Built Environment Project and Asset Management

Rethinking construction productivity theory and practice

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Background
The construction industry makes a significant contribution to the gross domestic product of many countries. Boosting construction productivity is thus important for the sustained growth and competitiveness of any economy. However, there have been allegations of stagnant or even reduced productivity in the construction industry vis-à-vis other industries (McKinsey Global Institute, 2017; Zhan et al., 2016). There is thus a need for a fundamental review of the underpinning body of knowledge, along with a systemic exploration of the future productivity narrative, including its core concepts, system boundaries, evaluation protocols and applications. Increasing challenges such as climate change, resource scarcities, rising societal aspirations and systems complexities should be considered alongside opportunities arising from emerging technologies such as automation, robotics, virtual reality and visualisation.

Many metropolises witness fast development of construction and infrastructure in the past and today, whilst they face severe challenges for the future. An example of that is Hong Kong where the construction industry faces challenges such as an ageing workforce, skill shortage, cost escalation and systems complexities (Pan et al., 2016). Learning from and exploring the basis of productivity assessment and improvement initiatives in more progressive regions could provide valuable examples for others, given rapid worldwide urbanisation. Such drilling down and in-depth comparisons could contribute significantly to a step-rise, if not a paradigmatic improvement in the body of knowledge on productivity, apart from direct benefits from its deployment in practice. The Centre for Innovation in Construction and Infrastructure Development of The University of Hong Kong is one of the leading research units in the world which pursues a better understanding of the nature and feature of construction productivity and develops solutions for its enhancement. The Centre has conducted a number of studies of construction productivity covering the industry appraisal, project-level measurement and workers training and skills, as well as innovative construction technologies such as modular construction and robotic and automatic technologies. The Centre in collaboration with the Construction Industry Council organised two international productivity forums in Spring 2017 (CICID, 2017a, b) to enable the sharing of the state-of-the-art research and practice of construction productivity enhancement within the complex socio-technical context.

Theoretical approach
This special issue was initiated within the development context of both theory and practice of construction productivity. A fourfold theoretical systems approach was proposed to rethinking construction productivity (Figure 1): ontology denoting what construction productivity is and will be; epistemology denoting how knowledge on construction productivity is created; methodology denoting how construction productivity is researched at different levels and in various processes; and axiology denoting what socio-technical values construction productivity embraces. This fourfold theoretical approach was adopted in the literature of studying complex multi-project environments of construction (Blismas, 2001), of examining the dialectics of strategic alliances (De Rond and Bouchikhi, 2004), of addressing the dialectics of sustainable buildings (Pan and Ning, 2014), of exploring the system boundaries of zero-carbon buildings (Pan, 2014), and of investigating the system
boundaries of life-cycle carbon assessment of buildings (Pan, Li, and Teng, 2018). This special issue seeks to explore and also validate these four theoretical aspects drawing on evidence of research into construction productivity.

An outline of the papers
In this special issue, the first paper by Arshad Javed, Wei Pan, Le Chen and Wenting Zhan reports on “A systemic exploration of drivers for and constraints on construction productivity enhancement” at the industry, project and activity levels. It is based on the combination of a critical literature review, an interview-based survey with 32 industry experts and five focus group meetings participated by 109 representatives of a wide range of industry stakeholder groups in Hong Kong. The paper conceptualises and validates a systemic framework for examining construction industry productivity, and develops three causal loop diagrams (CLDs) for illustrating the dynamic structures that underpin the complex systems of the drivers and constraints. The paper contributes to knowledge by supporting the systems thinking of industry stakeholders in the formulation of holistic strategies for long-term construction industry productivity enhancement. It also provides empirically supported CLDs to facilitate future investigations into the complex system of construction productivity.

The second paper by Tillmann Böhme, Alberto Escribano, Emma Heffernan and Scott Beazley examines “Causes and mitigation for declining productivity in the Australian mid-rise residential construction sector”. It is based on two in-depth case studies conducted with a builder and developer which both are significant entities of the Australian mid-rise residential construction network, with the data collected through a five-stage process including semi-structured interviews and archival information. The paper identifies drivers for declining construction productivity under the categories of industry, firm and project-level productivity, as incomplete documentation, design changes, inefficient project management, and supply chain fragmentation among others. The paper identifies that the sub-structure and super-structure are the construction phases during which most productivity losses occur. This paper echoes the first one of the issue in advocating a multi-level approach to examining construction productivity.

