation* were filtered to have a zero impact by BIM tools.

Questionnaire survey results indicate that, three QS functions, Tender/ Bid preparation, Value management and Arbitration and dispute resolution are performed using BIM tools in the Hong Kong construction industry even though there is no literature about these functions being performed in a BIM based environment (See Table 1). However, according to the response rates generated, the popularity of these three functions in BIM based environment is inconsiderable. According to the researcher's point of view, there are no tailormade BIM tools for these three functions. Therefore, no written evidence could be found. However, companies get the aid of some BIM tools to perform sub functions of these main QS functions. For example, ArchiCAD or Autodesk Revit can be useful in acquiring quantity information and Primavera can be useful in acquiring progress information for the function of Value management. Accordingly, 77 % of traditional QS functions are affected by BIM and therefore, it is concluded that BIM has a greater impact on QSs role in the construction industry. Even though some functions cannot fully perform using a specific BIM tool, some tools can be incorporated as accessories. For example, in subcontractor payment certificate preparation, QS has to cross check the accuracy of the quantities included in the payment application. Similarly, the payments should be approved for the actual progress of the project. These data can be obtained with using BIM tools such as Autodesk Revit and Primavera. Furthermore, when preparing variation and claims, QS can get the support of Autodesk Revit or ArchiCAD to obtain quantities of the varied work. In such a way, all these QS functions can be performed fully or partially with use of BIM tools.

Popular BIM Tools for Performing Contractors' QS Functions in the HK Construction Industry

Based on the results, Autodesk Revit (for F1: Quantification of works and F13: Arbitration and dispute resolution), Bentley (for F6: Payment application preparation and F12: Progress reporting), Virtual Environment (for F9: Life Cycle Costing), Virtual Reality (for F10: Risk management), Primavera (for F12: Progress reporting) and Vico Office Client (for F11: Financial reporting) are the most popular BIM tools among contractor QSs in Hong Kong. In researcher's point of view, Bentley can be used even for F3: Cost monitoring and controlling, F8: Sub-contractor payment certificate preparation, F9: Life cycle costing and F11: Financial reporting.

Recommendations for Enhancing the Efficiency of the Contractors' QS Functions through BIM Adoption

To Contractors

No BIM tools were used for three QS functions: F4: Project cash flow preparation, F7: Variations and claims preparation and F8: Subcontractor payment certificate preparation. Construction System and Jobpac Connect by Viewpoint are suggested for F4, PriMus IFC is suggested for F7 and eSUB Bolt Subcontractor software is suggested for F8 respectively. These tools were obtained from developer websites and contractors are advised to do more research on these BIM tools in terms of their price, reliability and efficiency.

Moreover, Wang *et al*. (2015) have explicitly recommended five major actions as the BIM strategies of contractor organizations which are (i) form partnership with IT software company to obtain efficient service of BIM tools and processes, (ii) utilize the ICT technologies and refine the working processes, (iii) have a BIM friendly organizational structure, (iv) adaptation of BIM friendly procurement arrangements and (v) use of BIM functions to leverage the tendering and mange external relationships. Considering these suggestions, researcher also recommends the contractors to follow those as much as possible. Particularly, continuous training and helping employees gain required BIM knowledge i.e. (Wang *et al.,* 2015) is also suggested by the researcher.

To the Government

Survey results suggest that adoptability of BIM is higher in both public and private sectors. Yet, priority has given to the public projects. Considering the project types, only Public housing, office, commercial and infrastructure project majorly inherit BIM (see Figure 5.6). Even though the government set out regulations and standards to implement BIM, collaborating with Hong Kong housing authority, Hong Kong construction industry council (HKCIC), MTR Corporation and other related institutions, execution of those standards should be streamlined. Involvement of the contractors and private clients should be encouraged by promoting BIM and providing incentives. For example, the government can reduce tax and government fees for BIM adopted construction projects. Moreover, HKCIC, Hong Kong Institute of Building Information Modeling (HKBIM) can increase BIM training programs among construction professionals.

Similarly, Wong (2018) has mentioned that resource utilization should be done during planning of BIM execution. Researcher agrees with that suggestion as the HKSAR has the authority and capacity to do resource planning for public housing projects. Likewise, Chan (2014) stressed the point that the government and the professional bodies are required to improve the uptake of BIM by providing guidance/training on BIM, defining levels of BIM working and developing data exchange standards and new forms of contracts.

To the Academic/Professional Institutions

According to the questionnaire survey results, most of the participants have obtained the knowledge on BIM through the training programs run by the Employer. The popularity of training programs by the employer can be reasoned due to lack of update of curriculums run by the Educational institutions. Even though academic programs are up to date, only the theoretical aspects of BIM are taught. Practical knowledge can be obtained only from the Employer. Therefore, modules should include a hands-on experience of BIM. Smith (2014) also agrees with the fact that BIM education should be provided at tertiary level so that the graduates will have the required BIM knowledge and capabilities at the time they enter in to the industry.

Furthermore, educational institutes should focus on two groups, young QSs who are about to enter into the industry and the QSs who are already in the industry with several years of experience. Currently, Vocational Training Council (VTC) and Institute of Vocational Training (IVT) offers BIM training in their higher diploma programs and these programs should be updated and promoted accordingly. This suggestion tallies with Wong *et al*. (2011) as they have pin pointed some challenges faced by of BIM education applications such as lack of reference materials, model development not following the construction sequence, lack of efficiency of BIM software, limited choices of component databases and knowledge required to use BIM software. These should be addressed by academic/professional institutions.

In brief, contractors, the government and academic/professional institutions should conduct research and developments in this area. Continuous learning and knowledge sharing among professionals and organizations are also important. These three sectors have both individual and shared responsibility in implementing BIM properly in the Hong Kong construction industry and increasing the efficiency of performing various functions in a BIM based environment.

CONCLUSIONS AND RECOMMENDATIONS

To investigate the impact of BIM on contractor QSs' role research was carried out in two stages. First, thirteen key QS functions (Quantification of works, Tender/Bid preparation, Cost monitoring and control, Project cash flow preparation, Value management, Payment application preparation, Variations and claims preparation, Subcontractor payment certification preparation, Life cycle costing, Risk management, Financial reporting, Progress reporting and Arbitration and dispute resolution) were identified and then, BIM tools being used for each QS function were identified by literature and survey findings. It was found that, ten QS functions out of thirteen (Quantification of works, Tender/Bid preparation, Cost monitoring and control, Value management, Payment application preparation, Life cycle costing, Risk management, Financial reporting, Progress reporting and Arbitration and dispute resolution) were impacted by BIM. Therefore, it is concluded that BIM has a significant impact on contractors' QS functions.

Moreover, the most popular BIM tools being used for contractor QS functions in the Hong Kong construction industry were also recognized as: 'Autodesk Revit', 'Bentley', 'Virtual Reality', 'Primavera' and 'Vico Office Client'. In addition, 'ArchiCAD', 'Golden', 'Sketchup', 'Vico Cost Explorer' and Synchro 3-D.

For the three QS functions which BIM tools were not used, potential software such as Construction System and Jobpac Connect by Viewpoint for F4, PriMus IFC for F7 and eSUB Bolt Subcontractor software for F8 were suggested as well.

Recommendations were suggested based on three groups, contractors, Government and Academic/ professional institutions. It was suggested that contractors need to focus on obtaining the best and most suitable BIM tools for their projects and increase the amount and scope of BIM training for the employees. It is also suggested to fully or partially incorporate BIM tools for functions which are performed without BIM, to increase the efficiency of QSs.

Suggestions for the government are basically focused on promotion and implementation of BIM in the Hong Kong construction industry. Attracting private clients, redefining policies, providing incentive schemes to the projects which are adopting BIM are the suggestions given. Furthermore, it is recommended that educational and professional institutes need to focus more on providing practical BIM exposure with the theoretical background.

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THE IMPACT OF EDUCATION ON CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT IN VICTORIA

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Construction and demolition (C&D) waste is surplus materials or solid waste produced during any construction or demolition activity. In Australia, in 2010-2011, 14,491,073 tonnes of C&D waste was sent to landfill. This wastefulness and unsustainability is due to behaviour and attitudes suggesting that the general population would rather waste mindlessly than preserve resources thoughtfully. Thus, the aim of this research is to explore the role of education in improving C&D waste management in Victoria. This research was undertaken via meta-analysis of published literature on the issue of sustainability, with reference to waste and C&D waste and web-scan of secondary data from schooling, tertiary and alternative education websites to analyse the educative methods related sustainability and waste management. Across Victorian schools, sustainability education is of a high standard with the implementation of an initiative known as 'ResourceSmart', in which students are enabled to make decisions and physically help in making their school and community more sustainable. Alternate education was also analysed for its effectiveness and techniques in conveying sustainability content. Five Victorian campaigns were found to be utilising three different techniques to educate and raise awareness around sustainability; training, recognition awards and commitment. It was also found that each of these techniques coincided with four education techniques; social, deep, strategic and surface learning. Overall in Victoria, school level education helps students build a strong body of knowledge in regards to sustainability. This sentiment is not fully reflected at tertiary level as the sustainability knowledge acquired at school is only partially built upon, leaving much to be desired. Alternative education offers an effective informal route to educate on sustainability and C&D waste management, although to be effective the audience must be targeted. These findings will be beneficial for policymakers to improve C&D waste management practices in future projects.

Keywords: Construction and Demolition Waste, Education, Environment, Sustainability, Waste Management.

INTRODUCTION

Consideration towards human responsibility to the environment is constantly being reviewed. As the fight to reduce the negative impacts on the environment from human activities continues, identifying the catalysts to inspire change and improve sustainability processes could not only win the fight but ultimately the battle too. Wasteful actions as a result of high resource consumption are linked to increased air, water and soil pollution (Gao and Tian 2016). Although individuals may be aware of the wasteful tendencies of society and attempt to make environmentally conscious decisions, often good intentions do not come to fruition. Lin and Chang (2017) found that it is far easier to waste resources without thought, rather than intentionally preserving them. Van den Bergh (2011) further highlights that good intention may be the driver behind conservation, rather than an in-depth knowledge and good oversight of all its consequences. This is a dangerous ideology when it comes to sustainability as the consequences of being a wasteful society do not change, but society's actions change, regardless of intention or consequence, varying the outcome and inevitably exacerbating the consequences. This attitude and the behavioural problem can occur due to the perceived cost, time, inconvenience and effort to change habits (Lin and Chang 2017). Adverse to any initiative to care for the environment, the 'rebound effect' is an organically occurring phenomenon that continues to exist. Research by Van den Bergh (2011) uncovered that intentions or policies aimed at conservation and sustainability may simply aggravate, rather than alleviate, environmental pressures due to the perception that more resources can be used, purely because the said resource is 'green' or environmentally friendly. Thus, current behaviours and attitudes defeat the purpose of sustainability because over-consumption of

resources will have adverse effects, irrespective of the resources apparent environmental impact. Lu and Yuan's (2010) exploration found that awareness of resource saving and environmental protection were catalysts for C&D waste management. They highlighted the importance of integrating education and training on C&D waste in training courses, universities, research institutions and government departments. Thus, the primary aim of this research is to explore the role of education in improving C&D waste management in Victoria.

LITERATURE REVIEW

Construction and Demolition Waste and Waste Management

Construction and demolition waste accounts for approximately 35% of solid waste going to landfill globally (Ajayi and Oyedele 2017; Ajayi et al. 2015). Ajayi and Oyedele (2017) and Lu and Tam (2013) report that in Australia, 44% of waste sent to a landfill is created in the construction industry. In their study Udawatta et al. (2015) ranked C&D waste management causes and highlighted the existence of few incentives and resources for C&D waste management in Australia. The Environment Protection and Heritage Council (2009) defines waste as any discarded, rejected, unwanted, surplus or abandoned matter intended for recycling, reprocessing, recovery, re-use, or purification by a separate operation from that which produced the matter, or for sale, whether of any value or not. Wu et al. (2017) point out that C&D waste is a resource that has been wrongfully placed. This ideology provokes the industry to consider if any by-product of construction or demolition is actually waste, or simply an untapped resource that needs conversion. Derivatively, placement of effective management systems for C&D waste can encourage economic and fiscal benefits to any given construction project or the industry in general (Ajayi et al. 2015; Wu et al., 2017). This could be achieved by job creation for specialist facilities designed to handle what is currently considered C&D waste (Ajayi et al. 2015; Victoria 2009), as well as cost savings for disposal. This process will hereafter result in the conservation of land area due to the reduction in waste going to landfill (Wu et al., 2017). When given perspective, Ajayi et al. (2015) report that previous evidence displays that in the United Kingdom construction industry a reduction of 5% of C&D waste would result in an industry-wide saving of up to £130million. These sentiments are echoed by the State Government of Victoria (2009, p. 3), through the implementation of a strategic plan that aims towards a production of zero waste. These factors will have fiscal and environmental benefits that exceed the cost of implementing a policy.

The Western Australia Local Government Association (2012) defines C&D waste management as avoiding generating and sending waste and excess materials to landfill, whilst maximising the number of materials sent for reuse, recycling or to be reduced. Therefore, effective C&D waste management can be divided into five areas: avoid, reduce, reuse, recycle and disposal. Avoid refers to avoiding the generation of C&D waste at the source and therefore stopping waste entering landfill, and the need for treatment at the end of its lifecycle (Broujeni et al. 2016). A number of factors corresponding with this strategy include: design for material optimisation (Ajayi et al. 2017), awareness of C&D waste management (Lu and Yuan 2010), research and development in waste management (Omran and Eltayed 2016), vocational training in waste management (Lu and Yuan 2010), stringent legislation, regulations, policy and incentives (Akinade et al. 2017), increased targets for design (Ajayi and Oyedele 2017), improving communication amongst project participants and material usage and storage system (Omran and Eltayed 2016).

Reducing as a strategy to manage C&D waste is closely aligned with avoiding. By reducing waste, much like avoiding, the amount of generated waste is diverted from landfill because it is non-existent. Factors for reduction are: fewer design changes (Lu and Yuan 2010; Wang et al., 2014), deconstruction design process and competencies (Ajayi et al. 2017; Akinade et al. 2017), material recovery (Ajayi et al. 2017; Akinade et al. 2017), prefabrication (Ajayi et al. 2017), modular design (Wang et al., 2014), low-waste construction technologies, improving conventional construction processes (Omran and Eltayed 2016), sorting ability of waste (Wang et al. 2010), better management (Wang et al. 2010),

waste reduction investment (Wang et al., 2014), taking waste management into consideration in bidding and tendering (Omran and Eltayed 2016) and waste efficient procurement (Ajayi et al. 2017). Reusing, what would otherwise become waste, is an effective way of diverting surplus construction materials from landfill, whilst requiring minimal processing. This can be done through material reuse (Ajayi et al. 2017; Akinade et al. 2017), use of reusable formwork (Wang et al., 2014) and building flexibility (Ajayi et al. 2017; Akinade et al. 2017). Not dissimilar to reuse, recycling also helps alleviate pressure on landfills, and therefore the environment, by reusing materials, but requiring some processing. Factors in regards to this are: manpower (Wang et al. 2010), site space (Wang et al. 2010), equipment for sorting of C&D waste (Wang et al. 2010), on-site waste supervision systems (Omran and Eltayed 2016), waste management systems (Lu and Yuan 2010; Omran and Eltayed 2016) and a market for recycled materials (Wang et al. 2010). More than 40 years ago, Spivey (1974) proposed optimum methods of disposal by introducing four steps: evaluate and estimate the volume of waste generation; establish the possibility of recycling; evaluate the available disposal options; and match disposal options to the volume and composition of waste taking into consideration the economy, environmental protection and resource depletion.

Impact of Education on Construction and Demolition Waste Management

Lu and Yuan (2010) found that awareness of resource saving and environmental protection were catalysts for C&D waste management. As a new generation is phased into the construction industry, research shows that education and training on C&D waste has been included in many training courses, universities, research institutions and government departments (Lu and Yuan 2010). This is a potential response to alternate research suggesting that managers' and labourers' minimal education on C&D waste can be a contributing factor to waste generation (Omran and Eltayed 2016). As an extension of education, it has been suggested that research and development on C&D waste management should be led by the government and focus mainly on government policies, companies' internal waste management systems and technology into waste management, with the primary aim to provide guidelines and support for avoiding, reducing, reusing, recycling and disposal of C&D waste (Lu and Yuan 2010; Omran and Eltayed 2016). Existing research strongly agrees that the skill-level of workers is a major influence on waste generation as insufficiently trained participants in construction are likely to mishandle, misuse and misplace materials, resulting in higher levels of waste, leading to the inevitable need for an on-site waste supervision system (Lu and Yuan 2010; Omran and Eltayed 2016). Similarly, it is important that all appropriate managerial participants commit to a synergetic environment so that a common goal of improved C&D waste management can be achieved (Wang et al. 2010).

Different levels of education can be helpful to improve C&D waste management practices including the primary and secondary school levels, tertiary education, professional development, and alternative or informal education. Research undertaken by Park et al. (2016) promotes a modernised process, virtual reality (VR) to formally educate students. It is thought that traditional learning, like that of lectures and tutorials, is ineffective and insufficient for construction as they are notoriously low unstimulating and the content is distant from reality (Park et al. 2016). The proposed alternative, VR, has been found to be more valuable and engaging than traditional classroom-based learning as students have a simulated experience (Park et al. 2016). This could be the possible solution to the problem identified by McKenzie-Mohr (2011) that education by itself is simply not enough to encourage consistent sustainable behaviour, but rather additional measures must be taken to reinforce good practice. Supplementary to this, Moore's (2005b) investigation lists recommendations to potentially improve tertiary sustainability education. They are: infuse sustainability in all decisions, promote and practice collaboration, promote and practice transdisciplinary, focus on personal and social sustainability, integration of planning, decision-making and evaluation, integration of research, service and teaching and create space for pedagogical transformation (Moore 2005b). Thus, it is important to understand the current educative methods available and their characteristics, to

determine their effectiveness to educate on sustainability. A study conducted by Warburton (2003) uncovered three formal techniques for education, which includes surface learning, strategic learning and deep learning. Surface learning is molded around memorisation and simple descriptions, merely learning the basics of a topic. Strategic learning, however, attempts to maximise academic achievement with minimal effort by utilising the competitive nature of education to induce learning. Deep learning is education on a more stringent level, requiring more attention from students to discover the depth and complexity of the topic, not just what the topic is. From these, deep learning is identified as the most valuable in revitalising and introducing sustainable education, combining the mastery learning and discovery learning so that a solid core is provided, but areas can be further explored if students are interested (Warburton 2003). However, Moore (2005a) has identified four barriers specific to sustainability education, including: the disjointed nature of inter-discipline education and how this hinders development of students, the competitive environment in education between disciplines and students, the misdirected criteria for evaluation thrust upon students and unclear priorities, decision-making and power (Moore 2005a).

A consultancy report prepared by URS (2003) for the Environmental Protection Authority and the Government of South Australia outlines campaign and message delivery requirements for effective sustainability content. A media campaign as a tool for promotion can include television, websites, promotional materials, signage, displays and booklets (URS 2003). Vehicles to raise awareness throughout the community are not limited to the aforementioned, but networking with social groups and face-to-face communication are also effective means of education (URS 2003). As a campaign on sustainability does not yield results immediately, as that of a product or service, special consideration must be given to focusing on: providing a sincere reason to recycle, identifying attitudes of the community and their collective wishes for a change and frequently exposing the population to important credible campaign information about waste generation and sustainability (URS 2003). Wals et al. (2009) discuss the importance of using different perspectives when educating and is designed to be used when people are learning about sustainability from one another. However, social learning is more than just learning from each other, it is about creating a trust, social cohesion and social ownership in regards to learning processes and outcomes. Social learning as a tool identifies the importance of not what an individual necessarily knows, but how they learn, what they want to know, how they evaluate and resolve a social issue and what skills and knowledge are required to achieve the ultimate goal of sustainability (Wals et al., 2009).

RESEARCH METHOD

In-depth exploration of published academic literature provided the study with qualitative data to be compared with secondary data that was collected and analysed via a web-scan. Web pages scanned for content included: government initiatives at the primary and secondary school level, a multitude of tertiary institutes in regards to the subjects offered and their sustainability content, and Victorian campaigns in relation to raising awareness in the community through alternative or informal education methods and recognition awards.

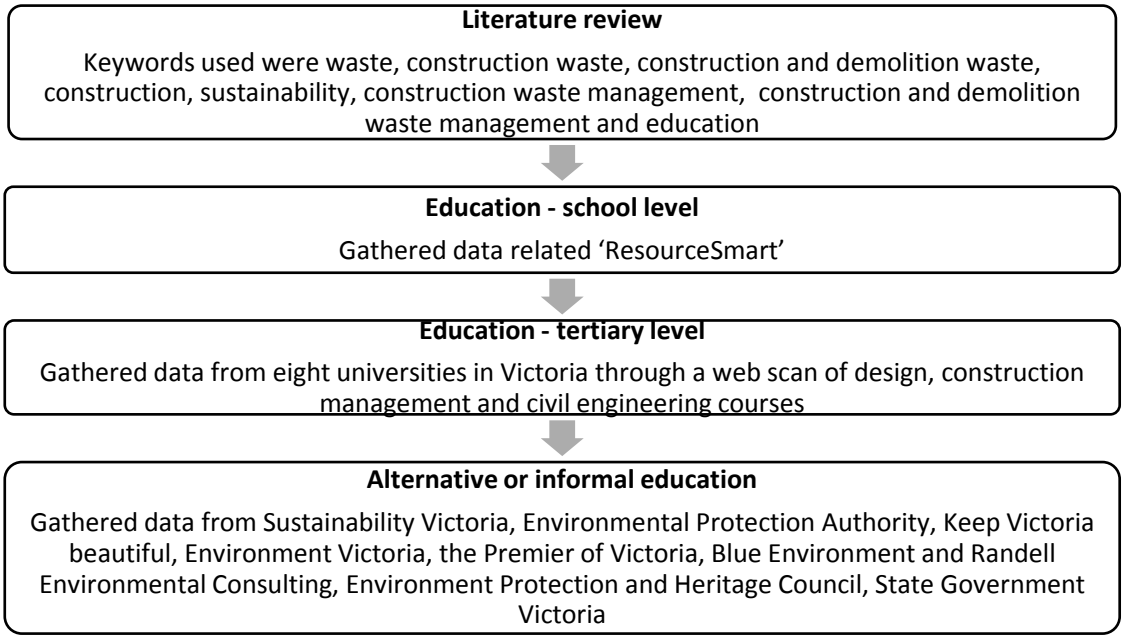

Figure 1 Process of data collection

As shown in the above diagram, education was broken into three categories or levels, those being: school, tertiary and alternative or informal education. While C&D waste management is not specifically taught at school, tertiary and informal levels, education-related sustainability was considered in this research to evaluate education in C&D waste management. Data related to school education was obtained through Sustainability Victoria's initiative 'ResourceSmart', an interactive educational process that is implemented across Victorian schools. This program was examined for qualitative data to uncover the processes implemented to promote sustainability and the effectiveness of it, evaluated through assessing 'ResourceSmarts' overall achievements.

In order to analyse the amount of sustainability content at tertiary level, core subjects were identified and analysed in each undergraduate course of eight selected universities in Victoria. Electives are often allowed from a variety of fields, relevant and irrelevant to construction, therefore the focus was placed firmly on core subjects. Of the eight universities across the three disciplines, there are eighteen undergraduate courses, each with their own set of subjects. A total of 412 subjects were analysed for sustainability content. An initial word search for keywords was undertaken. Due to education not usually specifically referencing C&D waste, the link to sustainability was drawn upon, and a search of the following four words was carried out: sustainability/sustainable, environment/environmental, impact and waste. Whether or not this search returned results, the description, outline and requirements for every subject were read to identify any sustainability conscious undertones. A spreadsheet was created and notes were taken on every subject as to their link to sustainable content. Each subject was assigned a zero, one or two, corresponding directly with the worth (credit points) of the subject within its courses context. That is, a subject assigned a two was worth twice that of a regular unit, but a subject assigned a zero was not worth anything, and therefore did not affect the results but was compulsory for the successful completion of the given course. Subjects were then grouped according to their area of education including science & maths, construction, design, management, finance, law & business, history and university-specific subjects. This helped define the areas of study that are best covering sustainability. An overall analysis was also carried out to evaluate which of the three disciplines, architectural design, construction management or civil engineering, best-considered sustainability. Ultimately, an overall result was found as to what percentage of subjects, across courses deemed to be considered 'construction' based, have sustainability content.

Alternative or informal education data were analysed by identifying five campaigns running in Victoria to raise awareness around sustainability, in not only the construction industry but in everyday living.

FINDINGS

Sustainability Education at School Level

In order to raise awareness and the profile of the environment, the 'ResourceSmart' Schools initiative was instigated and created by Sustainability Victoria and the Victorian State Government. 'ResourceSmart' presents an opportunity to not only teach students about sustainability in their formative and most impressionable years but let them physically contribute to making individual public schools sustainable. This concept aims to integrate sustainability into everything students do and produce intangible benefits that will ultimately encourage the continuation of sustainable practice in individuals' personal lives from a young age. There are many aspects to the program in regards to society's environmental responsibilities including minimising waste, saving energy, conservation of water, promoting biodiversity and reducing greenhouse gas emissions. Since 'ResourceSmart' establishment in 2003, the statistics for participating schools have been documented. Partaking in the program are 1022 schools across Victoria, with students and staff working together to implement sustainable practices. In accordance with environmental regulations, twenty-six of participating schools have achieved a five-star rating. Combined, all of these schools have saved $5,200,000 through sustainable practices (SV 2013b). Within the program, there are five modules that a school can complete, each with a set of criteria that must be fulfilled before being credited with that module as shown in the following table. As per Table 1, there are sixty-three actions within the waste module, of which forty-seven must be completed.

Table 1 ResourceSmart modules (SV 2013a)

Module	Description	Minimum Actions
Core	Evaluate where you are, where you want to get to, and how you will get there	23 of 24
Biodiversity	Protect and improve the land (school grounds and surrounds), the local ecosystem, and plant and animal habitats	34 of 48
Energy	Work on energy conservation, energy efficiency, reducing greenhouse gases and improving air quality	26 of 65
Waste	Implement a planned approach to waste management to maximise reuse of materials and minimise waste sent to landfill	47 of 63
Water	Improve water usage in the school grounds and the community through river health, waterway protection and coastal care	32 of 57

There are nine steps outlined by Sustainability Victoria (2013a) to complete any of the given modules. They are: start the module, record two years of data on past resource usage, complete required actions, upload billing data, documents and add comments to the online system, track progress, submit verification, certify your module, print certificate and celebrate the achievement. More specific to waste, 'WasteSmart', the guidelines for the waste module of 'ResourceSmart', set out the seven specific steps for waste, some of which coincide with the generalised steps. The first step is to review your billing data and waste contract, essentially requiring each school to contact the contractor or authority responsible for dealing with their waste and quantify their generation, to help with data collection. The next step is to conduct a waste and litter audit. This requires schools to assess what is currently becoming waste, establish the main waste streams generated by the school and current practices for managing it, provide information on which activities produce the most waste and identify and prioritise opportunities to improve waste reduction and management. Setting goals and targets is the third step, requiring participants to take the information from the audit and understand which materials can be removed from the waste stream and set monthly or annual targets for mitigation and recycling. To fulfil the fourth step, schools must find innovative ways to reduce waste with use of an

action plan that is developed in accordance with the audit and set targets. Separating waste into streams is the next step, as identifying the different waste materials can create a financial opportunity for schools through recycling. The sixth step is in regards to clear communication of the implemented waste management systems in the school, including the types of bins and the waste that each bin is responsible for. The seventh and final step is 'right bins, right place, right signage' and stresses the importance of having bins placed in appropriate locations to maximise the impact of waste generation awareness and effective separation of waste. Additional to the waste modules is the 'waste checklist', which is used to ensure that the minimum amount of actions are undertaken by the schools (SV 2017b).

Sustainability Education at Tertiary Level

For this research, eight universities in Victoria were selected, of which undergraduate courses concerned with construction were analysed in areas of study including civil engineering, architectural design and construction management. The following table shows the courses evaluated and their corresponding university.

Table 2 Victorian university construction courses

Course	University							
	1	2	3	4	5	6	7	8
Civil Engineering	√	√	√	√	√	√	√	√
Design	√	√	√	√	√	N/A	√	N/A
Construction Management	√	N/A	N/A	√	√	N/A	√	N/A

For the purpose of analysis, the subjects offered by each course from each university were grouped into one of seven categories based on the following areas: science and maths, construction, design, management, finance, law and business, history and university-specific requirements as shown below.

Table 3 Subject groupings of construction tertiary courses

Subjects	Sustainability content	No sustainability content
Science and Maths*	29%	68%
Construction	47%	53%
Design	49%	51%
Management	15%	85%
Finance, Law and Business	6%	94%
History	25%	75%
University Specific	0%	100%

* Researchers were unable to access 3% of the unit descriptions across the universities

Science and maths are subjects that largely revolve around calculation and applied sciences. Although unable to access 3% of the unit descriptions across the universities, a total of 68% of core Science and Maths units were without emphasis on the environment or sustainability.

Construction based subjects were grouped in regards to units that offered learnings based around construction processes and methodologies. From the forty-seven units across the eight tertiary institutes, twenty-two had sustainability content or 47% of subjects.

Contrary to construction, design based subjects include any teachings that are in regards to the design of a building whether it is architectural or structural. Victorian universities have therefore implemented sustainability in an average of 49% of design subjects. Management based subjects are concerned with training in regards to management processes and methods in business. Across the

civil engineering, architectural design and construction management courses only 15% of management units studied have sustainability content, leaving a large portion without sustainability consideration. Similarly, finance, law and business subjects were grouped together covering any units that are in relation to finance, economics, legalities and general business dealings, uncovering a mere 6% of these units reference sustainability.

History subjects were grouped according to content relating vastly to historical events. Across the three courses, there are sixteen identified units of study, of which four have content on sustainability or 25%. The final group of subjects are university specific and are generally awarded no credit points as the content is related to academic conduct and safety. Within the learnings for these subjects, across the entirety of the universities, and subsequent courses analysed, there is no sustainability content, with analysis showing 100% of the units having no reference to it.

When all the subjects are evaluated simultaneously, there is a clear ratio between subjects that offer sustainability content and findings are shown in the following figure.

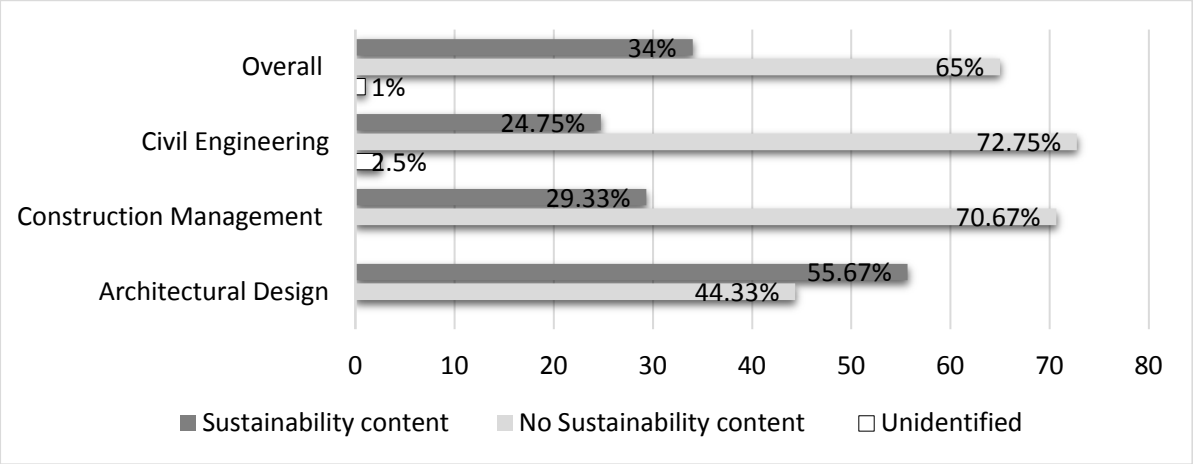

Figure 2 Tertiary course sustainability content

Overall, as shown in Figure 2, 34% of subjects have sustainability content, 65% have no reference to it and 1% of subjects' content could not be identified. Sustainability content, when broken down by construction course, indicates results that are quite clear as to which area of study incorporates sustainability most frequently. Civil engineering as a whole includes minimal sustainability education. Across the eight major universities in Victoria that teach civil engineering, an average of 24.75% of subjects include sustainability. Of these eight universities, six offer courses in architectural design. These results are far more favourable with 55.67% of subjects including sustainability. Further to this, four of the eight universities offer construction management courses. Subjects with sustainability content in these courses sit at an average of 29.33%.

Alternative Sustainability Education Methods

Within Victoria, the five campaigns identified, as shown in Table 4, are working to improve the state of the environment by raising awareness in the community. This is done by the method of a traditional campaign where strong sentiments and important pieces of information are reinforced with the public or sustainability awards which highlight the achievements of participants, using them as an example for society as a whole.

Table 4 Sustainability Campaigns in Victoria

Organisation	Title of the initiative	Target audience	Achievement
Environment Victoria	GreenTown	Multi-cultural Australian communities, Culturally and Linguistically diverse (CALD) communities.	Participating households are saving an average 4 tonnes of CO2e, 61,000 litres of water and 191kg of landfilled waste annually.
Keep Victoria Beautiful	Sustainable Cities	Cities of Victoria.	Reoccurring recognition of efforts that further a sustainable Victorian future.
Premier	Premier's Sustainability Award	Government organisations, businesses, community groups and individuals working on sustainability.	Efforts by Victorians have been publically recognised for 15 years.
Keep Victoria Beautiful	Tidy Towns	Regional communities of Victoria.	Reoccurring recognition of efforts that further a sustainable Victorian future.
Sustainability Victoria	Take2	Victorians.	Raising awareness around the wasteful habits of Victorians.

GreenTown is an initiative by Environment Victoria that is aimed at the multi-cultural element of the Australian population (EV 2017). The objective of this educational campaign is to show members of society, perhaps those who have English as a second language, sustainable practices with the hope of teaching a group to conduct free sustainability audits for their community (EV 2017). Environment Victoria's 'GreenTown' has had quantifiable success. Although largely directed towards culturally and linguistically diverse Australian communities, this initiative has successfully reached households in four targeted communities, averaging a reduction of four tonnes of CO2e pollutants, 61,000 litres of wasted water and 191 kilograms of municipal waste per household per year (Bailey 2011). Keep Victoria Beautiful (2017a, 2017b) aims to educate the community through a different means. Rewarding cities and rural communities, through their two recognition awards 'Sustainable Cities' and 'Tidy Towns', for their efforts in bettering their communities wastefulness, raises awareness and promotes sustainability. Due to the nature of the campaigns, quantifiable data is not readily available. That being said, since 1983, when Tidy Towns was introduced to Victoria (KAB 2017b), Keep Victoria Beautiful has worked through this campaign to prevent littering, promote recycling, protect the environment and action sustainability programs (KVB 2017b). 'Sustainable Cities' has a similar truth to that of 'Tidy Towns'. Since its introduction to Victoria in 1992 (KAB 2017a), this campaign has encouraged cities around the state to participate and take pride and ownership for their local environment (KVB 2017a). In a similar manner, the Premier's Sustainability Award (2017) is an initiative that is aimed more closely at local governments, businesses, community groups and individuals furthering sustainability. An active recognition award established in 2002 in Victoria, the Premier's Sustainability Award is aimed at celebrating sustainability and Victorians who are leading the way to a sustainable future (PSA 2017). A slightly different approach is taken by the Sustainability Victoria initiative 'Take2'. This campaign is aimed at bringing members of the community together to pledge to combat the effects of climate change. A predicted two-degree rise in global temperatures has spurred action by Sustainability Victoria, with the sole purpose of not letting global temperatures reach this increase by encouraging members of the Victorian community to pledge (SV 2017a). Essentially, this campaigns ultimate outcome is to reach a net zero emissions target by 2050 (SV 2017a).

DISCUSSION

School Level Education

Learnings integrated into Victorian schools are hands-on with regards to how sustainability is taught. Construction and demolition waste management is such a specific topic and would be unable to be taught at a school level, so it is imperative that the importance of sustainability as a concept is introduced to students. 'ResourceSmart', as reflected upon in the previous sections, could provide the missing link between theory and practice. This stands testament to findings of McKenzie-Mohr (2011) confirming that the answer to effective sustainable education may be in fact through implementation. The sense of achievement imparted by taking an active role in this program will likely lead students to implement sustainable activities in their personal and work lives.

The steps to achieve the 'WasteSmart' module of the 'ResourceSmart' initiative has some strong similarities to initiatives taken in C&D waste management. Setting goals and targets cannot be overlooked and is a compulsory part of achieving the 'WasteSmart' module in Victorian schools, meaning students and staff must reach certain benchmarks on a monthly or annual basis. 'ResourceSmart' has intertwined the creation and implementation of an innovative action plan as a requirement to achieve the 'WasteSmart' module, reflecting a real-life situation that the next generation of construction professionals are more than likely to face. Through the process of recycling and sorting waste at the school level, students are creating a financial opportunity for their schools, albeit an opportunity to reduce costs of the disposal of waste, rather than creating an opportunity to create an income. This practice is reflected similarly in the construction industry as Wang et al. (2010) identified the importance of having a market for recycled materials, thus creating financial opportunities for construction organisations. Clear communication along with the concept of 'right bins, right place, right signage' as required by 'ResourceSmart' (SV 2016), are important processes in the management of C&D waste. A base of knowledge has been created amongst the Victorian school community, creating an unparalleled platform for further education in sustainability practices, and even that of C&D waste management. The 'ResourceSmart' initiative incorporates a style of education outlined by Warburton (2003) known as deep learning, where students are taught base content but allowances are made for individuals to discover additional sustainability content of more interest to themselves. Furthermore, it largely overcomes issues with learning about sustainability flagged by Moore (2005a). Firstly, the disjointed nature of inter-disciplinary education is addressed with the implementation of student's active role in effecting change in their school community. Secondly, the competitive environment in education between disciplines and students is made redundant as students and the entirety of the school are working together to reach a common goal. Thirdly, the misdirected criteria for evaluation thrust upon students is overcome by considering tangible results in regards to the reduction of waste. Finally, unclear priorities, decision-making and power lie ultimately with the school body but are assumed by the students.

Tertiary Level Education

A more theoretical process than that of school education, tertiary education was analysed in relation to its apparent sustainability content. The current climate for sustainability education in construction-related courses in the Victorian tertiary education system is overwhelmingly clear-cut. When architectural design, construction management and civil engineering are all evaluated together only 34% of subjects incorporate sustainability content leaving 65% with no mention of sustainability or aligned practices (allowing 1% for subjects that were unable to be defined). It is noted by Moore (2005b) in their seven recommendations for improving sustainability at the tertiary level that sustainability needs to be infused in all decisions. Nevertheless, it is notable that architecture has single-handedly improved the ratio of sustainability content by including subjects, on average across Victoria, with 56% with sustainability content. As architects are responsible for the concept behind any given project, it is no surprise that the findings are aligned closely with existing research in that architects need to be conscious of materials in regards to designing out waste (Ajayi et al. 2017), designing buildings that can be decommissioned to allow for recovered materials to be recycled or

reused (Akinade et al. 2017) and perhaps add another level of attention to detail in order to eliminate the need for late-term and waste creating design changes (Lu and Yuan 2010; Wang et al., 2014).

Construction management and civil engineering fall severely behind the architectural design. Within the four construction management courses evaluated, sustainability content averaged at 29%, putting this area of study the next closest to architecture. However, this is a substantial difference between the two disciplines, especially when it is considered how closely the two professions must work to achieve a common goal in the industry. Education into construction management requires knowledge in a variety of fields, encompassing both design and engineering, but also management and construction processes. Although it is important that this profession, as a whole, is aware of their obligation to undertake sustainable practices and care for the environment, often they will be merely managing others, such as consultants and subcontractors, who are responsible for the physical completion of the work. That being said, there is an array of research into areas that need to improve within construction management. Low-waste construction technologies (Lu and Yuan 2010) and improving conventional construction processes (Omran and Eltayed 2016) are two areas that have the potential to be developed and incorporated into education at a tertiary level within the construction management suite of courses. Civil engineering comes in closely behind construction management with 25% of subjects making reference to sustainability content. Although a staggeringly low percentage, it is not completely incomprehensible. Civil Engineering's foremost concern is the structural integrity of a building, with any sustainable considerations being secondary to that. However, there is an opportunity for more consideration to be given to waste and sustainability within this area of study, which may have been overlooked considering the current state of Victorian construction tertiary education. Although intended as an architectural issue, design for material optimisation (Ajayi et al. 2017), is applicable to the engineering field, though on a structural level. The streamlining and improvement of engineering processes is imperative to the maximisation of materials, therefore reducing the generation of virgin materials and waste going to landfill. Similar to design for material optimisation, Akinade et al. (2017) identified that prefabrication can reduce up to 65% of on-site C&D waste. Prefabrication, as an engineering concept could help engineers maintain structural integrity, but also reduce C&D waste.

Alternative Education

Across the five campaigns studied, there are three different focus areas: training/organising activities, recognition awards and commitment to change. The aim of the five remains the same to raise awareness and educate large amounts of people about sustainability.

GreenTown is an example of a campaign designed to train groups of people. Aimed specifically to train people from a culturally and linguistically diverse background, this initiative has seen great success with large amounts of emissions, waste and water saved amongst targeted communities (EV 2017). Sustainable Cities, Tidy Towns and the Premier's Sustainability Award are all competitions in which different groups implement processes to further the sustainability cause (KVB 2017a, 2017b; PSA 2017). Although educating communities, organisations, local governments and even individuals about sustainability, campaigns such as these have a much larger impact. By these parties taking part in such a competition, whether successful or not, sustainable practices have been implemented and enforced, which is the ultimate outcome. Take2 is a campaign organised by Sustainability Victoria to encourage Victorians to do their part in combatting the predicted two-degree temperature rise (SV 2017a). To pledge, individuals or groups access the Take2 webpage and make a commitment to themselves, each other and to the environment that they will implement pledge actions, for example reducing wasted food. The campaigns studied fall under one of the three types of learning outlined by Warburton (2003), deep, surface, or strategic. GreenTown as a training concept is an example of deep learning, as people trained under the initiative are expected to practice their learnings, creating a depth to their knowledge. The campaigns based around awards, Sustainable Cities, Premier's Sustainability Award

and Tidy Towns are examples of strategic learning in that communities, organisations and individuals are pitted against each other in a competitive environment, thus inducing an educative process. Finally, Take2 is an example of surface learning as participants gain a basic knowledge of the campaign, but are not urged to study at great lengths, rather simply following a pledge.

Environmental campaigns in the past have been difficult to promote to the general public as results are not immediate, thus causing participants to lose interest (URS 2003). However, these campaigns are designed to expedite, or seemingly so, the outcomes. GreenTown, as a training program gives contributors a sense of ownership and pride in combating adverse effects on the environment, a powerful tool for keeping the momentum of sustainable behaviour. In the case of the recognition awards, by recognising the achievements of participants in sustainable efforts, the environmental conscious behaviour is being positively reinforced. As a commitment to change, Take2 offers an incentive to follow through on sustainable practices, as the participant has made a pledge and therefore committed to undertaking their given action. Ultimately these campaigns, although designed for the general public and without a specific reference to an individual industry, will have an impact on C&D waste management. When groups and individuals learn about sustainability in one aspect of their life it will inevitably become involved in other aspects, such as their professional life. This is to say that when sustainable behaviour is learnt and reinforced in the personal life of a construction professional, it can filter through to their work.

Effective Education Practices

This study has uncovered a number of educational methods that could improve C&D waste management and best serve combatting waste generation. If implemented correctly, the potential damaging state of the construction industry could be better understood and ultimately taught. One of the largest hurdles in teaching construction at the tertiary level is the need for students to gain meaningful experience in order to reinforce learnings. Although sustainability is taught thoroughly and through a hands-on approach at both Victorian primary and secondary schools, and in slightly over one-third of architectural design, construction management and civil engineering courses, waste generation still persists. The concept of Virtual Reality, or VR, has been considered as a means to give an element of authenticity to learning in the construction industry (Park et al. 2016). The implementation of this form of education could be invaluable to the next generation of students, as it is well noted that education itself may not be enough to reinforce sustainable behaviour, rather taking part in a relevant activity is more effective. As work experience may not be readily available to all students in the construction industry, VR offers an alternative with the possibility of gaining simulated experience. Collaboration is highly regarded amongst sustainability and C&D waste management education techniques (Development 2005; Jiang and Xu 2016; Lordsleem et al., 2014; Moore 2005a, 2005b). Throughout the educative methods studied, it is clear that when individuals come together to learn sustainability as a group it is far more effective. With technological advances, cloud-based learning (Jiang and Xu 2016) could be an invaluable resource for members of the construction industry, allowing groups and individuals to share educative content, experiences and thoughts instantly between parties, organically creating an online community that is accessible by not only students but those that have already begun their career. This collaborative process has the potential to create an informal education source, one that would be ever growing, as collaborative nature would allow individuals to contribute as they wish. As a continuation of collaboration, the concept of social learning is based around individuals coming together to learn about sustainability, learning from one another, building trust and taking ownership of their own learning outcomes (Wals, Hoeven and Blanken 2009). This process empowers the collective individuals to assess sustainability and the issues under consideration, evaluate opposing opinions on the matter, explore and choose a possible solution, and design and implement a plan of action (Wals et al., 2009). This educative concept allows for the process to be evaluated at its completion, so that future members of social learning can enjoy the benefit of an improved process, an essential characteristic of effective sustainability education.