The third paper by Rex Ugulu and Stephen Allen examines “Using learning curve theory in the investigation of on-site craft gangs’ blockwork construction productivity”. It is based on quantitative observation of seven craft gangs’ blockwork with an average of five members in each gang, using the learning curve model application in a 17-storey tri-tower
government office building located in Abuja, Nigeria. The paper reports that the overall blockwork craft gangs learning observed at the site level shows an average learning rate of 94.21 per cent resulting in 5.79 per cent improvement gains. The paper imposes the implications for the development of on-site blockwork craft gangs learning. The significant impact of learning rate improvement in the paper can be used in the planning to fast-track the productivity of construction craft gangs. This paper represents a focussed study of productivity at labour activity level with clearly defined metric and value.

The fourth paper by Florence Ling presents “International comparison of performance of public projects” in Beijing, Hong Kong, Singapore and Sydney to uncover which areas project managers should focus on when managing public projects in different countries. It is based on a structured questionnaire that led to the collection of 244 sets of data of completed public projects. The paper finds significant cost and schedule overruns in all four cities, with Hong Kong’s public projects having the highest cost and schedule overruns, Singapore’s public projects having the lowest cost overrun and Beijing’s projects having the lowest schedule overrun. Public projects in all four cities recorded significantly good project quality. The value of the paper is that it discovers which areas project managers should focus on when managing public projects in different countries. In laissez-faire or free market economies, more attention should be paid to managing the project cost and schedule. When a country has a lower transparency index, more attention should be paid to controlling project quality. Project team members should focus on delivering public projects to the highest level of quality in developed countries.

The fifth paper by Chukwuka Ohueri, Wallace Enegbuma, Ngie Wong, Kuok Kuok and Russell Kenley develops a “Labour productivity motivation framework for Iskandar Malaysia” (IM) construction projects. It is based on two sets of questionnaire with 40 skilled labourers and 50 construction professionals selected using purposive sampling technique. The paper finds that the factors ranked hierarchically using relative importance index including effective management, viable construction practices, financial incentives, continuous training and development and safe working environment were the most significant motivation strategies that positively influence IM construction labourers. The paper develops and validates a framework that can be used to boost the morale of IM construction labourers and their productivity. This paper has the same focus on labour productivity as the third paper does, but uncovers the complex systemic influencing factors to that.

The sixth paper by Bruno Tanko, Fadhlin Abdullah, Zuhaili Mohamad Ramly and Wallace Enegbuma, develops “An implementation framework of value management in the Nigerian construction industry” by establishing the effect of critical success factors on current construction practices to aid stakeholders to improve productivity. It is based on self-administered questionnaires from 344 registered construction professionals in Nigeria. A structural model validated the requirements of applying value management on current construction practices. The established requirements (environment, people, government and information/methodology) can be used by decision makers and stakeholders to improve the productivity of the current construction practices in the Nigerian construction environment.

The seventh paper by Abid Hasan, Abbas Elmualim, Raufdeen Rameezdeen, Bassam Baroudi and Andrew Marshall reports on “An exploratory study on the impact of mobile ICT on productivity in construction projects”. It is based on a focus group session involving ten experienced construction management professionals from different organisations of the South Australian construction industry, moderated by a group of four researchers to gather data on mobile ICT usage and its implications for construction productivity. The paper finds that despite noticeable advances in mobile ICT, differences in usage style and user attitude have limited their overall impact on productivity. The paper highlights the importance of strategising the use of mobile ICT to achieve the desired productivity rates through policy, training, work-life balance and deeper and wider understanding of these technologies.
Summary
The seven papers in the special issue together address construction productivity at industry, project and activity levels, with the use of a range of methods including document analysis, case study, questionnaire survey, interview and focus group. Also, the papers together examine the various factors influencing construction productivity in the social, political, economic, technological, cultural and legislative aspects bearing value of different stakeholder groups. Furthermore, the papers collectively draw on both empirically collated productivity performance data and measured productivity perceptions in examining the factors and forming the productivity enhancement strategies. All these features of the papers in the special issue help to validate the fourfold theoretical systems approach to rethinking construction productivity. Nevertheless, none of the papers aimed to produce systemic metrics of construction productivity of single, partial and total factors, and to elaborate how knowledge of construction productivity is created and performance can be benchmarked consistently. Thus this is recommended for future researchers to explore in depth. Room for future efforts is also suggested in the area of exploring innovative technologies such as robotic and automatic technologies, and offsite and modular construction (see Pan et al., 2008; Pan, Linner, Pan, Chen, and Bock, 2018) for productivity enhancement.