CONCLUSIONS

The aim of this research was to identify the role of education in improving C&D waste management in Victoria. The importance of this research is evident in the findings. When the impact of education on C&D waste management is explored, specific to Victoria, it resulted in a better understanding of the three levels of education (school, tertiary and alternative methods). This research found that the implementation of the 'ResourceSmart' initiative in schools across Victoria puts students in a favourable position to be taught about, and implement, sustainability in construction, specifically how to manage C&D waste. Findings also suggest that across tertiary courses considered to be 'construction based', only an average of 34% of subjects have reference to sustainability practices, daring potential students to consider strongly the role that they would like to play in the industry, with architectural design courses averaging 55.67% sustainability content, construction management at 29.33% and civil engineering at 24.75%. Furthermore, campaigns as an alternative education method were scrutinised for their content, objectives and target audiences by providing training/organising activities, recognition awards and commitment to change. Similarly, these alternative education methods address deep, surface, or strategic learning aspects of sustainability. These three different methods of learning were implemented across the selected five campaigns aiming to raise awareness and educate people on the same topic. Overall, the findings of this research are important as they can help educators and construction professionals better understand the effectiveness of education and how to use education on sustainability as early as school level to produce positive impact on future practices of C&D waste management. Similarly, as these sustainable behaviours learnt and reinforced into the personal life of an individual, it can filter through to their professional work as well.

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THE IMPLEMENTATION OF INCENTIVE SCHEMES IN CONSTRUCTION CONTRACTING

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Abstract

Cost overruns, delays and accidents remain the recurrent happenings in many mega construction projects. In Hong Kong, many mega projects are facing serious delay and cost claims. The construction industry is seeking efficient ways to improve project performance. Research suggested that construction project performance, in terms of cost, time and quality can be improved if participants adopt collaborative working. Financial incentive schemes are seen as one of the commonly used strategies to energise team members and achieve mutual benefits. Drawing upon the theoretical knowledge base of incentive schemes used in construction contracting, this study investigated the current usage of financial incentive schemes in Hong Kong. Based on interviews with senior construction professionals from government, developer, contractor and consulting companies, an overview of the recent implementation status of incentive schemes in Hong Kong is summarised. Cost, schedule and quality incentive schemes are now being used and popularized under different forms in construction. The aims of establishing incentives are to enhance inter-organizational collaborative efforts through equitable distribution of benefits and losses. It was found that goal commitment, risk and reward allocation, monitoring method application and performance evaluation are the features of incentivisation in construction contracting.

Keywords: Incentive scheme, construction contracting

INTRODUCTION

Cost overruns, delays and accidents remain the recurrent happenings in many mega construction projects (Morris et al., 2011). The damages on project efficiency and social implications have drawn public attention. Construction is characterised by adversarial relationships and inequitable risk allocation. Project participants are thus lacking the motivation to work together collaboratively (Hughes et al., 2012). Based on that, efficient ways are demanded like establishing a more collaborative working climate to improve project performance. One of the commonly suggested strategies is to implement incentive schemes to incentivise project participants. The tangible objectives are to enhance performances in cost, quality, and time performances (Hughes et al., 2007). It is believed that incentive schemes are effective arrangements to move the contractor's focus away from short-term financial gain to long-term mutual benefits to the client (Richmond-Coggan, 2001). And it is also seen as a common use strategy to establish and enhance long term organizational relationships (Oliver, 1980). The success of incentivisation in construction contracts vary with the intended purposes (Suprapto et al., 2016). For example, the effectiveness in improving project performance metrics by safety incentive schemes has been proved in UK, US, Singapore and Australia (LANGFORD et al., 2000; Goodrum and Gangwar, 2004; Teo et al., 2005; Lai et al., 2011). The Pay for Safety Scheme (PFSS) was firstly introduced in 1996 by Works Bureau of Hong Kong. It encourages the safety awareness by taking the contractor's pricing for safety-related items out from the consideration of competitive bidding (Choi et al., 2011, 2012). Key benefits are focused in enhancing safety climate and attitude, promoting effective safety-related communication, streamlining safety procedures and ensuring adequate safety training(Chan et al., 2011). Wider application of PFSS is have been advocated with a view to achieving better safety performance within the industry(Construction Industry Council, 2012).

The critical review of the literature is needed for the construction industry to summarize the various perspectives and applications of incentive schemes. Consequently, there are also demands for more in-depth studies of the nature and forms of incentive scheme. The use of financial incentive scheme is an important way in reinforcing collaboration in the short term and helping to build trust between clients and contractors in the long term (Bresnen and Marshall, 2000). This study has the following foci:

- Identify the types of incentive schemes commonly used in construction industry;
- Investigate the current implementation status of incentive scheme in Hong Kong
- Discuss the pattern of incentivisation in construction projects.

IDENTIFICATION OF THE TYPES OF INCENTIVE SCHEME IN CONSTRUCTION

Bower et al. (2002) define incentivisation as 'a process by which a provider is motivated to achieve extra 'value - added' services over those specified originally and of material benefit to the user. The main purpose of incentivisation is to adopt client's objectives as well as maximize its own profits (Meng and Gallagher, 2012a).

Motivation can also be derived from incentivisation, dis-incentivisation or both (Bubshait, 2003), this can variously refer to 'risk–reward' or 'gain share–pain share' arrangements (Bresnen and Marshall, 2000). Financial incentives such as fixed-price incentive contracts, cost-plus-award-fees and share-in-savings incentives all concluded monetary rewards. Non-financial incentive schemes such as more frequent payments and letters of appreciation, are trying to offer rewards through an indirect way(Hughes et al., 2007). The type of reward is often related to the contractual / extra contractual incentives (Meng, 2015). The differences of these two were discussed by Rahman and Kumaraswamy (2008): contractual incentives may include clear and fair risk allocation and benefit sharing system in contracts, whereas non-contractual incentives may include a change in the attitude for such equitable risk allocation. According to the time occurrence in construction projects, incentives are also classified into Pre-plan, Responsive and Reactive (Richmond-Coggan, 2001). The "Iron Triangle" illustrates the ultimate objectives in measuring project success: Time. Cost and Quality (Atkinson, 1999). Respectively, incentive schemes are related to three categories: cost incentive scheme, schedule incentive scheme and quality incentive scheme (Herten and Peeters, 1986).

- Cost incentive scheme

As cost is one of the most significant performance indexes for construction projects, many incentive schemes are derived from a cost-saving perspective. The savings obtained are then shared based on an agreed formula. Because of different project characteristics, the major differences between these incentives are in the payment method and risk allocation. The examples are like: 1) Fixed-Price Incentive (firm target) Contracts, it provides for adjusting profit and establishing the final contract price by application of a formula based on the relationship of total final negotiated cost to total target cost. The final price is also subject to a price ceiling; 2) Cost reimbursable contract, the contractor is reimbursed the actual costs they incur in carrying out the works, plus an additional fee. One notable example is the NEC3 contract with Option E, the contractor assumes a relational share of the risk with an incentive-fee structure, and is rewarded with a greater share of fee; 3) Cost-Plus Incentive-Fee contract (CPIF), like NEC 3 Contract with option C/D, a banded calculation of pain/gain share system is accumulated in this type of contract to incentivise contractors to reduce cost; 4) Cost-Plus-fixed fee contract (CPFF), it provides for a fee consisting of an award amount that the contractor may earn for cost saving (Perry et al., 2000; Chan et al., 2010; Savio et al., 2013; Kwawu and Laryea, 2014).

- Schedule incentive scheme

Schedule incentive scheme entails a premium being offered to the contractor for the early completion of the project (Abu-Hijleh and Ibbs, 1989; Richmond-Coggan, 2001). The key motive behind schedule incentive scheme is to reward directly to contractors for early completion of work and, otherwise, to penalize them for late completion. The design and implementation of schedule-based incentivisation are relatively straight forward. Based on schedule targets, it can be further divided into: (1) final project completion date; (2) intermediate milestone periods; (3) intermediate physical completion milestones; or (4) a combination of final and milestone assessments (Abu-Hijleh and Ibbs, 1989). Incentive plans targeting a project completion date have the advantage that bonuses and penalties are directly linked to the specified completion date with less administration effort. Conversely, milestone plans involve the risk that bonuses will be paid for the achievement of individual milestones, but final results will nonetheless be disappointing. The advantage of milestone plan is that it provides greater flexibility, both in their design and administration.

- Quality incentive scheme

Quality incentive schemes are used for meeting performance targets, other than cost and schedule. A performance bonus arrangement can be applied to a wide range of performance areas such as quality, functionality and safety. The quality or functionality incentives are used for achieving zero or minor defects, and safety incentive scheme for complying with stricter rules and standards (Meng and Gallagher, 2012b) . Quality incentive scheme often contain detailed assessments. Different from cost or schedule incentive schemes, the assessment for technical performance bonuses is more complex. Compared to cost and schedule incentive schemes, they are more related to the specific construction requirements and client's project objectives.

Cost, Schedule and Quality incentives are likely to be inter-linked. Composite incentives are used for complex tasks. In cost-plus environments, schedule incentive scheme often goes hand in hand with cost-incentive schemes(Abu-Hijleh and Ibbs, 1989). Frequently, quality, safety, general performance, productivity, or a combination thereof from part of one single incentive program in some mega construction projects. Table 1 summarizes the classifications and manifestations of incentive schemes in construction projects.

Table 1. The classifications and examples of incentives in construction projects

Categorization method	Types of incentive scheme	Examples in construction projects	Key References
Project Objectives/ Outcomes	Cost (Share of saving incentives)	Fixed price incentive contract Cost reimbursable contract Cost-Plus-Incentive-Fee Contracts (CPIF) Cost-Plus-fixed fee contract (CPFF)	Kwawu and Laryea (2014);Bubshait, (2003)
	Schedule/Delivery	Penalty/bonus for: Final project completion date; Intermediate milestone periods; Intermediate physical completion milestones A combination of final and milestone assessments	Abu-Hijleh and Ibbs (1989)
	Performance/Quality incentives	Technical Performance bonus Safety Incentive Scheme	Rose and Manley (2011); Herten and Peeters, (1986)
	Multiple incentives	Multiple incentives	Bubshait, (2003)
Penalty or reward	Incentives	Gain share system for cost-saving	
	Disincentives	Pain share system for risks and overspending	Meng, (2015); Bubshait, (2003)
	Combination of both	A combination of pain & gain share system	
Type of rewards	Direct reward	Financial incentive scheme	Hughes *et al.* (2007); Rose and Manley (2011b); Savio *et al.*, (2013)
	Indirect reward	Non-financial incentive scheme	
Stage of a project	Pre-planned	Agreements before tendering	Richmond-Coggan (2001);
	Responsive	Concessions in tendering for winning a project	
	Reactive	Emergency work for delay/cost overrun/ technical difficulties	
Whether incorporated into contracts	Contractual incentives	Clear and fair clauses written in contracts	Meng, (2015);Rahman and Kumaraswamy (2008)
	Extra-contractual incentives	A change in the attitude for gains/risks	
	Combination of both	Combination of both	

THE IMPLEMENTATION OF INCENTIVE SCHEMES IN HONG KONG

To understand the current use of incentive schemes in construction industry, 10 structured interviews were conducted with senior construction professionals in Hong Kong. Table 2 gives the particulars of interviewees.

Table 2. The particulars of the interviewees

No.	Company Nature	Scope of business	Types of incentive scheme		
			Cost	Schedule	Quality
1	Government	Government department for public facilities other than public housing	√		√
2	Government	Government department for public housing			√
3	Government	Government department for land planning & infrastructure management	√		√
4	Developer	Historical building conservation		√	
5	Developer	Private developer, listed local company	√		√
6	Developer	Private developer, Chinese Capital		√	√
7	Contractor	Main contractor	√		√
8	Contractor	Main contractor		√	√
9	Contractor	Main contractor	√	√	√

10	Consultant	QS Consultant	√	√

The key findings from these interviews are summarized in Table 3:

Table 3. The contents of the structured interviews

No.	Questions	Types of incentive scheme		
		Cost	Schedule	Quality
1	Examples of incentive schemes encountered in Hong Kong	NEC contract with Option C	Reacting behaviour to prevent project delays	Performance Assessment Scoring System Pay for Safety Scheme
2	Purposes of setting incentive schemes	Communication tools to enhance collaborative working and attract contractors to come to the negotiation table and drive them to focus on the specific targets of the contracts.		
		Collaborative working; Generate innovations to save project cost	Quicker completion	Better project performance
3	Difficulties/misgivings for implementing incentive schemes	The conflicts between the project management style and current organizational managing system for adopting target cost contracts.	1)The manoeuvrability based on limited labour and resources. 2) The contractor may overly on the rewards, they may lay back only for bonus.	The standard may be too strict and combat the enthusiasm of the workers.
5	How to make sure the incentive schemes works effectively?	Target cost estimation at each stage to evaluate the extent of cost-saving.	Set milestones and distribute bonus at each stage	Set detailed assessment standards; hold monthly meetings to adjust targets flexibility.
6	How the incentives affect the behaviour and working climate among different organizations?	For individuals, the effect of the incentives usually comes from the pressure of the senior managers. From organizational basis, all the cooperative behaviour is based on the achievable of their commercial benefits.		
7	Profound influence incentive scheme may bring to project teams/organizational management.	1)Obtain commercial benefits 2) Enhance organizational relationships	1)Obtain commercial benefits 2) Enhance organizational relationships	1) Obtain social reputation 2) Enhance organizational relationships 3) Cultivate the working climate of improving the quality of the project

- Cost incentive scheme

A significant trend is shown for adopting target cost contract with pain/gain share system for public projects. It has used for about 8 years from trial to comprehensive promotion. The successful cases like Tin Shui Wai Hospital, Happy Valley water storage project and Secondary School at Kai Tak Development are using NEC contract with Pain/Gain share Mechanism. There is a significant trend of adopting NEC contract into public projects from 2009 to 2017 (Development Bureau of Hong Kong, 2017). The central idea of using target cost contract is to pursue a win-win solution for projects between government and contractors. An open book accounting approach is adopted to strengthen budgetary control and transparency. It is also what relational contract advocates that parties should act in "a spirit of mutual trust and co-operation" and “enhance communication within time limits” (Albertini, 2017) . Another intention of using target cost contract is to promote innovation. Facing the challenges of high construction cost and lack of manpower, the contract is set to encourage use of innovative technology to enhance productivity, cost-effectiveness and safety performance (Cheung and Chan, 2014). Setting cost incentive scheme also attracts the contractors, as construction professionals, to innovate for new methods to save costs.

The trend of applying pain/gain share system is also notable in many other commercial projects. Public projects typically aim to achieve the lowest outrun cost to the client and derives a profitable outcome for the contracting parties. With this purpose, the mission is that the parties must collaborate to underpin the successful commercial outcome of the contract. Differ from a common 50%-50% ratio in public projects, the ratio of the shares for commercial projects are more detailed and specified based on project nature and project targets. For example, in one case, the shares for the first 3% profit is distributed as 30% to client and 70% to contractor. The significantly higher weight motivates the contractor to take measures to save cost. After the 3% profit, client would take back 70% of the benefits to guarantee their own benefits.

- Schedule incentive scheme

Compared with cost incentive schemes, there are fewer examples of use of schedule incentive scheme in Hong Kong. One reason for some clients is that it considered that the schedule should be well-estimated based on previous working experience and negotiations before the construction period. The occurrence of schedule incentive scheme is usually in the middle of the project and act as an amendment to the original plan and response to unforeseen events. The monetary rewards are often divided and distributed according to the achievement of milestones. Because of the time limitation and the unpredictability, contractor take more consideration to if they have sufficient resources and how to transfer the task to the next tier of the supply chain.

- Quality incentive scheme

Attaining high quality is one of the major challenges in construction projects. General views hold that achieving better quality would bring organizational reputation. The notion of continuous quality improvement is based on the belief that there is always room for improvement in any process (Tam et al., 2009). It was opined that the success of quality management is due to having clearly defined and measurable quality goals (Culp et al., 1993).

In 1990, the Hong Kong Housing Authority (HKHA hereafter) introduced Performance Assessment Scoring System (PASS hereafter) to manage public housing construction. The system is designed to reward contractors who perform up to the required standard with greater tendering opportunities (Tam et al., 2009). It was noted that the tender evaluation is based on 75% of price score and 25% corporate and performance score(The Hong Kong Housing Authority, 1998). This means that contractor with higher standard project performance would experience have competition advantages in bidding evaluations. PASS consists of outputs (Works) Assessment and Input (Goals) Assessment to be conducted during the construction project and the substantial completion stage of the building contract. The critical concerns are in schedule, safety, clean disciplinary record and no offence, malpractice, or misconduct causing damage to the client's image. Assessments are evaluated regularly by site monitoring staff and the confirmed by both assessor and the contractor's representatives.

Safety incentive scheme is rooted in social consciousness for protecting worker's physical and mental health. The Pay for Safety Scheme (PFSS) was firstly introduced in 1996 by the Works Bureau of Hong Kong (Construction Industry Council, 2012). PFSS endeavours safety awareness by taking the contractor's pricing for safety-related items out from the consideration of competitive bidding (Choi et al., 2011, 2012). Purposes are identified such as enhancing safety climate and attitude, promoting effective safety-related communication, streamlining the safety procedures and ensuring adequate safety training(Chan et al., 2011). Under the initiative of the government, safety initiative schemes are incorporated into different kinds of construction projects. They are also provided to encourage contractors to achieve better safety performance. Examples include Quality Safety, Environmental Safety, Safety Hero Schemes and so on (MTR Corporation, 2013). Monetary rewards are set with reference to the contract value and are distributed at different stages. Differing from other incentives, Safety incentives focus on the condition of workers, some rewards were worker-based instead of organizational-based.

- The application of incentive schemes

Clients are the key initiators of installing financial incentives in the Hong Kong construction industry. As commercial organizations are profit-oriented, they can be motivated by harvesting the benefits associated with the incentive schemes. Incentive schemes can also be used as sweetener to attract contractors to come to the negotiation table. Usually, setting an incentive scheme at the earlier stage is considered helpful to prevent some accidents and achieve better performance. The selection of incentives is related to clients' priorities of their objectives and the confirmation of responsibility. For private companies, the realisable benefit does matter. Incentives occurs more for cost saving and quick completion. The compatibility of the contract management and the organization operation also influences the consideration of incentive schemes. Due to the difficulty doing reports for exact cost estimation to their seniors, target cost contracts are less frequently used as compared with lump sum contracts in some organizations. The preference of gain share system to pain share system represents the intention and expectations of contracting parties. It is also well-noted that selecting the right partner is as equal importance to setting incentive schemes. The contractor who pays more attention to safety are better co-operators when the client needs safety as one of the main objectives. Also, clients align more the contractor to focus on the gain share system instead of the pain share system

as it improves the expectancy for project success. The downsides of financial incentive schemes come from the effect of over-reliance. For example, if the schedule incentives are set, the contractor may overly on the rewards, they may lay back only for bonus. Thus, some projects only set disincentives to prevent delays. For some performance incentives, setting unrealistic goals may make the working climate stressful. Though there are no extra punishments for some performance incentives, the failure would hamper enthusiasm of workers.

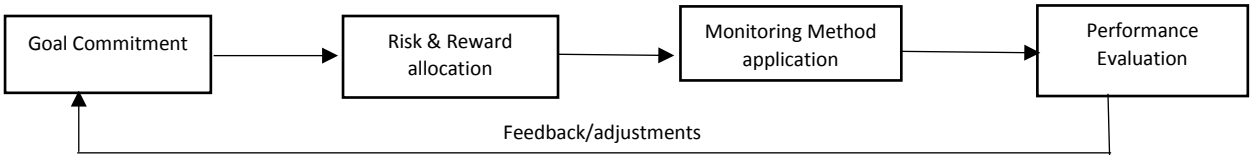
From Contractor's point of view, input/output ratio may well be the main consideration in committing to incentivisation. It is common that for projects, the contractor needs to achieve a certain level of performance based on the contract. Higher standard of project performance requires higher costs. Based on that, Incentives are welcome but the effectiveness is also relevant to the resources the contractors' have. For example, large organizations are more willing to accept the incentives because they have sufficient labour/resources to achieve targets. The sensitivity of incentive scheme is more related to confidence of goal achievement and goal compatibility. They believe that it is important to create a comfortable, satisfied working environment with achievable targets.

For consultants, the focus is on the monitoring method and execution process. Trust and contract are commonly mentioned as key factors in this section. Clear and detailed clauses help prevent disputes. Also, sometimes the monitoring method is relied on advanced techniques such as Building Information Modelling (BIM).

DISCUSSIONS

Through analysing these different types of incentive schemes, some general patterns of incentive schemes are concluded. Generally, there are four parts necessarily occurred in the contract contributing to the implementation of incentive schemes in construction projects: 1) Goal Commitment: Identify additional objectives apart from original contracts and provide general overview of the whole procedure; 2) Responsibility and reward allocation: Redistribute the risks and responsibilities due to the additional targets, and set rewards correspondingly matches the additional duties. 3) Monitoring method application: Set sub goals or monitor procedure due to the targets such as meetings or reports at each stage; and 4) Performance evaluation: establish assessment systems to evaluate if these objectives are achieved. Fig 1 shows the relationships of all these factors:

Fig 1. The pattern of implementing incentive schemes in construction projects



- Goal Commitment: A goal is whatever an individual is striving to accomplish (Locke, 1996). According to goal-setting theory (Locke and Latham, 1984), goals need to be meaningful, specific, challenging and acceptable to those who are attempting to achieve them. When incentives and rewards are contingent on goal attainment, a performer's goal acceptance increases in proportion to the perceived benefits of attaining the goal (Locke & Latham, 1990). Incentives contribute positively to a performer's willingness to accept a goal regardless of its difficulty, origin, or the credibility of the person assignment.
- Risk and reward allocation: Additional efforts need to be paid by project participants for additional goals. Incentive scheme is also seen as an approach to reallocate benefits and risk compared to the original contracts and make it more appropriate for a project under specific market conditions (Richmond-Coggan, 2001).
- Monitoring Method application: When using external events as incentives, organizations also generally seeks to guide others an extrinsic motivator for engaging in that activity (Reeve, 2009). Much of the spirit behind the use of incentive scheme is therefore to shape, influence or outright control others' behaviour to increase some desirable behaviour or to decrease some undesirable behaviour. For construction projects, some monitoring methods are therefore included such as monthly report or monthly meeting (Abu-Hijleh and Ibbs, 1989; Construction Industry Council, 2012) as a performance control mechanism within highly detailed contractual specifications.
- Performance evaluation: For different kinds of incentive scheme, the assessments are detailed for how to evaluate if the contractor can achieve these targets. For some incentive schemes, some sub

goals would be set in this section or some assessment systems to evaluate if all the project objectives are satisfied.

The core construct of goal commitment is “discrepancy” that means the difference or mismatch between one’s present state and one’s ideal state. In this area, two types of discrepancies exist (Bandura, 1993): The first is discrepancy creation that due to intrinsic motivation of pursuing better performance, one party sets a future, higher goal in an ideal state generate in mind; the other is discrepancy reduction which is the effort people may pay to narrow the gap between existing facts and requirements or feedbacks such as results of previous project evaluations (Locke, Latham and Erez, 1988).These two features determine that the goals of incentive schemes are affected by subjective requirements and objective facts. The adjustments and feedbacks for goal setting would also occur based on previous project experiences.

CONCLUDING REMARKS

Incorporating incentive schemes in contract package is seen as one of the efficient ways to improve project performance. Reported researches suggest that construction project performance, in terms of cost, time and quality can be improved if participants adopt collaborative working. Drawing upon the theoretical knowledge base of incentive schemes used in construction contracting, the objectives of this study are:1) Identify the types of incentive schemes in construction industry; 2) Investigate the current implementation of incentive schemes in Hong Kong and 3) Discuss the pattern for applying incentive schemes in construction projects. Interviews were conducted for construction professionals in Hong Kong. An overview of the recent implementation status is presented. Based on all the findings, a general pattern of adopting incentive schemes is further discussed.

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THE RISE OF BIM AND THE NEXT CHAPTER FOR QS

Sharon Yap, Altus Group

1. Worldwide BIM Development Today

Country	Development	Mandatory (Yes / No / In Progress)
UK	As part of the UK Government Construction Strategy (GCS), all the centrally procured Government projects will be delivered in BIM Level 2[i]	Yes
France	2017, BIM was mandate for France as part of the French strategy for "digitizing" the construction industry.	Yes
Germany	2015 the German government announced the formation of the Digital Building Platform to develop a national BIM strategy with the intention to mandate all transportation projects in 2020.	In Progress
Scandinavian	Finland – In 2007 mandated that any design software needed to pass Industry Foundation Class (IFC) Certification[ii] Norway - Since 2010, Statsbygg, a public-sector administration company in Norway has been leading the BIM adoption and using BIM for the whole lifecycle of their buildings. (Smith, 2014)[iii] Denmark - has mandated its state clients to adopt BIM practices. Sweden – Swedish Transport Administration has mandated the use of BIM from 2015.	Yes In Progress Yes Yes
US	In 2010, Wisconsin was the first US state to require BIM on all public projects[iv].	Yes (Partly)
Canada	No mandate for public projects as yet. However, Canada BIM Council (CanBIM) is starting to drive integration with other construction organizations across Canada to accelerate the rate of BIM adoption (Zeiss,2018) [v]	No
Singapore	Since 2015, BIM e-submissions have been mandated for all projects greater than 5,000 sq mts	Yes
Hong Kong	A policy is published for Capital works projects with cost estimates more than $30 Million	Yes

	shall use BIM technology.[vi]	
Dubai	In 2013 Dubai Municipality (DM) mandated the use of Building Information Modelling (BIM) tools for most large-scale projects	Yes
Australia	Australian Government has elected not to mandate the use of BIM. However, various state government departments are increasing their efforts to promote and adopt BIM.	No / (Partly)

2. What is Preventing QS using BIM data for Cost Planning

- Cost – Software, training
- Negative perception within the industry – Unreliable data, discrepancies
- Lack of BIM Knowledge – Purpose of BIM, LOD?
- Reluctance of consultants to allow BIM model to be used – Only for visual aesthetics

3. QS Roles in BIM Implementation

3.1 NZIQS & AIQS BIM Best Practice Guidelines

- Pre-contract stage role of the Quantity Surveyor
- Post-contract stage role of the Quantity Surveyor

3.2 NATSPEC BIM GUIDE

- Responsibilities in BIM Management Plan (BMP) Development – Support alignment of ***project procurement*** to BIM development and ***cost containment*** strategies
- BIM Responsibility – ***Data development and integration***. Use of model

4. QS Initiatives in BIM Adoption

- Instead of relying on the industry, QS to redefine own Roles and Responsibilities in BIM

4.1 QS Role 1: Improving the Model which will enable QS to use BIM data

4.1.1 Implement Model Matrix for QS Use – See figure 1

a) adopt and agree a standard coding system
b) outline the LOD of each object. Where the object is not modelled in detail, the QS is "pre-informed" and is able to bridge the gap by incorporating the missing link into their costing.

4.1.2 Assist in Developing standard "keynote" data – See Figure 2

a) data acts as a brief object specification.
b) tailor data to be project specific; allow QS to extract the right info / specification for cost planning.

Figure 1 : Model Matrix for Cost Planning and Quantity Take-off

Modeling Matrix For Cost Planning and Quantity Taking Off

Rating Definition	
0	Not Required
1	In General
2	Approximate
3	Precise

Rating Definition	
0	Not Required
1	In General
2	Approximate
3	Precise

Rating Definition	
0	Not Required
1	In General
2	Approximate
3	Precise

Level	Element ID	UniFormat ID	Omiclass	QS Elemental Code	Modelled? Yes / No	LOD 100 - 150 (Concept / SD) Expected Level of Details					Remarks	LOD 200 - 250 (Design Development) Expected Level of Details					Remarks	LOD 300 - 350 (PTE) Expected Level of Details					Remarks
						Dimension	Location	Code	Grade	Spec		Dimension	Location	Code	Grade	Spec		Dimension	Location	Code	Grade	Spec	
Level 1	SUBSTRUCTURE	A																					
Level 2	FOUNDATIONS	A10	21-01 10																				
Level 3	Standard Foundations	A1010	21-01 10 10	SB	Yes	1	1	0	0	0		2	3	2	1	1		3	3	3	3	3	
Level 4	Wall Foundations	A1010.10	21-01 10 10 10	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Column Foundations	A1010.30	21-01 10 10 30	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Standard Foundation Supplementary Components	A1010.90	21-01 10 10 90	SB	No	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 3	Special Foundations	A1020	21-01 10 20	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Driven Piles	A1020.10	21-01 10 20 10	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Bored Piles	A1020.15	21-01 10 20 15	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Caissons	A1020.20	21-01 10 20 20	SB	No	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Special Foundation Walls	A1020.30	21-01 10 20 30	SB	No	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Foundation Anchors	A1020.40	21-01 10 20 40	SB	No	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Underpinning	A1020.50	21-01 10 20 50	SB	No	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Raft Foundations	A1020.60	21-01 10 20 60	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Pile Caps	A1020.70	21-01 10 20 70	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	
Level 4	Grade Beams	A1020.80	21-01 10 20 80	SB	Yes	1	1	0	0	0		2	2	2	1	1		3	3	3	3	2	

SAMPLE

Figure 2: Keynotes Table

KeyNote - Code	Standard Descriptions	Unit	Cost / Unit
300	**STRUCTURE**		
301	PILING	No	
304	CONCRETE	m3	
305	CONCRETE FOOTING	m3	
0305_C1	300X250 CONC FOOTING	No	
0305_C3	450X250 CONC FOOTING	No	
0305_C9	300X300 CONC FOOTING	No	
0305_C2	400X250 CONC FOOTING	No	
0305_A1	CONC FOOTING	m3	
0305_A2	CONTINUOUS CONC FOOTING	m3	
0305_A3	EDGE THICKENING	m	
311	CONCRETE FORMWORK	m2	
312	CONCRETE REINFORCEMENT	kg	
0312_A	TRENCH MESH	m	
0312_A01	SL63	m2	
0312_A02	SL82	m2	
0312_A03	SL8TM	m	
0312_B	REINFORCING MESH	m2	
0312_C	REINFORCING BARS	kg	
313	CONCRETE POST-TENSIONED	m2	
314	CONCRETE IN SITU	m2	
0314_A	CONCRETE MONOLITHIC	m2	
0314_A1	100 SOG	m2	
0314_A2	100 SLAB ON GROUND	m2	
0314_A3	125 SLAB ON GROUND	m2	
0314_A4	150 SLAB ON GROUND	m2	
0314_B	SET DOWN	m	
0314_C	CONCRETE FOOTINGS	No	
0314_F100	700X700X300 COL PAD	No	
0314_H	CONCRETE COLUMN	m	
0314_K	CONCRETE SUSPENDED SLAB	m2	
0314_K1	172 SUSPENDED SLAB_2C	m2	
0314_K5	250 SUSPENDED SLAB	m2	
0314_K6	300 SUSPENDED SLAB	m2	
K0314_B2	257 SUSPENDED SLAB_3C	m2	
315	CONCRETE FINISHES	m2	

SAMPLE

4.2 QS Role 2 – Amending QS Standard

- ASMM – Modification of ASMM to allow "composite BIM object" measurement.
- Standard Preamble – Modification of standard preamble to allow composite rate for BIM objects.
- Form of Building Contract - Modification to the extent of use of quantities which form part of the contract.
- Supplementary agreement to main contract – New clauses to be added for time, cost and responsibilities for the BIM development throughout the project.

4.3 QS Role 3 –1st Principal Estimation in BIM Objects

- Developing BIM Objects cost library to be in line with the open BIM Objects.
- Developing the unit rate for each object that will include materials supply, install, delivery and any other cost loading factor.
- Provide constant update of cost / unit rate in accordance with the market trends.

4.4 QS Role 4 – Bridging the Gap – BIM Diagnoser

- Provide peer review for the BIM development in relation to the "information" incorporated in the building model to make sure a BIM is developed not just an aesthetic building model.
- "Information" embedded carry enough "details" and is ready to be costed.
- Setting the parameters and define the "details" required for costing at different stages of the project (inter-related to Model matrix and keynotes).
- Instead of extracting quantities; carry out a diagnosis in quantities to identify flaws and improvements; e.g.
    - duplications
    - missing info
    - value analysis
    - material analysis

5.0 Preparation Today for the "BIM Storm"

- Software / IT ready – Investment and exploration of new technologies that suit the local practices.
- Collaboration with other disciplines to fill the gaps between design and cost.
- Support from management – Open-minded attitude towards engagement with BIM
- Collaboration among the institute members to set the parameters of BIM use for QS quantities take-off and cost planning in accordance with the best practice guidelines.

Keywords: BIM, NATSPEC, NZIQS, AIQS, BIM Best Practice Guideline, Model Matrix, Keynotes, QS Code, BIM Objects Cost Library, BIM Diagnoser.

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[i] BIM Level 2 requires all project and asset information, documentation and data to be electronic, which supports efficient delivery at the design and construction phases of the project. At the design stage, designers, clients and end users can work together to develop the most suited design and test it on the computer before it is built. During construction BIM enables the supply chain to efficiently share precise information about components which reduces the risk of errors and waste. BIM Level 2. 2016. BSI. http://bim-level2.org/en/about/

[ii] https://www.geospatialworld.net/blogs/bim-adoption-around-the-world/; https://constructible.trimble.com/construction-industry/global-bim-standards-is-your-country-next

[iii] Dr Smith, Peter. 2014. "BIM Implementation – Global Strategies"

[iv] projects with a budget of $5 million or more and all new construction with a budget of $2.5 million or more

[v] **Zeiss, Geoff,2018. Accelerating the rate of BIM adoption in Canada**

[vi] The Government of the Hong Kong Special Administrative Region, 2017. Technical Circular (Works) No. 7/2017. "Adoption of Building Information Modelling for Capital Works Projects in Hong Kong

TOWARDS A NEW ERA OF MODULAR BUILDINGS: A CRITICAL REVIEW OF PREFABRICATED PRE-FINISHED VOLUMETRIC CONSTRUCTION (PPVC)

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The application of techniques and automation has made the global construction industry innovative and helps to improve the productivity and sustainability of construction practices. As one of the advanced modular construction technologies, Prefabricated Pre-finished Volumetric Construction (PPVC) is introduced to achieve high productivity and better environmental performance in construction projects. Thus, the aim of this research is to develop a framework for the successful implementation of PPVC in construction projects. A comprehensive literature review and an illustrative case study were used in this research to achieve the above-mentioned aim. The literature review covered the key themes related to the modular construction, implementation process of PPVC, advantages and challenges of implementing PPVC in construction projects. Singapore was selected as a case study to examine the implementation process of PPVC by reviewing the government strategies on PPVC implementation and two recently completed projects using PPVC in Singapore. According to the results, the key advantages of implementing PPVC are time savings, overall cost savings, fewer manpower requirements, safer workplaces, quality improvements and waste reduction. The challenges identified include limited site spaces, transportation difficulties and increased costs in implementing the PPVC. Also, it was identified that mandatory regulations, financial supports and logistical supports had a positive impact on promoting PPVC technology in Singapore. Similarly, this research provides strategies to overcome limitations and challenges of implementing PPVC in future projects. Thus, these findings will be helpful for policymakers and construction practitioners to promote the implementation of PPVC technology.

Keywords: Challenges, Construction projects; Prefabricated Pre-finished Volumetric Construction (PPVC), Strategies.

INTRODUCTION

The construction industry plays a significant role in the global economy. However, construction industry practices are criticised for the amount of waste generated from construction activities. If construction waste generation cannot be managed properly it can cause severe damage to the environment. As a result of moving towards sustainable development, construction industry practices are, in turn, moving towards advanced technologies that promote high productivity and better waste management practices. Prefabricated modular construction is one of those methods as it helps to reduce on-site cast in-situ activities. The idea of modular building was firstly proposed by Le Corbusier in 1947 (Baldwin and Clark, 2000). The modularity significantly influences the mass customisation and it can be an effective method to respond to the fast-changing building environment and its influence on limited natural resources (Mesa et al., 2015). In recent decades, a number of different countries have promoted the application of modular buildings by establishing relevant development strategies and policies (Tam et al., 2007). This is mainly because of the advantages of modular buildings which include cost-effectiveness, adaptability, effective productivity and optimal material usage (Tam et al., 2007). Modular building construction has been widely applied and promoted in Singapore, China, Hong Kong and some European countries (Tekla, 2016). However, the industry is still exploring the potential of prefabricated modular manufacturing based on modular building principles. Prefabricated Pre-finished Volumetric Construction (PPVC) is one of the advanced technologies, created through continual technology innovation and advancement. The previous modular building systems use pre-assembled, factory produced volumetric units that form the structure of the building while assembly

and finishing processes are implemented on-site. The PPVC technology comprises complete off-site manufacturing and assembly, including finishes. The PPVC technology significantly contributes to increasing productivity, reducing materials wastage and minimising pollution on construction sites due to the shorter construction period and optimal manpower usage (Rui and Yahya, 2016). However, the research related to PPVC and its application are quite limited at this stage. Thus, the purpose of this research is to develop a framework for the successful implementation of PPVC technology in construction projects.

LITERATURE REVIEW

Since the fast-changing construction industry is moving towards higher productivity and sustainability, a range of advanced construction technologies has been introduced to improve building practices. As one of the most recent technologies, Prefabricated Pre-finished Volumetric Construction (PPVC) combines the architecture principles and construction techniques to advance the modern building construction.

Sustainable Concepts and Modular Construction

The concept of sustainable development was initiated as a solution to the dilemma of environmental protection and economic development (Lerum, 2016). The promotion of sustainable development in construction is challenging for construction professionals due to the high resource consumption and production of pollutants during the construction activities (Ruozhu et al., 2016). Gibb and Isack (2003) mention four categories of off-site construction in their research including component manufacture and sub-assembly, non-volumetric pre-assembly, volumetric pre-assembly and modular building. Among these four categories, the modular building has been widely applied in many countries. In modular construction pre-assembled volumetric components are manufactured in an off-site factory and then craned to sites for assembly (Gibb, 2001; Arif and Egbu, 2010; Xun et al., 2014). The on-site activities are limited to assembly and finishing (Arif and Egbu, 2010). Modular construction controls the building quality through the application of strict quality control systems during the prefabrication process to achieve better performance. When it comes to structural units, every modular component provides its own structure that can self-support rather than relying on other structural systems. Similarly, the spatial units suggest that the inside of the unit can be divided into different spaces and be equipped with different facilities depending on the performance requirements of the building (Xun et al., 2014).

Modularity has significantly influenced mass customisation and it can be an effective method to respond to the rapid changing building environment and its influence on limited natural resources (Mesa et al., 2015). From the economic aspect, modular buildings not only reduce the cost but also improve construction efficiency and shorten the construction period due to the use of prefabricated components. The study conducted by Lawson and Ogden (2008) showed that large off-site manufacturing projects can experience about 10-20% cost savings besides time savings as a result of reduced site mobilisation costs and improved productivity. From the environmental aspect, modular buildings not only optimise labour arrangements but also contribute to better control of dust and noise pollution during the construction process. According to Lawson et al. (2012), waste generation in modular construction is equal to 5% of the overall construction weight, which is less than conventional construction at 10-13% of the overall construction weight. A study conducted by Tam et al. (2007) showed that the percentage of waste minimisation for four major types of materials (reinforcement, concrete, plastering and tiling) can reach up to 84.7% by adapting prefabricated techniques. Similarly, Lawson et al. (2012) and Mesa et al. (2015) evaluated the potential for energy saving, waste reduction and safety of construction activities by using prefabricated modular building components. They found that the capacity for energy savings and energy storage of modular buildings can reach up to 70% compared with the conventional methods (Mesa et al. 2015). Furthermore, Liu and Lin (2016) stated that as most of the prefabricated modular units are made of renewable and

environmental-friendly construction materials, this could significantly reduce the usage of concrete and cement in construction projects.

Prefabricated Pre-finished Volumetric Construction (PPVC)

PPVC technology was initiated as part of the design for manufacturing and assembly (DfMA). The DfMA consists of three construction innovations, which are PPVC; virtual design and construction (VDC); and 3D printing. These techniques were developed to drive the construction industry towards off-site manufacturing for on-site assembly. In PPVC technology, free-standing modules are produced and assembled in an off-site factory before being craned to the construction site for installation (Rui and Yahya, 2016). It involves prefabrication of modules including a structural frame, finishes, light work and accessories. These modules are then delivered to the construction sites and assembled in a Lego-style (Rui and Yahya, 2016). The implementation of PPVC technology includes prefabrication, transportation and installation. Firstly, each module is prefabricated off-site by constructing walls, floors, ceilings, finishing works, plumbing works and installation of electrical sockets and light switches prior to transportation to the sites. After that, the finished modules are transported to the construction site by using large load-bearing trucks. The finished modules are stacked similar to Lego pieces on site and fastened together. The installation procedure of PPVC can be further divided into three stages including pre-installation, installation and post-installation. In the pre-installation stage, prefabricated pre-finished units will be delivered to the construction site and unloaded to a designated location where dowel bars will be installed on the units. During the installation stage, a range of preparation works including placement of shim plates and grouting, pre-mark reference line, application of sealant strip and waterproofing membrane will be applied. Then, the verticality check will be carried out after the units are craned into position. At the post-installation stage, units will be secured by reinforcing vertical and horizontal joints.

Benefits of Implementing PPVC Technology in Construction Projects

As highlighted by BCA (2016b), one of the main features of PPVC is its modularisation and standardisation approach with pre-finished volumetric units that give a range of benefits for improving productivity and performance of the construction projects. These benefits include productivity improvements, time savings, fewer manpower requirements, cost savings, better inventory management, better quality control, cleaner worksites, waste reduction and ease of deconstruction and reuse of building components. Researchers have identified that the construction programme can be accelerated by using PPVC technology in construction projects. A study conducted by Rui and Yahya (2016) showed that there is a potential to improve productivity up to 50% by using PPVC technology depending on the complexity and scale of the project. For example, they noted that about nine months of construction time can be reduced from a high-rise residential project by adopting PPVC technology, which requires three years to complete using conventional construction methods. Time savings can be achieved by using PPVC technology as finished modules are prefabricated in an off-site factory and then delivered to the construction site for installation. On-site and off-site activities could be carried out almost in a parallel manner as site activities can commence while the initial PPVC modules are being made in an off-site factory (BCA, 2014). Also, the factory manufacturing can then continue while the installation process is carried out on site (BCA, 2014). Transportation from the off-site factory to the construction site could be either via a staging procedure or on a 'just in time' basis (BCA, 2014). Thus, the construction period can be shortened significantly as different construction activities can be implemented at the same time rather than waiting for a specific sequence. Furthermore, on-site construction activities are less affected by weather conditions. Similarly, specialised services such as mechanical, electrical, plumbing and finishes are prefabricated in an off-site factory when using PPVC technology (Rui and Yahya, 2016). Therefore, the manpower requirement at the construction site is substantially reduced by using PPVC technology. Due to less on-site construction activities, site overheads can be reduced by 50% when using PPVC technology (BCA, 2016b). Also as on-site construction activities are significantly reduced, safe fabrication and erection can be carried out in

controlled factory environments, which leads to fewer accidents (BCA, 2016b). Furthermore, the traffic movements to and from the construction site can be reduced by 20% under PPVC system which can contribute to a safer workplace as well (BCA, 2016b).

Procurement of materials and machinery becomes simpler when using PPVC technology compared to conventional construction methods due to less on-site construction activities (BCA, 2016b). Therefore, inventory management can be improved by reducing the waste generation and efficient scheduling of mobilisation of machinery. As components and modules are fabricated in a controlled off-site environment, a high standard of quality can be achieved by using PPVC technology with appropriate quality assurance which helps to reduce reworks (BCA, 2016b). This is mainly because strict quality control systems in a factory environment results in a superior and uniform quality of prefabricated modules which then enhances the overall quality of the project (BCA, 2014). As well, when compared to conventional construction methods, the advantage of being fabricated in an off-site factory enables for tight tolerances as adjustment of elements can be completed in a controlled environment. Currently, the technology allows tolerance for each installed module within 5-10mm, which results in substantial additional internal forces that are extremely essential for high rise construction (Mills et al., 2015).