Hand in hand with theory is practice for rethinking and enhancing construction productivity. However, the link between theory and practice is normally weak in the construction society and community, with notoriously poor data sharing often hampered due to perceptions on commercial sensitivity and privacy. This is worsened by a typical cost-driven mentality in the construction industry, contributing to narrowly defined cost-driven measurement of construction productivity. Inspired by the fourfold theoretical systems approach, there is a strong need to reconceptualise and measure construction productivity systemically taking the whole project life-cycle perspective and multi-factor metrics of safety, quality, sustainability, cost-competitiveness into consideration. Construction productivity is also dynamic that is underpinned by interactions between the attributing factors and stakeholder groups and their institutional contexts.

This special issue should not only facilitate the sharing of the state-of-the-art knowledge of construction productivity and the debating on various approaches and techniques drawing on evidence, but help to identify the gaps in literature and knowledge. These implications should make an important contribution to furthering the pursuit for a better understanding of construction productivity as a very complex socio-technical system and its continuous enhancement in the construction industry.

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A systemic exploration of drivers for and constraints on construction productivity enhancement

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Abstract

Purpose – The purpose of this paper is to investigate the complex interdependence of the factors in driving or hindering construction productivity at the industry, project and activity levels in a systemic manner.

Design/methodology/approach – A mixed-methods design, which combines a critical literature review, an interview-based survey with 32 industry experts and five focus group meetings participated in by 109 representatives of a wide range of industry stakeholder groups, was employed to identify the drivers for and constraints on construction productivity enhancement in Hong Kong and explore the interrelated insights into the drivers and constraints.

Findings – The study conceptualised and validated a systemic framework for examining construction industry productivity, and developed three causal loop diagrams (CLDs) for illustrating the dynamic structures that underpin the complex systems of the drivers and constraints.

Research limitations/implications – Although the scope of the study was limited to Hong Kong, the results could be interpreted for critical learning in other urban contexts.

Practical implications – The systemic perspective of construction productivity and the CLDs of the drivers and constraints support the systems thinking of industry stakeholders in the formulation of holistic strategies for long-term construction industry productivity enhancement.

Originality/value – The study conceptualises construction productivity from a systemic perspective and provides empirically supported CLDs to facilitate future investigations into the complex system of construction productivity.

Keywords Construction productivity, Productivity growth, System dynamics, Causal loop diagrams, Industry development, Systemic framework

Paper type Research paper

Introduction

The construction industry makes a significant contribution to global gross domestic product; therefore, sustaining construction productivity is essential to economic growth (Barbosa et al., 2017). Productivity is often defined as the ratio of product output to input resources (Goodrum and Haas, 2004). Within the construction context, productivity is estimated by the quantity of output as well as the quantity of the intermediate, capital and labour inputs which are required to produce the output (Chau, 1993). Research on construction productivity concerns three levels: industry, project and activity (Chia et al., 2014) pertaining to the project-based nature of the industry.

The construction industry has achieved substantial improvements by adopting new construction methods, materials and technologies (Goodrum and Haas, 2004; Goodrum et al., 2009). Despite these improvements, labour productivity decline has been reported in multiple economies (Green, 2016; Teicholz, 2013). While the construction industry in Hong Kong performed well in terms of gross value during the past few years...
(Zhan et al., 2016), its productivity declined primarily due to high construction cost (Pan et al., 2016), and severe skilled labour shortage (Ho, 2016). The Hong Kong Construction Industry Council (CIC, 2015) has alleged that it is imperative to enhance productivity for the industry to stay competitive.

Construction productivity is influenced by multiple factors including drivers that enhance construction productivity such as offsite construction approaches (Eastman and Sacks, 2008) and constraints that hinder construction productivity enhancement such as rework (Palaneeswaran et al., 2008). In line with Porter’s (1998) assertions on productivity growth and the systems dynamics (SD) perspective (Sterman, 2004), the literature seems to imply that construction productivity could be understood as a complex system where multiple drivers and constraints interact with each other and evolve over time. The dynamic complexity of labour productivity in construction projects has been analysed through SD modelling (Nasirzadeh and Nojedehi, 2013). Nevertheless, investigation into the structure and dynamics of the overall construction productivity system is limited in the literature.