The waste generation under PPVC technology is significantly less than the conventional delivery method due to less use of raw materials on site, use of standardised dimensions in modules and fabrication of modules in a controlled off-site factory where waste can be reused (BCA, 2016b). Also, as on-site construction activities are mainly involved in assembly and installation, works for wet trade on-site can be removed, which, in turn, reduces water usage on site. Furthermore, improved environmental control can enable up to 30% reduction in the amount of carbon emission when compared to conventional delivery (BCA, 2016b). Also, the noise and dust pollution can be better controlled by using PPVC technology compared to other prefabrication techniques as fewer activities are carried out on construction sites (Rui and Yahya, 2016; Mills et al., 2015). Although it has not yet been put into practice, theoretically, PPVC has advantages in terms of reuse and deconstruction (BCA, 2016b). Due to characteristics such as modularisation and assembly in PPVC technology, removal and dismantling of components to reconfigure buildings or deploy to other places consume much fewer resources. Thus, it creates fewer pollutants when compared to the conventional delivery model (BCA, 2016b).

Challenges of Implementing PPVC Technology in Construction Projects

Although the use of PPVC technology has a range of benefits, there are some hindrances and challenges as well. The cost of using PPVC technology is higher than conventional construction methods due to a number of reasons. Firstly, transportation costs are expected to increase about 5-20% depending on the scale of the project and difficulties such as the size and shape of volumetric units and site accessibility (Shyan, 2014). As PPVC modules are prefabricated in volumetric units, requirements such as maintenance of smooth traffic flow and access of emergency vehicles around the construction site are more stringent (Shyan, 2014). Secondly, it is necessary to undertake specific training for construction workers to successfully implement PPVC technology in construction projects. Therefore, additional costs are incurred in training skilled labourers and in storing and delivering the prefabricated modules to the construction site (Shyan, 2014). Lastly, the initial cost of PPVC will be higher than conventional construction as developers or suppliers have to use new technologies to manufacture the PPVC modules (Shyan, 2014). As PPVC has only been explored during the past few years, its implementation is still in the experimental stage with limited mature products or experienced contractors. Unknown challenges and potential risks may make new participants hesitate to adopt this new advanced technology (Barve, 2016).

Similar to the existing modular building application, PPVC has also been criticised on aesthetic grounds. It is believed that the standardisation of modules will diminish the uniqueness and personality of buildings (Jaillon and Poon, 2009). Therefore, concerns regarding whether modularity will diminish the design creativity has been rising due to the repetitiveness of similar building blocks. Currently, leading modular techniques including PPVC mostly use steel to manufacture and it minimises the weight of volumetric units (Mills et al., 2015). As a result of adopting steel manufacturing, PPVC technology becomes particularly vulnerable to fire (Mills et al., 2015). As PPVC has characteristics of the cellular nature, its fire safety is required to be considered separately as well as a whole building, which means the individual unit has to achieve required fire resistance (Mills et al., 2015).

RESEARCH METHOD

A qualitative research approach was used in this research by conducting a comprehensive literature review and Illustrative case study to achieve the aim of this research. The literature review covered the key themes related to modular buildings, the implementation process of PPVC technology, advantages and challenges of implementing PPVC technology. Keywords such as modular construction, sustainable development, waste generation, construction productivity, PPVC, advantages and challenges were used to conduct the literature review. About fifty sources including journal articles, books, conference papers and newsletters were reviewed to draw the findings of this research. As mentioned by Yin (2004), case studies allow researchers to retain the holistic view on real-life events while analysing the empirical events (Yin, 2014). As a number of projects were successfully completed in Singapore by using PPVC technology, Singapore was selected as a case study to review the implementation of PPVC technology. To gather the information related to this case study, secondary data was collected by reviewing regulations and codes published by the Singapore government; workshops and manuals established by Singapore Building and Construction Authority; newsletters and comments related to PPVC implementation in Singapore; and two recently completed building projects using PPVC technology. A qualitative approach was used to analyse the data in this research, which mainly included content analysis of government documents, standards, guidelines and newsletters related to the implementation of PPVC technology. Based on these findings a framework for successful implementation of PPVC technology in construction projects was developed.

FINDINGS

Initiatives and Policy Revisions to use PPVC in Singapore

The Singaporean economy was affected by the broader regional collapse in exports and as a result of that annual GDP growth rate dropped from 5.8% to 1.8% from 2014 to 2016 However, the Singaporean construction industry showed a continual growth during this period (Alcimed, 2018). This is mainly due to the fact that the construction industry is significantly driven by strong demand from the public sector and the investment on transport infrastructure (Tekla, 2016). Although the construction industry in Singapore is one of the best performing sectors in the country, the productivity of construction industry was affected by challenges that arose from a manpower crisis and rising labour costs in Singapore (Jo, 2016). Indicators on labour productivity showed that the construction industry lags behind the manufacturing industry. For example, labour productivity in the construction industry decreased by 0.2% in 2011 while manufacturing indicated a growth of 7.7%. Also, there are restrictions on foreign labour permits, the lack of local talent and increasing labour costs in Singapore (Tekla, 2016). Since 2013, Singapore's Ministry of Manpower started to advise organisations to invest in productivity growth and reduce their reliance on low-cost temporary immigrant manpower (Faithful Gould 2014). Tekla (2016) argued that if Singapore is planning to reduce labour usage and improve the productivity of the construction industry, a greater effort to move towards standardisation and prefabrication is required. The Singapore Building and Construction Authority (BCA) pointed out the importance of improving the productivity of the construction industry through the adoption of

automation and prefabrication techniques (Tekla, 2016). The advancement of technologies in the construction industry not only contributes to reduce reliance on labour, minimise the impact on the surrounding environment and create safer construction sites but also helps to attract more locals to the construction sector to build up a powerful local workforce (Trade Link Media, 2016). It is believed that manual labour can be substantially reduced on the way towards more automation and prefabrication and routine labour moved to an off-site factory environment for more efficiency and better safety (Tekla, 2016).

The government of Singapore plans to increase the productivity of the construction industry by 3% each year until 2020. Thus, the BCA developed a construction and productivity research and development (R&D) roadmap by focusing on new technologies as they indicated that the next stage of advancement in the construction sector requires transforming the way of building. The PPVC is one of the heavily promoted technologies under design for manufacturing and assembly (DfMA) cluster along with Virtual Design and Construction and 3D Printing. It is believed that such strategies could contribute to productivity improvements, overcome manpower restraints, save time, reduce construction waste generation and improve worksite safety (BCA, 2016a). The government of Singapore has implemented a range of legislation and regulation to encourage the use of PPVC to improve productivity and quality in the construction sector. In the first place, they periodically sell land parcels to developers as Government Land Sales (GLS). These sites are sold under the condition that developers are required to adopt productive techniques like PPVC in their proposed projects on that selected lands (BCA, 2014). It is a powerful stimulus for developers because the land in Singapore is extremely valuable and scarce. Furthermore, the Code of Practice on Buildability Singapore 2016 outlines the minimum requirements and accepted procedures for PPVC technology used in a building project or components of a building project on selected GLS sites on or after 1st December 2015 (BCA, 2016b). The Code states that the minimum percentage of adoption of PPVC should be 65% of total super-structural floor area of the building (BCA, 2016b). Also, it lists the minimum percentage of fittings and finishing to be completed off-site for the volumetric modules. As well, BCA establishes the accepted framework for PPVC which comprises two parties named the Building Innovation Panel (BIP) and the PPVC Manufacturer Accreditation Scheme (PPVC MAS) (BCA, 2016b). Under the PPVC technology acceptance formwork, suppliers and manufacturers have to submit proposals to BIP for assessment before issuing letters of acceptances (BCA, 2016b). In addition, suppliers and manufacturers accepted by BIP are required to be accredited by PPVC MAS in order to promote self-regulation in the construction industry (BCA, 2016b).

As the construction sector in Singapore has historically adopted conventional on-site construction methods, it largely depends on migrant manpower. In response to the advice of Singapore's Ministry of Manpower on investing in productivity, BCA created the Construction Productivity Centre that promotes the use of construction techniques which could save time on site and reduce reliance on labour (Mills et al., 2015). The Construction Productivity Centre actively encourages the application of PPVC and other prefabrication construction by providing training and key information through regular seminars and publications (Mills et al., 2015). Also, BCA updates construction industry information through platforms like the Construction InfoNet (BCA, 2016c). BCA also provides courses to the workforce in Singapore such as a two-month Advanced Certificate in Construction Productivity and a five-month Specialist Diploma in Construction Productivity (Barve, 2016). In 2016, the BCA Academy cooperated with Stanford University to provide advanced management courses for senior managers to help them work with advanced construction technologies like building information modelling (BIM) and PPVC with an integrated approach to the whole life cycle of building projects (Barve, 2016). For logistical support, the BCA launched Integrated Construction and Precast Hubs (ICPHs) in 2015 to strengthen the capacity of local off-site manufacturing (Mills et al., 2015). Unique in Singapore, the ICPH is a highly automated and advanced multi-storey off-site factory for manufacturing prefabricated construction components including prefabrication of individual elements, prefabrication of integrated

sub-assemblies and PPVC (Mills et al., 2015). In July 2015, the Construction Productivity Gallery was opened to educate the industry's participants and promote better knowledge of construction productivity (BCA, 2016c). Those platforms significantly contribute to promoting the advancement of prefabricated manufacturing technologies in Singapore. The BCA established the Construction Productivity and Capability Fund (CPCF) in order to support organisations that use productive technologies, invest capability and optimise the workforce. The BCA had provided SG$335 million into CPCF from 2010- 2015 for promoting the application of productive technologies like PPVC and another SG$450 million has been put in place from 2015-2018 (Barve, 2016). The funding positively encourages organisations to adopt new techniques and develop workforce by helping them overcome any concerns and risks of using new techniques.

Examples of Implementation of PPVC in Singapore

Since late 2014, PPVC has been applied in several projects as a part of game-changing technologies that promote higher productivity and less reliance on foreign immigrant labour in Singapore. Three flagship PPVC projects implemented in Singapore are a Student Residence at Nanyang Technological University (NTU's student residence), an extension of the Crowne Plaza Hotel at Changi Airport (Crowne Hotel) and a City Development Limited's Executive Condominium at Canberra Drive (CDL Condominium). However, due to the lack of information related to the CDL Condominium project, only the NTU's student residence and the Crowne Hotel were evaluated in this research.

Nanyang Technological University Student Residence (NTU's student residence)

The NTU's student residence project consists of six blocks of a 13-storey building with 1,673 student apartments. This is the first residential building project constructed using PPVC technology in Singapore. The project also adopted precast stairs, jump formed cores and in- situ concrete elements (NTU 2016). The PPVC modules used in the project were manufactured at Moderna Homes' supply in China, Malaysia, Taiwan and Singapore. These modules were then shipped to the fit-out factory in Jurong for finishing before transported to the site for installation (NTU, 2016). Only a small proportion of the finishing works were completed on-site for joints' sealing between the PPVC modules. The repetitive modules enabled for design and technical coordination without compromising aesthetical appearance as there were more than 10 module types (NTU, 2016). In addition, as the design was finalised at the early stage, reduction in the number of variants contributes to achieving higher construction efficiencies (NTU, 2016). During the construction, three high capacity tower cranes were established on-site rather than using mobile cranes to hoist PPVC modules into position (NTU, 2016). It is recorded that each PPVC module took about 40 minutes and 12 labourers to install including the preparation of temporary safe working platform (NTU, 2016). Each tower crane had the capability to hoist 8 PPVC modules every day if the weather condition was advantageous (NTU, 2016). The project experienced advantages in terms of cost and logistics as the number of vehicle movements was reduced by nearly two-third, from up to 3,000 truck trips to just over 1,200 (NTU, 2016). However, because both PPVC technology and conventional construction elements were applied in the overall project, the interfacing between PPVC construction and cast in-situ works became a challenging task for the project team (Meixian, 2016). Furthermore, as a result of the demand for additional land for storage and fitting-out of prefabricated modules, it was essential for the contractor to establish a complete program to ensure on-time delivery (Meixian, 2016). Another issue that needed to be addressed in this project was the high cost of adopting PPVC due to lack of economies of scale plus the high costs of shipping PPVC modules (Meixian, 2016). In the NTU hostel project, there was an estimated 18% increase in cost compared to conventional methods (Meixian, 2016). Therefore, it is expected the government will continue to promote the building demand to encourage more suppliers to come on board and release more lands for PPVC storages (Meixian, 2016).

Extension of the Crowne Plaza Hotel at Changi Airport (Crowne Hotel)

The Crowne Hotel project was the first commercial project in Singapore that used PPVC to achieve significant savings in both manpower and time. It is a ten- storey building with the extension area of about 10,000 m^2 with extra 243 rooms (Shyan, 2014). Originally, the project was proposed to deliver by using conventional methods, but at the early design stage, the delivery mode was modified in accordance with the governmental promoting strategies on PPVC technology (Shyan, 2014). The PPVC modules were manufactured in a controlled factory in China and then shipped to Singapore. These modules were delivered to the site for installation from 10 pm to 5 am in order to minimise disruption to airport operation and road networks (Shyan, 2014). The repeated hotel room layout was well suited for the PPVC technology (Shyan, 2014). All of the modular units such as twin room, single room and stair cores were designed to fit in the standard grid (Shyan, 2014). However, the support area located on the ground floor was built in a conventional manner and a podium structure was created to facilitate the installation of PPVC modules (Lim, 2016). In this project, 252 PPVC units were used to build a 10 storey hotel in 26 days. The whole project was completed within 6 months by using PPVC method, which would take approximately 12 months to complete by using conventional method (Lim 2016). Furthermore, the labour requirement for on-site works was reduced by 40% and thus, the actual labour requirement was reduced from 75 labourers to 45 labourers (Lim, 2016). According to the Lim (2016), 10 PPVC modules were installed daily, which took 3 or 4 days to complete a layer compared to 14-21 days per layer if using conventional methods.

These results showed that government incentives including mandatory regulations, financial supports, associated training courses and logistical supports provided a positive platform for PPVC implementation in Singapore. Furthermore, two projects that successful adopted PPVC technology highlighted the benefits of using this advanced technology especially in time savings and labour reduction. However, some challenges existed in the implementation of PPVC including transportation difficulties and initial setup costs.

DISCUSSION

The PPVC technology is at the early stage of its promotion, therefore, a completed and well-structured system for its application is still under exploration. Findings of this research highlighted the benefits of this advanced technology and discussed the mitigation measures to minimise the limitations of PPVC technology. Also, the research discussed strategies and recommendations for decision-makers in the construction industry to successfully implement the PPVC technology in construction projects.

The literature review assessed the implementation process of PPVC technology in construction projects. It showed that key steps of PPVC implementation are prefabrication of PPVC modules in off-site factories, delivery to site and installation on-site (Rui and Yahya, 2016). PPVC technology provides various opportunities to improve the construction process and the performance of the completed building in terms of productivity, sustainable performance and economic outcomes. Research findings showed that construction waste can be reduced by using PPVC technology as fabrication is done in a controlled factory environment, which also provides greater opportunities for reusing and recycling waste. Also, better quality control can be achieved due to strict quality control systems used in off-site factories, which enable superior and uniform quality of prefabricated units. Furthermore, as off-site manufacturing and on-site installation can be implemented at the same time, construction projects can be accelerated and thus it enables earlier completion and early start-up of business operation. Noise and dust can be significantly reduced as a result of using less on-site construction activities compared to conventional building processes. As well, as found in case studies, PPVC technology promotes safer workplace and labour reduction in construction projects. It indicates that safety on-site can be improved as a result of fewer traffic movements to and from construction sites.

Some challenges of implementing PPVC in construction projects were found from the Singapore projects. Firstly, the cost was increased by 18% in NTU's student residence project due to the set-up

costs of machinery and plant for fabricating new PPVC modules. Also, transportation costs and handling of PPVC modules were increased depending on the size and shape of PPVC modules and site accessibility of the project. Another challenge was the demand for additional land for storage and fitting-out PPVC modules. Furthermore, both NTU's student residence project and the Crowne Hotel project showed that a highly collaborative work environment is required to implement PPVC technology as the interfacing between PPVC and cast in-situ works requires efficient and effective cooperation and communication.

Although there are limitations and drawbacks in the process of PPVC implementation, a range of measures can be considered to minimise or mitigate them. From the PPVC practice in Singapore, it was found that the optimal component size and delivery method can be considered at the early stage of construction projects to ensure appropriate implementation of PPVC technology (BCA, 2016b). Firstly, the size and weight of volumetric units should be carefully considered during the design stage to enable efficient and convenient transportation. Then, transport routes should be established and built into the logistics planning and site layout before site preparation (BCA, 2016b). Also, it was identified that the introduction of multiple layers of wall boarding helps PPVC units to achieve the required grade of fire protection (Mills et al., 2015). Although PPVC implementation requires a higher initial cost, Lawson et al. (2012) argued that besides the initial investment for the production machinery, transport and installation costs, economy of scale, efficiency gains in materials usage, benefits in speed of assembly, and savings in preliminaries should also be considered when assessing an economic model for PPVC technology. Therefore, the gains in manpower savings and site productivity could offset the incremental costs of the initial cost of PPVC technology including training costs and set-up costs. Similar to approaches used in Singapore, authorities have to provide financial support to promote new advanced technologies and offer relevant training courses for construction professionals. In term of regulations, stringent regulations and codes should be established, such as the mandatory use of PPVC on selected lands based on reasonable project programs, level of modularity and enforcement. The regulations should be developed by considering the project performance parameters, procurement policies and procedures, environmental regulatory and business practices. Also, more recognition should be given to organisations' productivity record during procurement assessment. Furthermore, supplementary documentation should be provided for participants such as reports, manuals, and guidelines to translate the commitments and present good practices adopted for PPVC or other new technologies. Also, the findings emphasised the importance of recognition of productivity enhancement and design for productivity in the procurement stage by giving weight to productivity in assessment criteria in tendering. Since the implementation of PPVC requires a highly collaborative workplace, management-led procurement models such as construction management, management contracting, and alliancing can be recommended rather than using conventional designer-led models when implementing PPVC. Furthermore, clients have to influence design teams to be productivity-oriented. Early inputs of specialist contractors could provide valuable contributions to PPVC during the design stage such as the optimal dimensions selection for finishes materials and weight of units for ease of fabrication, transportation and installation. These early inputs from contractors could also ensure cost-effectiveness and productivity of proposals. Training courses and workshops are required to increase the awareness of professionals and academics on PPVC and to make participants aware of transformation from conventional construction to advanced methods. Similar to the Singapore context, productivity centres and platforms can be built to share knowledge and practices on advanced construction techniques while several courses are provided to upgrade the workforce. A good relationship must be built among industry participants by providing consultancy, accepting their feedback and promoting product awareness. Authorities should retain flexibility in establishing regulations, processing applications and employ or consult with professionals who have a better understanding of the construction industry. Other participants have to hold an open attitude to support productivity initiatives and be less cost-driven while maintaining better communication.

Based on findings and discussion, a framework for successful implementation of PPVC in a construction project was developed as shown below.

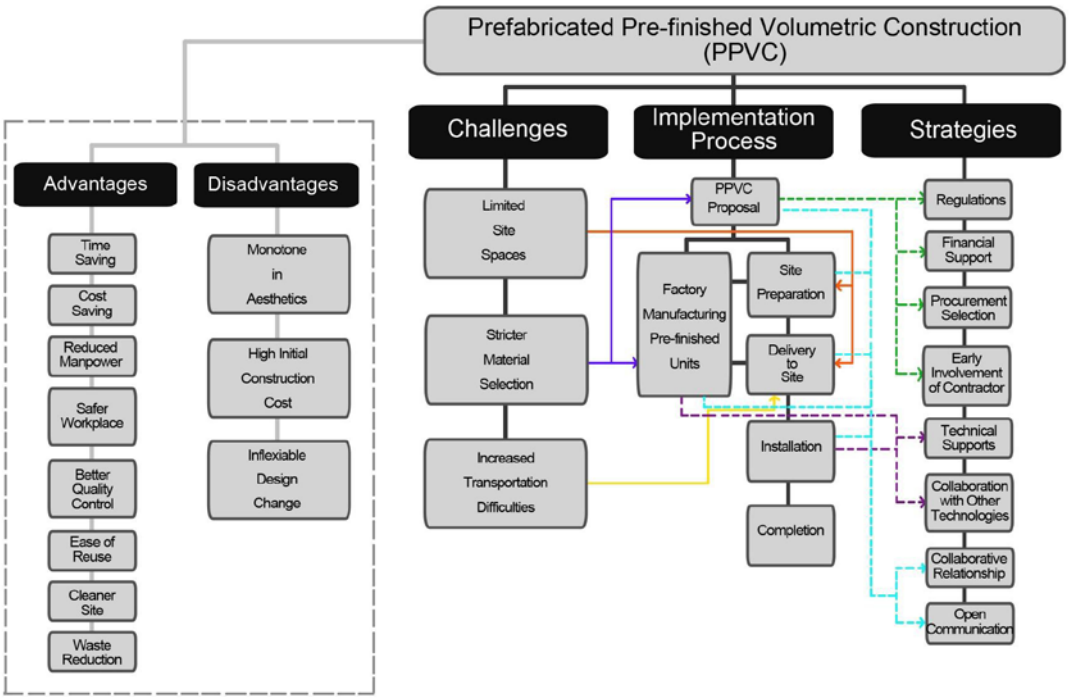

Figure 1 Framework for PPVC implementation in construction projects

CONCLUSIONS

The aim of this research was to develop a framework for the successful implementation of PPVC in construction projects. A literature and a case study were used to achieve the above-mentioned aim. The context of Singapore has been assessed as PPVC has been widely promoted in Singapore in the past few years to create a productive construction industry. It was identified that the government of Singapore established a series of strategies to promote the implementation of PPVC including financial support, training program, regulations and codes, which create an active environment for promoting PPVC technology. Advantages of using PPVC technology are evaluated through reviewing theories and analysing successful completed PPVC projects in Singapore, which shows PPVC technology substantially reduced construction duration, overall construction cost, waste generation and manpower requirements in construction projects while enabling safer and cleaner sites. Although challenges such as transportation difficulties, additional demands on storage lands and higher initial costs are presented, several measures have also been provided to mitigate the impact and to manage challenges effectively. The strategies such as government incentives, procurement, project management and relationship with industry are provided for various participants to drive efficiency and innovations in construction projects. The findings of this research give a positive view on the implementation of PPVC in future projects, which provides further research opportunities such as focusing on personalised design, manufacturing process, installation process and other aspects in relation to the implementation of PPVC technology in construction projects.