This paper addresses the research need through a mixed-methods study seeking to fulfil three objectives: to identify the drivers for and constraints on construction productivity enhancement; to reveal the important drivers and significant constraints within the context of the Hong Kong construction industry; and to explore how the drivers and constraints evolve and interact with each other. A critical literature review helps to construct a systemic framework for examining the complex system underpinning construction productivity. The framework is subsequently validated through analysing the data obtained from an interview-based survey and five focus group meetings (FGMs) participated by industry stakeholder groups of the Hong Kong construction industry. The analyses develop three causal loop diagrams (CLDs) of drivers and constraints revealing their dynamic impact on construction productivity enhancement.

Drivers for and constraints on construction productivity enhancement

Productivity growth of a regional industry is driven by a system formed by a wide range of attributes concerning production and demand conditions, supporting industries, company strategies and rivalry, which could be shaped by the regional government’s industrial policies (Porter, 1998). In order to identify the factors that affect construction productivity, the relevant construction management literature (e.g. Yi and Chan, 2014) and consulting reports (e.g. Barbosa et al., 2017) were reviewed. The analysis of the review was guided by the political, economic, social, technological, legal and environmental (PESTEL) analytical framework, which has been applied extensively in examining construction business environment (e.g. Zhao and Pan, 2015).

The review found that political factors are primarily reflected by government policies which catalyse construction industry development (Crescenzi et al., 2016; Hussain et al., 2017). Legal factors mainly concern regulatory requirements that govern the industry’s practices (Ling and Ng, 2011). Economic factors such as economic fluctuations affect construction cost, and ultimately the industry’s productivity (Chia et al., 2014). Technological and environmental factors are manifested by rapid technological advancement (Pan et al., 2008; Papadonikolaki et al., 2015) and sophisticated demand for sustainable built environments (Pan, 2014). These are the two major forces that drive smart and sustainable design and construction (Barbosa et al., 2017; Sezer, 2015), meanwhile impel integrated project management and administration (Hanna, 2016). Social factors such as aging population and negative societal perception of construction lead to labour shortage that challenges site operation efficiency (Ho, 2016).

Building upon the major themes identified by the review, the systemic framework (Figure 1) is constructed to contextualise the PESTEL factors in the built environment and
society, and structure them under five strategic aspects, namely, policy formation, regulatory requirements, planning and design, project management and administration, and site construction, at industry, project and activity levels. As discussed below, the review shows the co-existence of drivers and constraints in the five strategic aspects.

**Policy formation**
Government policies are developed to enhance construction productivity in both developed and developing economics. The major policies include developing construction workforce through training, encouraging innovation, applying new construction technologies and methods, and strengthening collaborations of construction supply chain (Barbosa et al., 2017; Green, 2016). However, slow local authorities’ approval was identified as the key constraint that hinders productivity improvement (Kadir et al., 2005).

**Regulatory requirements**
The impact of regulatory requirements on construction productivity could be positive or negative according to the literature. On the one hand, the implementation of health, safety and environment (HSE) regulations leads to less accidents and consequently less absenteeism, hence has a positive influence on productivity (Choudhry, 2017). On the other hand, the implementation of the requirements might save time through clarifying work uncertainty and ambiguity, but they consume time and resources without guaranteed tangible outcomes, thereby resulting in a mixed influence to productivity (Chang and Ibbs, 2006).
Planning and design

Lean construction principles have been widely used to develop production planning and control systems for productivity improvement (Howell et al., 2011). Building information modelling (BIM) (Papadonikolaki et al., 2015) and offsite technologies (Pan et al., 2008) are making radical changes in project planning and design. Waste and inefficiencies could be further eliminated through adopting standardised design, offsite prefabrication and automated construction processes (Pan et al., 2018; Pan and Sidwell, 2011). However, the initial high application cost could affect productivity negatively (Pan and Sidwell, 2011).

Project management and administration

Contract environment, management systems and strategies, experience and motivation, scheduling, manpower management, working conditions have been identified as key factors which may drive or hinder project productivity depending on specific contexts (Rojas and Aramvareekul, 2003). Collaborative procurement approaches have gained popularity due to their capacity of achieving better value for money and benefit project productivity (Hanna, 2016).

Site construction

Previous research suggested that factors including systematic flow of work, supervision, site layout, direction and coordination, material and equipment management, foreman competency, training, and on-time payment, all impose significant impacts on site work productivity (Dai et al., 2009). The possible causes for productivity decline were reported to include inadequate training for workers and managers, fewer younger workers entering the construction industry, more safety procedures, increased complexity of projects, greater time pressure on project completion and greater fragmentation of the work process (Kazazz et al., 2012).