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TOWARDS DECISION MAKING ON CARBON REDUCTION OVER THE BUILDING LIFE CYCLE – AN EMPIRICAL STUDY

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Abstract:

Efforts have been being made to foster carbon reduction in the construction development. However, few studies have acknowledged that the adoption of carbon reduction strategies is a matter of decision making. This study aims to identify the role played by individual stakeholders on the adoption of carbon reduction strategies for different stages of the building lifecycle. A questionnaire survey was conducted in the greater Melbourne region. Perceptive views of the construction practitioners were solicited. Monte Carlo simulations were conducted to depict the influential powers of different project stakeholders on adoption of carbon reduction. The results indicate that "Coordinate with sub-contractors at project level", "Install renewable energy devices to save energy when the building is in use"; and "Make redundant old machinery and adopting the use of new modern fuel efficient machinery" are the most frequently adopted carbon reduction strategies across all roles of project stakeholders. Future studies can contribute to identifying the carbon reduction strategies that are most effective to stakeholders; solutions can therefore be devised on these versatile strategies.

Keywords: carbon reduction, strategies adoption, stakeholders, lifecycle

INTRODUCTION

Building and construction sector annually accounts for more than one-fifth of the total worldwide carbon emissions (GRI 2011). In recent years, researchers have proposed a number of strategies to reduce carbon emissions over the building life cycle. For design and construction stage of the cycle, researchers proposed the industry to reduce the reliance on high embodied carbon construction materials (Petersen and Solberg 2003), adopt less carbon-intensive materials in buildings (González and García Navarro 2006), develop mechanisms to evaluate the environmental impact caused by the construction activities (Osmani et al. 2008, Li and Colombier 2009), and reduce energy consumption in construction operations (Osmani et al. 2008). For building use stage, researchers advocate the adoption of advanced technologies to optimize energy efficiency (Li and Colombier 2009), several energy efficiency rating systems were proposed (Deng et al. 2012; Todd et al. 2013). To foster carbon reduction at the end-of-use stage of the building life cycle, researchers advocated the more extensive use of recyclable building materials and the use of less polluted approach in building demolition (Wong and Zapantis 2013).

Reducing carbon emissions over the building life cycle has been advocated as vital for sustainable development (Alhorr et al. 2014). While previous research studies have made significant progress to devise carbon reduction strategies, project stakeholders have been criticised as slow and not motivated to adopt them (Wong and Zapantis 2013). In this study, project stakeholders are defined as the organisations collaborating in a construction project. This includes the developers (PSH1), design consultants (PSH2) including architects and engineers, non-design consultants (PSH3) including quantity surveyors and safety managers, main contractors (PSH4) and the sub-contractors (PSH5).
In order to foster an effective implementation of carbon reduction strategies, project stakeholders may have different priorities, concerns and roles to play. For examples, previous studies argued that contractors are indeed capable of but stay passive in adopting carbon reduction strategies (Ding 2008,

Zuo et al. 2012). This is not without a sensible reason. Research suggests behavioral issues or decisions of the developers and consultants hinder the adoption of strategies (Wong and Zapantis, 2013). As such, contractors may be constrained by other stakeholders to implement carbon reduction strategies. Over the life cycle of the project, construction contractors can be seen as the instructions' executers, nonetheless following the instructions can have a long term impact on the carbon emissions. Sustainable initiatives are a costly expense that developers may prefer not to adopt carbon reduction strategies, in particular when they are planning sell the ownership after the building is built. In another study, Spiegel and Meadows (2010) discussed that by understanding the perceptions of a knock on effect passing down the construction line from the developers and the consultant's perspective, reducing carbon emissions in the designs and operations phase could result in additional project costs that may consequently minimise profit margins. With such concern, consultants sometimes hesitate to propose more energy efficient designs to the developers.
The above review indicates that research efforts have been being made to devise carbon reduction strategies. However, few studies have acknowledged that the adoption of carbon reduction strategies is a matter of decision making. This study aims to study the project stakeholders' priorities on carbon reduction strategies.

CARBON REDUCTION STRATEGIES OVER THE BUILDING LIFE CYCLE

In recent years, industry reports in relation to introducing carbon reduction strategies to the construction projects have been published (ENCORD 2010; GRI 2011). Strategies relevant to advanced technologies that optimise energy saving, adopt less carbon-intensive materials in buildings and develop mechanisms for evaluating the environmental impact driven by construction activities were proposed (Fieldson 2009; Li and Colombier 2009; Tsai et al. 2012). While researchers advocated that the proposed strategies are conducive to carbon reduction, there is no objective measure to access if the applied strategies have achieved the anticipated outcomes. In this regard, the United Nations Environment Programme (UNEP) suggested some strategies to help the building sector reduce carbon in construction projects, these include: renovating buildings to maximize the reduction of emissions, working to introduce a carbon trade mechanism for buildings, working with governments to develop policies that make a difference in emissions behavior (UNEPSBCI 2009). Nevertheless, the proposed guidelines are not project-specific, implying that they may not be effective in evaluating project stakeholders' performance in carbon reduction. Global Reporting Initiatives (GRI) (2011) specifically developed guidelines for project stakeholders to report their sustainability performances whereby their performance is assessed under three key aspects: management approach, strategy and profile and performance indicators. Similar, the developed guidelines have not proposed any project-specific measure to evaluate these strategies.

In this respect, the European Network of Construction Companies for Research and Development (ENCORD) developed an inventory that evaluates the carbon emitted in a construction project specifically. The inventory proposes evaluation of carbon emission in construction projects in thirteen aspects as shown in Table 1. This study adopts the work of ENCORD (2010) as the carbon reduction strategies applicable to the design and construction stage of the building life cycle. In regards to carbon reduction strategies applicable to the building use and end of use stages of the building life cycle, literature review was conducted. The identified strategies are presented in Table 1.

Table 1: Operational statements to evaluate carbon reduction strategies adoption in projects

Code	Operational Statements
PSH[DC]	My company collaborates with the other project stakeholders in devising strategies that foster carbon reduction at the design and construction stage of the building life cycle
PSH[BU]	My company collaborates with the other project stakeholders in devising strategies that foster carbon reduction at the building use stage of the building life cycle
PSH[EOU]	My company collaborates with the other project stakeholders in devising strategies that foster carbon reduction at the end of use stage of the building life cycle
The following strategies were adopted in my project to foster carbon reduction at the design and construction phase of the building life cycle:	
DC1	Reduce fuel for plants and machinery in use on site
DC2	Reduce fuel for use in premises which support the company's activities (i.e Site Office and Amenities)
DC3	Reduce carbon emissions from physical and chemical processing involved in the production of mineral products (such as cements) and metal products (such as steel)
DC4	Reduce electricity for plants and machinery in use on site
DC5	Reduce electricity for use in premises which support the company's activities (i.e Site Office and Amenities)
DC6	Reduce heat purchased by the company for use at the company's project and premises
DC7	Reduce the use of vehicles traveling on public highways
DC8	Increase the use of public transports by the employees
DC9	Coordinate with sub-contractors at project level to achieve items DC1 to DC8
DC10	Reduce construction wastes and the associated transportation for disposal
DC11	Reduce the use of materials with high embodies of CO2 like structural steel concrete, reinforcement, cladding, aggregates and bituminous products
DC12	Reduce carbon emissions resulting from the built object through better design
DC13	Adopt efficient modes of logistics to and from site.
The following strategies were adopted in my project to foster carbon reduction at the building use stage of the building life cycle:	
BU1	Adopt energy efficiency rating systems (NABERs, Green Star and alike) would have on the end use of the building.
BU2	Install renewable energy devices (solar photovoltaic (PV) panels or alike) to save energy when the building is in use.
The following strategies were adopted in my project to foster carbon reduction at the end of use stage of the building life cycle:	
EOU1	Assess the effects demolition would have on the environment
EOU2	Use recycled materials throughout the project.
EOU3	Use materials that can be recycled once the building is demolished.

EOU4	Make redundant old machinery and adopting the use of new modern fuel efficient machinery.

RESEARCH METHODOLOGIES

The questionnaire design

To accomplish the research objective, a questionnaire survey was conducted for data collection. The survey questionnaire contains three parts. Part 1 deals with demographic information about the respondents. Respondents were asked to specify a project they had been involved in for at least one year, and the questionnaires of those not having taken part in a specified project for more than one year were discarded. Part 2 starts with three general questions that seeks to solicit the degree of respondents' agreement (from 1 to 5 representing 'strongly disagree' to 'strongly agree' respectively) on whether their companies collaborate with the other project stakeholders in devising strategies that foster carbon reduction at different stages of the building life cycle. Then perceptive views were collected in regards to the extent of the particular carbon reduction strategies were adopted during the project (from 1 to 5 representing 'very low' to 'very high' respectively) (refer to the operative statements of Table 1).

Data collection and analysis

Construction industry practitioners within the greater Melbourne region are the targeted participants of this study. In particular, construction practitioners who identify as developers, consultants, contractors and sub-contractors are the targeted respondents. A variety of these professionals were identified through a wide range of sources. These sources include authorised access to professional databases searched from official websites of the professional bodies that include; the Master Builders (MA), Australian Institute of Building (AIB), Australian Institute of Architects (AIA), Australian Institute of Building Surveyors (AIBS), Australian Institute of Quantity Surveyors (AIQS) and Royal Chartered Institutes of Surveyors (RICS). With an understanding that some professional webpages do not disclose the exact numbers of members in the search engine, this study also adopted a snowball technique to source targeted respondents from an internet social network called LinkedIn. A list of potential respondents was compiled and 200 people from this list were randomly selected as the targeted respondents of this study. Invitations were sent to these 200 targeted respondents to complete the questionnaire via the online Qualtrics questionnaire platform.

Regarding data analysis, firstly the mean scores of the respondents' degree of agreement on the adoption of carbon reduction strategies at the three building life cycle stages were compared. Furthermore, Monte Carlo simulations were conducted to examine how different project stakeholders may prioritise strategies at different stages of building life cycle. Monte Carlo simulation is a computerized mathematical technique that uses the Multiple Regression data set to provide an array of possible outcomes and probabilities based on sensitivity analysis. In this study, fifteen multiple regression analyses were conducted to investigate how may prioritise the adoption of carbon reduction strategies at the three stages of building life cycle. The broad equations of multiple regressions (at different stages of building life cycle) are shown as below:

$$\mathbf{PSH}[\boldsymbol{DC}]_x = \mathbf{a} + \mathbf{b}_1\mathbf{DC}_1 + \mathbf{b}_2\mathbf{DC}_2 + \ldots + \mathbf{b}_{12}\mathbf{DC}_{13} + \boldsymbol{\varepsilon} \quad (1)$$

$$\mathbf{PSH}[\boldsymbol{BU}]_x = \mathbf{a} + \mathbf{b}_1\mathbf{BU}_1 + \mathbf{b}_2\mathbf{BU}_2 + \boldsymbol{\varepsilon} \quad (2)$$

$$PSH[EOU]_x = a + b_1EOU_1 + b_2EOU_2 + b_2EOU_3 + b_2EOU_4 + \varepsilon \quad (3)$$

Where:

$PSH[stage]_x$ = Dependent variable (i.e. on whether their companies collaborate with the other project stakeholders in devising strategies that foster carbon reduction at different stages of the building life cycle PSH_1 to PSH_5)

DC_y = *Independent variables (i.e. the extent of carbon reduction strategies adoption at design and construction stage DC1 to DC12)*

BU_y = *Independent variables (i.e. . the extent of carbon reduction strategies adoption at building use stage BU1 to BU2)*

EOU_y = *Independent variables (i.e. . the extent of carbon reduction strategies adoption at end of use stage EOU_1 to EOU_4)*

a, b1, b2……b13 = *Unknown constant*

ε = *Random error for any given set of values for DC_1 to DC_{13}*

The Multiple Regression results were then further analysed through Monte Carlo simulation to examine the project stakeholders' priorities on carbon reduction strategy adoption at different stages of the building life cycle. Monte Carlo simulation allows easy identifiable visuals on what inputs have the biggest effects on the dependent variable. The same approach had been successfully adopted by Hong et al. (2016) who adopted Monte Carlo simulation to identifying parameters for measuring greenhouse gas emissions in construction projects.

FINDINGS AND DISCUSSIONS

Response rates and sample profile

A total of 200 questionnaires were dispatched through Qualtrics. 46 responses were received but 2 of them were subsequently discarded because the questionnaires were incomplete44 valid responses were used representing a 22% response rate. The study has attracted a reasonable response rate in comparison to other questionnaire surveys in the construction field normally ranging from 25% to 30% (Wong and Zapantis 2013). Among the respondents' backgrounds, 29 out of 44 (i.e over 70% of the) respondents have had more than 10 years' project management experience. The creditability of the respondents is indicative of their service to the industry thus their responses are considered to be reflective to the industry's views in the greater Melbourne region.

Adoption of carbon reductions strategies

Respondents were firstly asked whether their companies collaborate with the other project stakeholders in devising strategies that foster carbon reduction at different stages of the building life cycle. They were then asked the extent that the strategies enlisted in Table 1 were adopted in fostering carbon reduction. The mean scores and standard deviations (S.D.) are presented in Table 2.

Table 2: Respondents' opinions of carbon reduction strategies adoption in projects

Attributes	Mean	S.D.	Attributes	Mean	S.D.
PSH[DC]	2.90	1.15	DC9	3.02	0.98
PSH[BU]	2.06	0.91	DC10	2.64	0.97
PSH[EOU]	2.68	0.86	DC11	3.07	1.02
DC1	2.80	0.85	DC12	2.57	1.02
DC2	2.66	0.89	DC13	2.65	0.90
DC3	2.80	0.98	BU1	2.07	0.79
DC4	2.86	0.90	BU2	2.44	1.16
DC5	2.80	0.98	EOU1	2.64	0.94
DC6	2.84	0.99	EOU2	2.66	0.96
DC7	2.95	0.94	EOU3	2.68	1.05
DC8	2.95	1.10	EOU4	2.80	1.07

The respondents generally agree that their companies have been collaborating with the other project stakeholders in devising strategies that foster carbon reduction at the design and construction stage of the building life cycle (2.9 out of 5 which is higher than the midpoint of 2.5). Nonetheless, such collaboration may not be extended to devising strategies that can help reduce carbon at the building use stage (mean score = 2.06, S.D. 0.91). Similar results were found when the adoption of particular carbon reduction strategies was studied.

Out of the two building use stage strategies, both of them were lower than the midpoint of 2.5, BU1 'Adopt energy efficiency rating systems (NABERs, Green Star and alike) would have on the end use of the building' (Mean= 2.07, S.D. = 0.79) and BU2 'Install renewable energy devices (solar photovoltaic (PV) panels or alike) to save energy when the building is in use.' (Mean= 2.44, S.D. = 1.16). This indicates that respondents generally disagreed that these carbon reduction strategies have been adopted to facilitate carbon reduction at the building use stage. This may represent that project stakeholders might not be interested to plan on long term carbon reduction strategies that they don't have control. Such findings is in line with the study conducted by Wong et al. (2014) who pinpointed that carbon reduction strategies being adopted in the construction development were not robust in the sense that most project stakeholders are not the end users of the building.

End of use stage strategies were generally agreed to be adopted, but the extent to which they are adopted is still lower than the building and construction stage carbon reduction strategies. In relation to EOU4 'Make redundant old machinery and adopting the use of new modern fuel efficient machinery' (Mean = 2.80, S.D. = 1.07), that can be interpreted as the companies that the respondents working in may not worried with how the building is going to be utilized. Most of the carbon reduction strategies that were adopted were focused on the building and construction stage. The results indicate that, in regards to carbon reduction strategies, respondent's companies are very pragmatic to do what they can with the mandate they are required. They rarely collaborate to plan for strategies that can help reduce carbon during the later stages of the building lifecycle.

Project stakeholders' priorities on strategies adoption

Multiple linear regression analyses were used to examine the project stakeholders' priorities on carbon reduction strategy adoption at different building life cycle stages. The results were further analysed through Monte Carlo Simulation in order to articulate the preferences (in terms of the normalised contributions to variance (NV)) of project stakeholders on the adoption of the particular carbon reduction strategies. The outputs of the Monte Carlo simulations are presented in Table 3.

Table 3 – Normalised weightings of strategies adoption of various stakeholders.

	Normalised contribution to variance				
Strategies	Developer/Client (PSH 1)	Consultants – design related (PSH 2)	Consultants-design unrelated (PSH 3)	Main Contractor (PSH 4)	Sub-Contractors (PSH 5)
DC1	0.11	0.04	0.10	0.05	0.07
DC2	0.12	0.06	0.20	0.13	0.23
DC3	0.03	0.05	0.09	0.10	0.02
DC4	0.04	0.13	0.02	0.03	0.05
DC5	0.07	0.16	0.13	0.04	0.06
DC6	0.04	0.06	0.02	0.04	0.04
DC7	0.11	0.02	0.01	0.00	0.01
DC8	0.03	0.01	0.06	0.11	0.13
DC9	0.18	0.20	0.12	0.15	0.21
DC10	0.01	0.13	0.01	0.12	0.02
DC11	0.13	0.08	0.09	0.08	0.09
DC12	0.03	0.05	0.12	0.07	0.03
DC13	0.11	0.03	0.03	0.09	0.04
BU1	0.31	0.18	0.43	0.23	0.11
BU2	0.69	0.82	0.57	0.77	0.89
EOU3	0.37	0.12	0.06	0.11	0.03
EOU2	0.35	0.05	0.20	0.07	0.23
EOU4	0.27	0.50	0.27	0.52	0.55
EOU1	0.05	0.34	0.47	0.31	0.18

All project stakeholders showed great impact on adopting DC9 Coordinate with sub-contractors at project level (normalized weightings ranged from 0.12 to 0.21). Sub-contractors are the front line of operations. The results indicate that stakeholders realised the importance to coordinate with sub-contractors to reduce carbon at the operational stage. The results also indicate that different stakeholders may dominate different strategies adoption. For examples, design consultants and contractors prefer DC10 "Reduce construction wastes and the associated transportation for disposal". Such results can be interpreted that stakeholders really rationalised their plans on carbon reduction to "do what they can do".

Another example can be found on 'DC8: Increase the use of public transports by the employees' where consultant showed a clear lack of motivation of adoption. The results also signify that 'BU2: Install renewable energy devices to save energy when the building is in use' and 'EOU4: Make redundant old machinery and adopting the use of new modern fuel efficient machinery' are the most frequently adopted carbon reduction strategies adopted by consultants.

The above unfortunately indicates the attitudes of the project stakeholders for not taking any measure that they're not familiar with. It further suggests that to motivate project stakeholders to take real actions, one should first identify strategies within their comfort zone to strengthen their confidence to contribute to the carbon reduction exercise. The Monte Carlo Simulation results reveal that some

carbon reduction strategies are commonly reactive or inactive (high/low) across various stakeholders. By being able to understand and interpret the results it may help identify which strategies are likely to be effective when implemented and put in place in construction projects. This would signify that the specified strategy is the more effective attribute to reduce carbon throughout the building lifecycle.

CONCLUSIONS

While previous research studies have made significant progress to devise carbon reduction strategies, there is a candid need to determine why the construction industry were not motivated to adopt them. In this study, carbon reduction strategies were identified across the building lifecycle through a literature review. A survey was conducted in the greater Melbourne region to collect perceptive views about individual project stakeholder's priority of carbon reduction strategies.

The results of the Monte Carlo Simulations indicate that in regards to carbon reduction strategies, project stakeholders may have set boundaries to adopt those they are familiar with. Previous research studies report that a great portion of carbon is emitted during the building use stage and end of use stage of the building life cycle. Through better design and collaboration among project stakeholders, carbon emissions can be reduced. However, the results of this study reveal that project stakeholders may not be collaborating with each other in devising strategies that foster carbon reduction at the building use stage. Further studies that focus on fostering project stakeholders' collaboration in carbon reduction at building use stage are suggested.

The findings of this study offered an avenue to interpret the impact of stakeholders' priorities on carbon reduction strategies. However, they should be taken within the context of several limitations. First, it should be noted that the respondents of this survey were randomly selected from the contractors list registered in the State of Victoria, Australia. The results of this study can be viewed as a case study conducted in the greater Melbourne region. Second, comparison of mean scores reported in the discussion section should be read with due caveats on the limitations of the working sample and the constraint on the scope of research. Third, as a further study this survey can be extended to collecting data in other countries.

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TOWARDS UNDERSTANDING THE ADOPTION OF INNOVATION IN CONSTRUCTION- A SYSTEMATIC REVIEW

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Abstract

Research has long recognized the benefits associated with the adoption of innovation by construction project organizations (CPOs) in relation to increased productivity, performance and sustainability. However, despite the existing drivers, the implementation of innovation with in the construction industry, to date, has been low. CPOs do not exhibit the same level of acceptance in construction innovation. While some research studies linked this response to the adoption of innovation to the resistance to change, few have recognized that different organizations have different understandings of innovation and that this may impact their responses towards advanced technology adoption. This research typologises innovation through a systematic literature review that defined and classified different forms of innovation. Three main forms of innovation were identified: incremental innovation, radical innovation, and disruptive innovation. These forms of innovation were then compared based on their strengths, weaknesses, opportunities, and threats (SWOT). The research recognizes that an organizations' response to the adoption of advanced technology is affected by their different perspectives about innovation. A framework of construction innovation typology is developed, and may be used in future studies to understand how CPOs may perceive innovation that affects their attitudes towards advanced technology adoption. Measure can then be devised to help CPOs to prepare for the related challenges associated with adoption.

Key words: construction innovation; construction project organizations.

INTRODUCTION

Innovation can be defined as the realization of a new method, approach or process that may improve services or products, or significantly enhance an organization's operations and/or practice (OECD 2005). Innovation is not simply an the introduction of a new product or services into traditional disciplianry practice. The adoption of innovation requies evaluation, unlearning, trails and errors, continuous interactions collaborations at both inter-organizational and intra-organizational levels (Mention 2011; Snow 2007). Both government and industry reports recognise that innovation can be key to improving or maintaining a company's competitive advantage in the marketplace through increaed economic growth and productivity (OECD 2005; Ozorhon 2012; Xue et al. 2014).

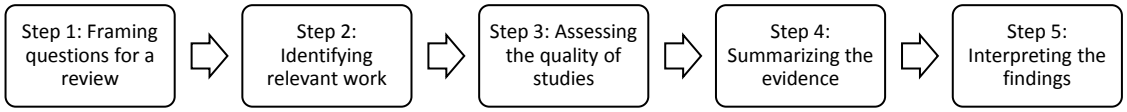
"Construction innovation" is a general term being used within the construction industry to describe a capture or creation of new ideas and technologies that are then embedded into organizations and/or their associated projects (Gann and Salter 2000). Construction innovation is inextricably intertwined with new forms of economy growth that have an emphasis on sustainability, the reduction on the reliance of labor and the enhancement of productivity (Gann 2003; Ozorhon et al. 2010). Such enhancement increases the aspirations and needs of society, clients, and the improved competitiveness of the organization and the industry in general (Latham 1994). In recent years, significant efforts have been made to develop new business models that increase productivity, achieve better supply chain

integration and promote innovation (Xue et al. 2014). The adoption of innovation, by construction project organizations (CPOs), is influenced by: developers, consultants, contractors and sub-contractors (Akintoye et al. 2012). Further, research indicates that different CPOs understand innovation in different ways due to different targets (Xue et al. 2014). Moreover, different professional practices and assumption result in the different categorization of innovation and the type of innovation associated. For example, building information modeling (BIM) was described as a disruptive innovation in the construction industry because it changes the professionals practice in design and project data mining (Gledson 2016; Kassem et al. 2014; Succar et al. 2012). Succar (2009) described BIM as an integrated and innovative model in which process and product information is combined, stored, elaborated, and interactively distributed to all relevant building participants and it is a technological innovation (OECD 2005). Disruptive innovation is defined as technology, product, or process that will expand existing services and may even replace them (Rafii and Kampas 2002). However, Murphy (2014) argued that BIM is usually regarded as radical innovation, which is defined as a new approach that can lead to major changes in the industry itself and this is a rare and unpredictable (Slaughter 1998). Since 1970s, Slaughter (1998) argued the adoption of BIM has been largely incremental. The slow adoption of BIM within the construction industry is only one of the many examples that illustrate the lack of consensus on how innovation is understood: its nature, its pre-conditions to succeed, its risks of failure, its complexity of implementation within the construction context. This paper presents a systematic review that investigates how construction innovation is currently understood within the construction industry. Additionally, it identifies different forms of innovation and their associated characteristics. The review assists in the understanding of how different perceptions of innovation may affect industry practitioners' behaviors in the adoption of innovation in projects. This study is conducted with a premise that the successful adoption of advanced technology in construction projects is dependent on whether CPOs would in construction practice change. However, their different perceptions about innovation may affect their attitudes towards accepting changes.

THE RESEARCH METHODOLOGY

The approach to systematic review adopted by Khan et al. (2003) has been employed in this study. A systematic review is a specific method of locating existing research, selecting and evaluating contributions of the research, analyzing and synthesizing data, and reporting evidence in a way that a reasonable conclusion about what is explored and unexplored can be drawn (Denyer and Tranfield 2009). Khan et al. (2003) proposed a five steps approach in the completion of a systematic review. This study consists of the following five steps as depicted in Figure 1.

Figure 1 Five steps approach for systematic review



Step 1 of the process requires the development of a research question to structure and guide the literature review. Keywords “construction innovation”, “types of innovation + construction”, and “forms of innovation + construction” were identified and used for the search of relevant articles. In the next step, the relevancy of the identified articles was checked through reading the articles’ abstracts and full texts. Moreover, the theory of construction innovation was identified in this study from the literature

review. Furthermore, after filtering, the forms of innovation in construction were selected and summarized (Khan et al. 2003).

RESULTS AND DISCUSSION

The concepts of construction innovation

This section of the paper presents the different definitions and forms of construction innovation based on the literature review conducted. "Construction innovation" is a general term used within the construction industry to describe a capture or creation of new ideas and technologies that are then embedded into organizations and/or the associated projects (Gann and Salter 2000). The concept of construction innovation was first developed in late 1970s by Rothwell (1976) to describe the adoption of an new idea or approach in the construction projects (Murphy et al. 2011). Since then the concept has been loosely developed until a comprehensive study was conducted by Slaughter (1998). She reviewed the existing definitions of innovation from other industries and specified that "construction innovation" can be defined as "the actual use of a nontrivial change and improvement in a process, product or system that is novel to the institution developing the change" (Slaughter 1998, p. 226). This definition is still widely applied within the construction management research context (Blayse and Manley 2004). However, there exist a variety of definitions of construction innovation from specify and narrow perspectives (refer to Table 1), i.e., from the perspective of technology (e.g., Freeman (1982), Tatum (1987), and Dale (2007)), behavior (e.g., Motawa et al. (1998), and spanning both sides from technology and behavior (e.g., OECD (2005)). A variety approaches were used in these studies but construction innovation is commonly described as a tool that foster advanced technology. Essential and consistent with each definition to the successful adoption of construction innovation was a need to change contemporay practice to accommodate the innovation; however, this was often recognised wihtin the literature as lacking (Blayse and Manley 2004; Dubois and Gadde 2002).

Table 1 A variety of definitions of construction innovation

Definition of construction innovation	Citations
Use an idea for the first time through a new adopter	(Rothwell 1976)
Non-trivial changes and improvements used in novel processes, products, or systems in evolving institutions.	(Freeman 1982)
Apply the technology to a construction company firstly.	(Tatum 1987)
Innovation is a complex multidimensional process with a series of outcomes, including updates and expansion of products and services and related markets; new methods of production, supply and distribution; and new forms and practices of organization and work.	(Barrett and Sexton 1998)
Applying new organizational techniques improves the design and construction of living space significantly by reducing installation costs, improving installation performance, and enhancing business processes.	(Motawa et al. 1998)
Innovation is "the actual use of a nontrivial change and improvement in a process, product or system that is novel to the institution developing the change."	(Slaughter 1998, p. 226)
Innovation is a novel process, product, or system for the development and change of institutions with the improvement of the actual use.	(Toole 1998)
The new concept becomes a new part of building a product that has economic, functional, or technical value.	(Seaden and Manseau 2001)
The significant new processes, products, or management methods are implemented to increase the efficiency of an organization	(Seaden et al. 2003)
Construction innovation as a system, where the elements of the models are goals, environmental challenges/drivers, strategies, and organizational factors	(Dikmen et al. 2005)
Innovation is the realization of a new or significantly enhanced product (or service), or process, a new marketing method, or a new organizational approach to business practice, workplace organization, or external relations	(OECD 2005)

The production, development, and implementation of ideas that are new to the organization and have commercial or practical benefits.	(Dulaimi et al. 2005)
The U.K. Chartered Institute of Building defines innovation as "the successful introduction of new technologies or procedures into an industry."	(Dale 2007)

Forms of construction innovation

The research reviewed recognized that there are different conceptualizations of innovation presented in table 2. In the associated studies, characteristics of different forms of innovation were distinguished by their "degree of change", "uncertainty" and, "drivers of change". These characterizations recognized that innovation has traditionally been characterized according to degree of change and pace. Incremental innovation and radical innovation were the first two systematically classified models defined by Schumpeter (Schumpeter 1934, 1942). Miles et al. (1978) then identified corporate strategy typology as disruptive-sustaining innovation typology. Henderson and Clark (1990) recognized the relationship between incremental innovation, modular innovation, architectural innovation and radical innovation through changed or unchanged and reinforced or overturned conditions. Slaughter (1998) further added systems innovation to the list of characterization, which can be described as the degree of change required through emerging new practice, i.e., incremental innovation, modular innovation, architectural innovation, system innovation and radical innovation range from small to major changes. Christensen (1997) classified innovation into sustaining innovation and disruptive innovation. Drew (2006) further categorized sustaining innovation into incremental and radical innovations. OECD (2005) classified innovation as product, process, marketing and organizational innovations. The majority of classifications focus on the degree of changes, the degree of uncertainty, as well as what drive changes.

Table 2 Conclude the different forms of innovations

Category innovations	References						
	A	B	C	D	E	F	G
Incremental innovation	★		★		★		★
Radical innovation	★		★		★		★
Market Niche innovation		★					
Regular innovation		★					
Revolutionary innovation		★					
Architectural innovation		★	★		★		★
Modular innovation			★		★		★
System innovation					★		
Sustaining innovation				★			★
Disruptive innovation				★			★
Product innovation						★	★
Process innovation						★	★
Marketing innovation						★	★

Organizational innovation						★	★

Note: (A) (Schumpeter 1934, 1942); (B) (Abernathy and Clark 1985); (C) (Henderson and Clark 1990); (D) (Christensen 1997); (E) (Slaughter 1998); (F) (OECD 2005); (G) (Mohr et al. 2010).

Based on the systematic review and the theory of construction innovation in this study, three common forms of innovation relating to construction industry based on the degree of innovativeness have been identified:
(1) *incremental innovation* (Henderson and Clark 1990; Mohr et al. 2010; Schumpeter 1934, 1942; Slaughter 1998);
(2) *radical innovation* (Henderson and Clark 1990; Mohr et al. 2010; Schumpeter 1934, 1942; Slaughter 1998); and
(3) *disruptive innovation* (Christensen 1997; Mohr et al. 2010).
The proceeding section will disussed the three groupings of innovation according to there similar characteristics, and the relationship between these forms of innovation established.

Incremental innovation, in this context, can be described as current knowledge and experience that has made relatively small changes to existing products and procedures, taking full advantage of the potential of established designs and often strengthening the dominance of existing businesses (Dewar and Dutton 1986; Ettlie et al. 1984; Jamrog et al. 2006; Nelson and Winter 1982; Tushman and Anderson 1986). It is a small degree of change whose impact is limited to the improvement of a particular element or component (Slaughter 1998). It often occurs in organizations that have developed knowledge for improvement (Tushman and Moore 1982). Therefore, the outcomes of incremental innovation are predictable. But incremental innovation can only be successful if it is widely supported by all stakeholders in projects to address that this type of innovation and not self-driven. Incremental innovation usually happens gradually and takes a long time. This form of innovation enhances the ability of an organizations to build human capital as it enhances core competencies (Abernathy and Clark 1985; Henderson and Clark 1990).

Radical innovation results in a new approach for understanding phenomena and for developing solutions to problems (Dosi 1982; Nelson and Winter 1977). Radical innovation is often driven from outside the existing industry. When organizations could not find adequate measures for improvements or combat failure where change results from learning from successful cases that have occurred within other industries. Radical innovation may be driven by the need for improvement that results from the application of new and advanced technology applied elsewhere. It may enter an industry through any channel, but it requires new companies and organizations to enter an industry that this results in the "new approach". Radical innovation forces organizations to innovative through the identification of new problems, and the development and application of new technologies, business skills and new approaches to problem-solving (Ettlie et al. 1984; Slaughter 1998). The degree of change that results from the adoption radical innovation is high, and it presents a clear challenge to established organizations because of undermining the effectiveness of existing capabilities (Henderson and Clark 1990). These changes require a different set of engineering and scientific principles and often open up new markets and potential applications (Dess and Beard 1984; Dewar and Dutton 1986; Ettlie et al. 1984). Radical innovation sometimes is described as the technology-based innovation changes the technological track and increases the customer's interest (Tushman and Anderson 1986; Zhou et al. 2005). Radical innovation is a new approach that can lead to major changes in the industry itself. The degree of change is high and the pace of change is faster than incremental innovation. Comparatively, radical innovation is a rare and unpredictable event (Slaughter 1998).

The concept of disruptive innovation stems from Schumpeter's "creative destruction" as a core of economic change that comes from innovation (Schumpeter 1942). Rafii and Kampas (2002) defined disruptive innovation as technology, product, or process that will expand existing services and may even replace it. Raynor and Christensen (2003) claimed to distinguish disruptive innovation in terms of low-end and new-market. Disruptive innovation can provide lower prices, new performance parameters, and new levels of scalability. Disruptive innovation is described as a new significant economic phenomenon that takes economic developing and entrepreneurship as a dynamic process (Klochikhin 2012). Christensen (1997) theory of disruptive innovation is based on the business market and this is different from the construction industry. In this context, disruptive innovation in the construction industry can be understood in relation to the opportunities for CPOs to gain advancements by undertaking traditional operations and delivering products in different ways that challenge them to rethink their organizational systems and approaches. The degree of change involved is the highest among all forms of innovation.

Overall, three forms of innovations related to the construction industry were selected, namely, incremental innovation (small or minor change of the CPOs' behaviors), radical innovation (major change of the CPOs' behaviors), and disruptive innovation (almost or totally changes the CPOs' behaviors but does not disrupt the construction industry). Table 3 summarizes the nature of these forms of innovation is Strength-Weakness-Opportunity-Threat (SWOT) approach. This helps articulate their differences.

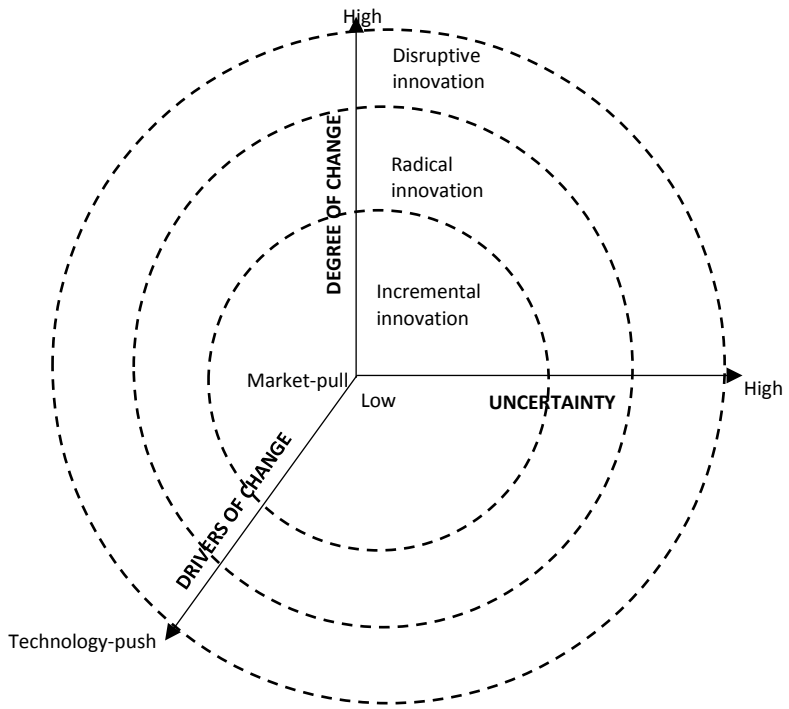
Table 3 SWOT analysis of innovation forms

Innovation forms	Strengths	Weaknesses	Opportunities	Threats
Incremental innovation	• Low resources used to meet low levels of improvement • Invariably and predictably occurred within a reasonably narrow range • Continues improvement in performance • Predictable	• The challenge of product and process differentiation	• Immediate reward • Lower risks after change and greater success achieved in a shorter period • Closer to customer's requirement and market	• Slowly achieving growth goals in front of competitors can lead to loss of competitive advantage • Many competitions participated • Focused on listening to customers, which may result in losing market to the new customer
Radical innovation	• Advanced technology • Similar products or behavior with a larger increment of performance	• Technological inexperience • Major change in the nature and the core concept • Unpredictable	• New standalone markets established or created	• Traditional management behavior undergoing a major change • Requires long-term development
Disruptive innovation	• Product turned into a simpler or more affordable product • A group of fixed customers will be captured with time	• Technological uncertainty • Unpredictable • Almost or totally changes the nature and the core concept	• New to the world • Carrying competitiveness into a new dimension	• Traditional management behavior almost or totally changed • Ineffective collaboration due to the new technology and behavior adoption

Typology of construction innovation

From the review of the literature a framework of construction innovation typology has been developed and articulated in three dimensions: degree of change, uncertainty, and driver forms (refer to Figure 2).

Figure 2: Tyoplogise construction innovation



Two reasons to establish this plane are as follows:

Firstly, the core idea of incremental innovations is not to change the nature of concept, but to keep products up to date and developed as planned; namely, it has a slight impact on the change the way of behavior. Conversely, disruptive innovation almost or totally changes the concept and is unpredictable. OECD (2005) stated that incremental innovations provided continuous changes, while radical innovations led to drastic changes. Additionally, there is a relationship between radical innovation and disruptive innovation (Mohr et al. 2010). Radical innovation is based on substantial technologies that relate to the existing industry (Chandy and Tellis 1998; Govindarajan et al. 2011; O'Connor 1998). When radical innovation leads to a major shift in the entire value network, it can also be called disruptive innovation (Christensen 1997).

Secondly, Dosi (1988) pointed out that incremental innovation is more likely to drive market pull innovation, while radical innovation, in general, originates in scientific advancement and regularly incorporates new technologies or new combinations of current technologies (Coccia 2006; Van de Ven and Garud 1993). The innovative model developed by Abernathy and Clark (1985), based on market capabilities and technical capabilities, is divided into one of four categories; market niche innovation, regular innovation, revolutionary innovation, and architectural innovation (Afuah 2003; Stein 2017). There are two forces that technological innovation may come from—market pull and technology push (Darroch and Jardine 2002). Due to this reason, innovation is usually referred to as incremental and radical (Coccia 2006). According to the Söderlund (2005) project, competencies must support the

operation of strategic and competitive projects that continually adapt to technology and market dynamics. Subramaniam and Youndt (2005) stated that the Abernathy-Clark model could be assigned two types of capabilities with incremental innovation and radical innovation capabilities. Therefore, radical innovation is usually as a technology push innovation (Coccia 2006; Cooper 1979; Green et al. 1995; O'Connor 1998).

The above review help typologises innovation. This can be further extended to understand how innovation theory can be perceived. In recent years, significant effort has been made by different CPOs across the construction supply chain to develop new business models, increase productivity, achieve better supply chain integration and promote innovation. The main stakeholders within the industry that influence the adoption of innovation include: consultants, suppliers, design, contractors and sub-contractors (Akintoye et al. 2012).

Nam and Tatum (1989) found consultants have a significant impact on product innovation. They have the potential to combine the knowledge of construction design science, process, materials, and constraints with technology tool and equipment in the innovative design (Ling 2003). Contractors also act as a motivator for thinking technical feasibility of options and the relationship with architects and other builders as system integrators (Akintoye et al. 2012). Contractors are involved in the use of modulation and prefabrication, and suggest reducing on-site skilled labors, decreasing project cost and shorten the construction period (Lim and Alum 1995). They are at the forefront of organizations and can develop new products and processes (materials and parts suppliers, expert consultants and trade contractors), and those that use innovations (Winch 1998).

Most construction innovation comes from suppliers of materials and components (Pries and Janszen 1995). A survey result from Ozorhon et al. (2010) shows that suppliers are the main drivers of technological innovations in the construction industry because they invest far more in research and development than contractors or consultants and are therefore more willing to develop product innovations (Gann 1997). Sustainable construction can have a considerable impact on global environmental sustainability, notably by drastically reducing the consumption of natural resources and the use of energy-intensive materials such as cement, steel, aggregates, and aluminum.

Customers also at a catalyst contribute to promoting innovation by applying pressure to supply chain partners to increase overall performance in the construction values chain (Gann and Salter 2000). According to the Smart Marker Report (Construction 2011), the requirements from clients act as catalysts to adopt the BIM in an industry, and they play a significant role in the process of BIM implementation.

While there is evidence of many forms of innovation within the construction industry, with the potential to change the nature of construction, there is little evidence of whole of industry application. This can be seen from the disparate adoption of BIM and prefabrication globally. Clearly, implementing innovation in construction is a long and slow process that requires persistence review, behavioral changes, flexibility, and acceptance. Successful implementation of construction innovation requires collaborative efforts. Nonetheless, the construction industry is highly fragmented that leads practitioners and researchers to overlook the different needs of CPOs for successful implementation of innovation. The transient nature of the construction projects constraints how organizations might conceptualize and implement innovation in practice. For instance, Gu and London (2010) claimed the organizations do not fully understand the necessary prerequisites that reflect the implementation and

use of BIM innovation in contracting organizations. Robustness of the construction contract and operational method has brought many CPOs to success in projects. It is hard to persuade them to give up their 'formula of success' and embrace with new ideas to cater future needs. As such, not all CPOs in the supply chain may feel the urgency and legitimacy to accept construction innovation.

LIMITATIONS

As with many literature review studies, this study consists of limitations. Although the findings of this study have been developed from the literature further validated by the use of empirical data would strengthen the main findings. While greater understanding of innovation adoption can be derived from the conceptual model, more analyses are needed to produce robust findings.

CONCLUSION AND FUTURE STUDY

This review has been conducted based on the premise that innovation, to be successfully adopted, within a specific sector should take into account the characteristics of that sector. This study indicates that CPOs might view advanced technology as different forms of innovation. Such different views should be addressed when we devise measures of fostering the use of advanced technology in projects. Future research should be conducted to identify different CPOs attitude towards implementation innovation in projects. The study based on a systematic literature review identified three forms of construction innovation that contribute to typologies innovation. The three main forms of innovation identified included: incremental innovation, radical innovation, and disruptive innovation. A conceptual model was developed to summarize the strengths, weaknesses, opportunities, and threats of each form of innovation. This study contributes to the knowledge that a better understanding of different CPOs and their perception of innovation in construction will influence the level of adoption. Based on the theory of construction innovation in this study it is possible to identify directions required to enhance greater adoption of advanced technology within the industry. This may lay a pathway for further research construction innovation in relation to future project to ensure the best outcomes are achieved.

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TYPES, CAUSES AND EFFECTS OF VARIATIONS IN RESIDENTIAL BUILDING PROJECTS IN THE UAE

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ABSTRACT

Variations are expected to occur in any construction project. They are inevitable in nature and result in both positive and negative impacts on a construction project in terms of project's time, cost and quality. This research aims to identify the types, causes and effects of variations in residential building projects in the United Arab Emirates (UAE) procured through traditional procurement route. Upon identifying the types, causes and effects, this research proposed a model for effective variation management, contributing to successful project delivery.

Mixed research approach with closed ended questionnaire survey and semi-structured interviews were used to collect the data. The sample size was 96 with a response rate of 70% and 5 industry experts were interviewed.

Three types of variations are identified namely; unavoidable, avoidable, and beneficial variations. The most common variation type is unavoidable variations. The main source to variations arises due to the practices of Consultants and the most frequent causes are created by the Owner. According to the findings, variations significantly affect the project time frame.

Keywords: residential buildings, UAE, variations

INTRODUCTION

People believe variations only add costs and time to projects leading to higher costs and delays (Sikan, 1999). Hao et al. (2008) stated that effort of managing variations gives considerable affliction to the project team and it should be avoided all time. The variations are not necessary to include in a contract as it motivate the client to make frequent unnecessary changes and the design team to make errors (Jayalath, 2013). By contrast, Sikan (1999) showed, having a variation provision within the contract permits to accommodate new ideas, regulatory requirements and so on. Therefore, the construction projects have both negative and positive effects due to the variations (Hao et al., 2008). Arain and Pheng (2007) mentioned that project team should have the capacity to manage variations effectively to avoid adverse impact to the project for project success. Variations can be minimized when it studies collectively and early as possible (CII, 1994a cited in Arain and Pheng, 2007). Hester et al. (1991) explained that managing variation means anticipating effects of variations and control it or give minimum effect to minimize their negative impact on project timeline, budget, and quality. Such management includes detailed understanding the origin (type, causes) of variations and their anticipated impact (Ibbs et al., 2001).

According to United Arab Emirates (UAE) statistics, 57% of buildings are residential villas and 32% are commercial spaces (EMIS, 2015). The statistic of the Emirates NBD (2014) and Dubai Statistic Center (2016) stated that the total number of residential building units are expected to increase significantly compared to transport, mixed-used, leisure/hotel, energy/power, retail and commercial buildings. The previous research studies focused mainly on public buildings (Sunday, 2010; Mhando et al., 2016). There is a clear lack of research studies on types, causes and effects of variations on residential building projects in the UAE procured using traditional procurement route. Initially, this research study identified the types, causes and effects of variations and afterwards, proposed a model for effective variation management.

LITERATURE REVIEW

Various researchers defined the term 'variations' in the literature. However, there is no specific and commonly accepted single definition to variation (Ssegawa et al., 2002). Association of Project Management Professionals (APMP, 2000) defined variation as a change in scope or timing of work which a supplier is obliged to do under a contract. However, it is imported to note that the variations should not change the contract, instead it refers to a change within the contract (Turner, 1984). According to the International Federation of Consulting Engineers (FIDIC, 1999), variation is defines as; "Any change to the Work which is instructed or approved as a variation which includes:

- Changes to the quantities of any item of work included in the Contract (however, such changes do not necessarily constitute a Variation),
- Changes to the quality and other characteristics of any item of work,
- Changes to the levels, positions and/or dimensions of any part of the Works,
- Omission of any work unless it is to be carried out by others,
- Any additional work, Plant, Materials or services necessary for the Permanent Works, including any associated Tests on Completion, boreholes and other testing and exploratory work, or
- Changes to the sequence or timing of the execution of the Works."

Types, causes and effects of variations

There are three types of variations namely; an unavoidable variation, variation for the convenience of the client and variation for the convenience of the contractor or consultant (NSW Government, 2008). Arain and Pheng, (2005) explained that beneficial variations and avoidable variations as other types of variations. However, the author argued, variations convenient to the client and, variations convenient to the contractor/consultant were identified by NSW Government (2008) can be considered as subcategories under avoidable variations. These variations arise due to the client, consultant and contractor convenient and not due to the project requirements. Therefore, these variations can identified and avoids as early as possible. Accordingly, unavoidable, avoidable and beneficial variations can be considered as the basic types of variations in construction projects.

Variations arise due to several causes (Mohammad et al., 2010; Memon et al., 2014). Moghaddam (2012) stated that it could be due to internal or external factors arising out from project design to construction. A detailed review of the causes of variation identified via literature explained that the causes of the variations can be universally grouped into five main categories namely; owner-related (ORVC), consultant-related (CRVC), contractor-related (CNRVC), combined (CVC) and other (OVC) variations as summarized in the table 1.

Table 1 - Causes of variations

Main Categories	Causes of variations	Literature sources
Owner-related variations causes	Change to plan/scope Client 's financial difficulties Change in specifications Change in schedule Changes to materials or procedures Hindrance in timely decision Inadequate project objectives Fraudulent and kickback practices	Arain (2005); Mlinga (2006); Zou (2006); Nachatar et al. (2010); Mohammad et al. (2010); Asamaoh and Offei-Nyako (2013); Memon et al. (2014)
Consultant-related variations causes	Inadequate working drawings Differing site conditions Change in design/specifications Conflicts between contract documents Poor of coordination Consultant’s lack of knowledge on existing material and equipment Lack of judgment and experience Non-compliant design with government regulations Errors and omissions in design Poor scope of work for contractor Design complexity Consultant’s lack of required data	Fugar and Agyakwah (2010); Sunday (2010); Mohamad et al. (2012); Halwatura and Ranasinghe (2013); Memon et al. (2014); Oloo et al. (2014; Lokhande and Ahmed (2015);
Contractor-related variations causes	Misinterpretation of contract documents Poor strategic planning Poor judgment and lack of experience Defective workmanship Contractor's financial difficulties Unavailability of materials and equipment	Mohammad et al. (2010); Sunday (2010); Ubani (2010); Halwatura and Ranasinghe (2013); Mizanur (2014); Lokhande and Ahmed (2015);

	Complex design and technology Contractor lack of involvement during design stage Lack of modern equipment Unfamiliarity with local condition Lack of a specialized construction manager Fast track construction Contractor desired profitability Differencing site condition Long lead procurement Poor procurement process Poor communication	
Other variations causes	Weather conditions Change in economic conditions Change in government regulations Socio-cultural factors	Mohammad et al. (2010); Hwang and Low (2012); Asamaoh and Offei-Nyako (2013); Halwatura and Ranasinghe (2013); Lokhande and Ahmed (2015);
Combined variations causes	Two or more causes illustrates above giving rise to variations	

The project success criteria are broader as the project stakeholders have different requirements (Takim and Akintoye, 2005). When a project is successfully completed, it is believed to be completed by achieving several stakeholders' requirements. Therefore, the project ensures that project has completed with required quality standards, completed within allocated budget and time. Accordingly, table 2 summarized the effects of variations in successful project delivery.

Table 2 - Effects of variations

Main categories of effects of variations	Effects	Literature sources
Effect of variation on project time	Affected project progress without any impact to project completion	Assaf et al. (1995); CII (1995); Arain and Pheng (2005)
	Delay in project completion	Ibbs (1997b); Kumaraswamy et al. (1998); Arain and Pheng (2005)
	Delay in procurement	O'Brien (1998)
	Logistic delays	Fisk (1997)
Effect of variation on project cost	Contract price increase	Assaf et al. (1995); CII (1995); Arain and Pheng (2005)
	Increase in the project overhead	O'Brien (1998); Arain and Pheng (2005)
	Payment delay	CII (1990)
	Additional payment to the contractor	O'Brien (1998); Arain and Pheng (2005)
	Additional professionals	CII (1995); Fisk (1997)
Effect of variation on project quality	Quality Issues	CII (1990); Fisk (1997)
	Productivity Issue	Ibbs (1997a); O'Brien (1998); Thomas and Napolitan (1995)
	Rework and Demolition	CII (1990); Arain and Pheng (2005)
	Poor safety conditions	O'Brien (1998)
Effect of variation on overall project	Poor professional relationship	Fisk (1997)
	Damages to firm's reputation	Fisk (1997)
	Disputes	CII (1986)

As above literature suggested, there are negative effects of variations in successful project delivery, which needs to be observed and address for effective variation management.

RESEARCH METHODOLOGY

The study adopted a mixed research approach to test the theories and verify the individual opinions. Survey research strategy was selected. Data collection for this research was done in 3 stages which includes pilot study, questionnaire survey, and semi structured interviews. To obtain a numerical picture of the salient features of variations in residential building projects in the UAE, questionnaire survey (self-administrated internet and intranet mediated questionnaires) was selected. A pilot study was carried out to improve the quality of the questionnaire before administering it among the sample. It was disseminated among five professionals who had more than 15 years of experience in construction industry. A web based platform was used to develop and share the questionnaire among the sample selected within the population. As it was not practical to survey full population, the sample was drawn from the potential respondents in construction professionals who worked in residential building projects in the UAE. Sample size was determined according to Creative Research System (2016) and equation was used to determine the sample size is detailed below (Equation 1).

$$SS = \frac{Z^2 \text{ x } P \text{ x } (1-P)}{C^2} \quad (1)$$

Where;
SS = Sample size

Z = Z value (1.96 for 95% confidence level)
P = Percentage picking a choice, expressed as decimal (0.50 used for sample size needed)
C = Margin of error (+/-, expressed as decimal 0.1)

The sample size was identified as minimum 96 numbers to achieve 95% confidence level, 10% of margin of error with 50% respond rate. The final version of the questionnaire was circulated among 160 industry professionals, expecting to reduce the margin of error with minimum 60% of professional's responses. However there was a 70% response rate which can be considered as very good responses rate. As the close-ended questions were utilized to avoid the complexity of the responses, open-ended semi-structured interviews were conducted to gather the opinions of the experts. Five industry experts were questioned on the salient features of variations (types, causes and effects of variations) in residential building projects in the UAE, and suggestions for effective variation management and successful project delivery.

Data from the questionnaire survey was analyzed using statistical data analysis process. In this study, descriptive statistics had been used for the analysis as it includes the methods of organising, summarizing and presenting data in an informative way. Percentages and importance index were the descriptive statistical tools employed in this research study. El-Haram & Horner's (2002) formula for Importance index (Equation 2) was used to calculate each variable rank based on the response frequencies.

$$\mathrm{II} = \left(\sum_{i=1}^{5} W_i \text{ x } f_{xi}\right) \text{ x } \frac{100}{5n} \qquad (2)$$

Where;
II = Important index
W_i = Weight of ith response (1 to 5)
F_{xi} = Frequency/response of ith rating
N= total number of response

In addition to that spearman's rank correlation coefficient technique was used with spearman rank significance table to see the correlation (Equation 3) among the causes specific to residential building types (villa and residential buildings).

$$R = 1 - \frac{6\sum d^2}{n^3 - n} \qquad (3)$$

Where;
R = Spearman rank correlation coefficient
d = Difference in ranking
n = Number of observations

The results of the interviews were used to validate the result of questionnaire survey and analyze the overall results during the triangulation process. The questionnaire and interviews combined result of the survey was further used to generalize and draw suggestions of the extent and shortfalls of practices and to obtain an insight on the suggestion on improvement for effective variation management for overall project success by overcoming the weakness.

The sample of professionals who had experience in working with residential buildings, 52% had the most experience in residential buildings than other types of projects. Within the sample professionals, 65% had high-rise residential buildings experience (Table 3). It confirmed that this research

worthwhile as the data collected from the selected sample suitable and trustworthy to give reliable research output.

Table 3 – Profile of the respondents

Description	No.	%
By organization		
a. Contractor	30	31%
b. Consultant	37	39%
c. Client/Developer	21	22%
d. Sub-Contractor	4	4%
e. Other (please specify)	4	4%
	96	100%
By profession		
a. Project Manager	1	1%
b. Quantity Surveyor	80	83%
c. Engineer	5	5%
d. Architects	1	1%
e. Other (please specify)	9	9%
	96	100%
By years of experience		
a. Less than 2 years	3	3%
b. 3-5 years	28	29%
c. 6-10 years	26	27%
d. 11-20 years	31	32%
e. Over 20 years	8	8%
	96	100%
By project experience		
a. Residential building	50	52%
b. Commercial building	25	26%
c. Industrial building	4	4%
d. Infrastructure	10	10%
e. Other (please specify)	7	7%
	96	100%
By type of residential project experience		
a. High-rise	62	65%
b. Villa	12	13%
c. Other (please specify)	22	23%
	96	100%

Data analyzed explained that the most of residential building projects in the UAE were procured via traditional procurement route. The use of design-build, management contracting and construction management as a procurement route for residential buildings is rare in the UAE construction industry.

FINDINGS AND DISCUSSION

Form and type of variations

The literature proposed constitute of variation slightly vary depends on the type of forms of contract have been used (FIDIC, 1999). The FIDIC 99 red book was drafted for traditionally procured (designed by the employer) re-measurement projects. The UAE building projects are heavily procured via traditional procurement route with lump sum payment mechanism followed by re-measurement. However, cost-plus projects were very limited. In connection with that, building projects have used the FIDIC versions with a certain amendments to the contract provisions such as the method of measurement and payment by making the form into lump sum contract in the UAE. The forms of variations extracted from the latest version of FIDIC 99 was tested within the sample to observe what constitute of variations in residential building projects in the UAE. It was noted that the most frequent variation form is changes in the quality and/characteristics in the UAE residential building projects. Secondly, any additional work/plant/materials or services for the permanent works necessary followed by the omission of work and changes to the quantity. It was very clear that variations relate to changes to the level, position, the dimension of the work and changes to the sequence/timing of the execution arise fairly less percentage than any other forms of variations in the residential building projects in the UAE.

The variation type most regularly arise is an unavoidable variations. During the interview, interviewee 3 elaborated that in most of the cases, the designs developed by the consultants contradict with authorities' requirements leading to the most common unavoidable variation. Therefore, during the design and construction, it is required to change certain design elements to align authorities' requirements which are unavoidable. The opinion of interviewee 3 coincided with NSW Government (2008) report stating that the project has to adopt these variations to avoid the project from being incomplete.

Causes of variations

The 42 causes of variations have been identified through literature review and these were used for the questionnaire survey. The survey results concluded that there are 39 common causes above 50% importance index (II). Table 4 illustrates the causes related to variations in the UAE together with the importance index values. Changes of plan or scope is the main cause of variations with an importance index value of 86.88% and changes in the specification by the client takes second place with an importance of 74.79%. According to the literature, this is mainly due to unclear project objectives which need to be shaped early in the project stage (Arain, 2005; Asamaoh and Offei-Nyako, 2013). The third, fourth and fifth causes are changes in design/specification by the contractor, the conflict between contract documents and lack of coordination which lead to variations (refer Table 4). Socio-cultural factors, weather conditions and fraudulent and kickback practices are understood to be rare causes for variations in the UAE residential building projects due to the state leadership and region. Similarly, interviewee 4 declared, "I have not seen weather condition in the UAE affects the project variations severely. However, the main reason, I have observed is lack of coordination/communication among the project team".

Table 4 - Causes related to variations in the UAE residential building projects

Main categories of causes	Causes	Importance indexes	Ranks
ORVC	Change of plans or scope	86.88	1
ORVC	Change in specifications	74.79	2
CRVC	Change in design/specifications	74.38	3
CRVC	Conflicts between contract documents	72.92	4
CRVC	Lack of coordination	71.88	5
CRVC	Inadequate working drawings	71.25	6
CNRVC	Lack of communication	71.25	7
CRVC	Errors and omissions in design	69.17	8
ORVC	Replacement of materials or procedures	68.75	9
CNRVC	Contractor lack of involvement during design	68.75	10
CNRVC	Complex design and technology	68.33	11
ORVC	Hindrance in prompt decision making	68.13	12
CNRVC	Misinterpretation of contract documents	68.13	13
CNRVC	Poor procurement process	67.71	14
CNRVC	Fast track construction	67.50	15
CRVC	Design complexity	65.42	16
CVC	Any cause above detailed happening together	65.21	17
CRVC	Inadequate scope of work for contractor	65.00	18
ORVC	Client 's financial problems	64.17	19
CNRVC	Contractor desired profitability	64.17	20
ORVC	Inadequate project objectives	63.54	21
CRVC	Consultant’s lack of required data	63.33	22
CRVC	Non-compliant design with government	62.92	23
CNRVC	Differencing site condition	62.92	24
CNRVC	Long lead procurement	62.92	25
CNRVC	Lack of strategic planning	62.71	26
ORVC	Change in schedule	62.50	27
CRVC	Differing site conditions	62.08	28
CNRVC	Lack of judgment and experience	61.88	29
CNRVC	Contractor's financial difficulties	60.42	30
CNRVC	Defective workmanship	58.96	31
CRVC	Lack of judgment and experience	58.33	32
OVC	Change in government regulations	58.33	33
CRVC	Consultant’s lack of knowledge on available	57.92	34
CNRVC	Lack of modern equipment	56.67	35
CNRVC	Unavailability of materials and equipment	55.83	36
CNRVC	Unfamiliarity with local condition	55.00	37
CNRVC	Lack of a specialized construction manager	55.00	38
OVC	Change in economic conditions	51.88	39
ORVC	Fraudulent and kickback practices	48.96	40
OVC	Weather conditions	48.75	41
OVC	Socio-cultural factors	48.54	42

Although the first and second frequent variation causes are due to the causes of owners in the UAE residential building projects, it is highlighted through data analysis that consultants are the reason to several causes of the variations within the top ten causes. Therefore, it is prominent that the consultants play a major role in variations while the owner and the contractors take next positions subsequently in the UAE residential building projects. Interviewee 5 stated, "In my experience, I have worked with many residential building projects and consultant is the main source for the variations".

Owner-related variations causes (ORVC)

The findings depict that the owner contributes to many of the top ten variation causes. In addition to that, the owner-related variation cause, change of plan or scope is the most prominent cause. Importance index is above 60 for all the causes identify as owner-related causes. Interviewee 3 agreed to this saying that, "the UAE as a country under the visionary leader who rules with the absolute monarchy the opening for fraudulent and kickback practices are very limited".

Consultant-related variations causes (CRVC)

The findings are in line with literature and the consultants are the prime cause to variations for majority of the top ten variation causes in relation to the UAE residential projects. In addition to that, the consultant-related variations causes take third, fourth, fifth and sixth consecutive ranks within the top ten causes. Moreover, II is above 50 for the causes related to the consultants. Therefore, these causes need to be addressed effectively by identifying the root causes early as possible. Further, literature findings, (Mhando et al., 2017; Arain, 2005; Halwatura and Ranasinghe; 2013; Fugar and Agyakwah-Baah, 2010; Oloo, 2014; Lokhande and Ahmed, 2015; Mhando et al., 2017) statistical data analysis findings and the comments of the interviewee 3 coincides with each other. As an example the interviewee 3 explained " It is obvious that the most of the consultants, that we worked, come up with several changes during the design and the construction due to errors in the design, an improve the efficiency and reduce the maintenance cost etc. of the projects".

Contractor-related variations causes (CNRVC)

The contractor-related variation causes take the middle rank in relation to the UAE residential building projects and there are several variations causes related to the contractor than others. The crucial cause is led by the contractors' is poor communication while II of all the causes identified as contractors related scored more than 50 for the II. In addition to that, the interviewee 4 stated" Ineffective communication and coordination issues give rise to many contractor related variations".

Other variations causes (OVC)

The II of the other causes specific to residential projects are below 50 except for variation, changes in government legislations. As explained in the section above, it is mainly due to the characteristics unique to the UAE.

Combined variations causes (CVC)

The combined variations causes take 17th rank from all the causes with an II above 50.

The top ten causes identified as reasons for variations in the residential building projects were further analysed (cross-case analysis) in detail based on the project type (villa vs. high rise). As detailed in the below table 5, it is prominent that the fundamental cause for variation is owner's change of plan or

scope irrespective of the type of poject. Further, the causes of variations related to the residential high rise project almost alines with top ten causes identified. There is moderate deviation from top ten causes in relation to the residential villa projects.

Table 5 - Ranking of the top 10 causes of variations vs. correspondence ranking of the causes based on project types

Main categories	Causes	Overall		High rise		Villa	
		II	Rank	II	Rank	II	Rank
ORVC	Change of plans or scope	86.88	1	86.13	1	87.06	1
ORVC	Change in specifications	74.79	2	75.16	3	72.35	4
CRVC	Change in design/specifications	74.38	3	77.42	2	72.94	3
CRVC	Conflicts between contract documents	72.92	4	73.55	5	70.59	7
CRVC	Lack of coordination	71.88	5	73.55	6	69.41	13
CRVC	Inadequate working drawings	71.25	6	73.55	4	68.24	14
CNRVC	Lack of communication	71.25	7	69.35	8	74.71	2
CRVC	Errors and omissions in design	69.17	8	70.00	7	68.24	15
ORVC	Replacement of materials or procedures	68.75	9	68.71	9	69.41	11
CNRVC	Contractor lack of involvement during design stage	68.75	10	66.77	13	72.35	5

The spearman's rank correlation coefficient technique was used to summerize the stregnth (negative or positive) of the relationship between ranks of the top ten overall causes and correspondence ranks of each building type. The spearman's rank correlation coefficient between ranks of top ten overall causes and correspondence ranks of high rise residential building projects (R) = +0.96 and Spearman's rank correlation coefficient between ranks of top ten overall causes and corespondance ranks of villa residential building projects (R') = +0.92 which state overall causes can be used for both building types.

Effects of variations in successful project delivery

Table 6 presents the effects of variations in the UAE. According to Table 6 , the main effect is on time leading to project delays. Next, variations significantly affect the projects' cost through additional payments to the contractors and ultimately increase in the contract prices. Most of the responses related to the UAE residential building projects show disputes as a result of variation and it is the fourth critical effect of the variations. The last among the five critical effects of the variations is the impact to the project time due to delay in procurement. The interview conducted with the interviewee 2 mentioned, "There are very less substantially completed project as per the original completion date and the main reason for that delay is the project variations which are not properly communicated or coordinated".

Table 6- Effects of variations in the UAE residential building projects

Effects headings	Effects	Important indexes	Ranks
Project Time	Delay in project completion	83.54	1
Project Cost	Additional payment to the contractor	77.29	2
Project Cost	Contract price increase	77.08	3
Overall	Disputes	75.83	4
Project Time	Delay in procurement	75.00	5
Project Cost	Payment delay	73.96	6
Project Cost	Increase in the project overhead	71.67	7
Project	Rework and Demolition	69.58	8
Project Time	Logistic delays	68.54	9
Project Time	Affected project progress without any impact to project	67.50	10
Project	Quality Issues	67.08	11
Project	Productivity Issue	66.67	12
Project Cost	Additional professionals	65.83	13
Overall	Poor professional relationship	64.17	14
Overall	Damages to firm's reputation	63.13	15
Project	Poor safety conditions	59.38	16

Moreover, literature (Ren et al., 2008; Ramabodu and Verster, 2010) and data findings, revealed that the top ten critical effects of variations in the projects are either on projet time or cost. Further, the interviewee 3 confired, " The previous project that I engaged was delayed by two months and there was 30% cost over run due to variations".

CONCLUSIONS

The finding of this research shows variation are depending on the procurement route, the word "variation" defines in the forms of contract. Thus, variation can defined in general, addition or omission to the scope of work including any changes to the timing of work which could be a source of another change and not to a change to the contract. There are several residential building projects procured through traditional procurement route using FIDIC 99 red book in UAE for the works designed by the employer, definition for 'variation' refer to check the variation nature in the UAE context. Accordingly, it is noted that changes to the quality, characteristics (is the most common variation form. The studies conducted revealed that there were many causes of variations (Arain, 2005; Asamaoh and Offei-Nyako, 2013). The consultant as a key stakeholder to the residential building projects, also give rise to many variation causes. The owner and the contractor also cause many causes to variations within top ten causes of variations in the UAE. However, it is noted that the first and the second most frequent causes of variations fall within the owner, namely; changes of plans or scope and changes in specification with II 86.88% and II 74.79% respectively. It is noted that variations have a strong effect in successful construction project delivery in terms of project time, cost, quality, and the overall project. The crucial effect of variations on project time is delay in project completion. . As the variations are inevitable and the projects are affected negatively, managing variations are important in construction projects.

This research study limits to residential building projects procured via traditional procurement route to avoid complexity in data collection and analysis. Thus, this may not be a realistic picture for all the construction project in the UAE or for the projects procure via different procurement routes.

Further studies can be carried out on opportunities and barriers in the UAE for effective variation management and how those barriers can eliminate and improve the opportunities.

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