SD approach to examining drivers and constraints

SD is an objective-oriented simulation methodology that models complex systems, in which multiple influencing factors interact with each other and change over time (Forrester, 1992). SD modelling has a capacity to simulate processes involving changes over time and allowing feedback loops, thus are widely used in public and private sectors for the design and analyses of policies and strategies (Sterman, 2004). SD has been applied in construction productivity research for developing CLDs, flow diagrams and governing equations (e.g. Nasirzadeh and Nojedehi, 2013). From the SD perspective any fragmented identification of drivers and constraints would introduce theoretically flawed assumptions and fail to effectively tackle the fundamental issues with productivity, thereby leading to less robust strategies. Therefore, this paper employs the SD perspective to reveal the complexity of drivers and constraints that affect construction productivity.

Methods

Research design

A mixed-methods design, which combines a critical literature review, an interview-based questionnaire survey and FGMs, was used to achieve the research objectives and ensure validity and reliability of the findings (Zou et al., 2014).

In this research, the literature review was undertaken to identify the drivers for and constraints on construction productivity enhancement. The review was guided by a socio-technical systems approach (Pan and Ning, 2014), and explored and evaluated both technical and institutional factors affecting construction productivity. PESTEL framework was adopted to provide the initial coding categories for ensuring the comprehensive
inclusion of drivers and constraints in the broad construction business environment. The five major themes derived from the process of coding and analysis were used as the five strategic aspects to construct the systemic framework.

Scopus was chosen to identify the articles, given the search engine’s effectiveness in supporting literature review of construction productivity research (Yi and Chan, 2014). Keywords of “productivity” “productivity and construction” and “productivity and construction industry” were used to undertake title/abstract/keywords scan of articles published in the top-ranked construction management journals defined by Chau (1997), as well as other journals from 2008 to 2017. The titles and abstracts of the 1,387 articles derived by the scan were further reviewed to identify 155 articles that are closely relevant to the research issues of this study; attention was especially paid to the articles of large numbers of citations. Further, 11 highly cited articles published between 1997 and 2007 by the authors who have reported extensively about construction productivity studies were also included in the scope of the review. In addition, 15 industry literatures including government documents, consulting papers and industry reports were also reviewed.

The identified drivers and constraints were then verified through face-to-face semi-structured interviews with 32 industry experts carefully selected from the Hong Kong construction industry. During the interviews, the interviewees were asked to respond to a survey on the drivers and constraints. The analyses of the interview transcripts and completed survey questionnaires helped to identify the important drivers for and the significant constraints on productivity enhancement within the context of Hong Kong construction industry.

Five FGMs were held after that to synthesise the findings from the interview-based survey and also to explore the interdependent nature of the drivers and constraints. The five strategic aspects (see Figure 1) were, respectively, adopted as a theme of each of the FGMs. A total of 109 participants attended the FGMs. The analyses of the FGMs records helped to reveal the insights into the drivers and constraints and their impacts on productivity.

The interviewees and FGM participants represented different stakeholder groups including government agencies, clients, developers, contractors, consultants and suppliers (see Table I). Three-section criteria were used to select interviewees and FGM participants from the industry stakeholder groups, i.e. held senior management positions in their respective organisations, had over 15 years of working experience with the construction industry and were involved in at least one construction project, by the time of this study. Academic scholars and researchers specialized in construction productivity research were also invited to participate in the FGMs.

<table>
<thead>
<tr>
<th>No.</th>
<th>Major stakeholder group</th>
<th>Interview-based survey</th>
<th>1st FGM Frequency</th>
<th>2nd FGM Frequency</th>
<th>3rd FGM Frequency</th>
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<td>4</td>
<td>Consultants</td>
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Notes: FGM, focus group meeting. First FGM focused on the theme of “policy formation”; second FGM focused on the theme of “regulatory requirements”; third FGM focused on the themes of “planning and design”; fourth FGM focused on the theme of “project management and administration”; Fifth, FGM focused on the theme of “site construction”. Institutions include professional institutions and educational institutions.

Table I. Profile of participants

Construction productivity enhancement
The interviews and FGMs were audio-recorded with prior permission of the participants. The transcripts of the audio-recordings were analysed using QSR NVivo 10 analytical software to yield meaningful themes and insights. The SD perspective was applied in the analysis of FGM transcripts to depict the key drivers and constraints underpinning each strategic aspect, as well as the interrelationships among them.

**Design and analysis of interview-based survey**

The interview-based survey was designed under three parts. Part 1 collects information of the interviewees and their affiliated organisations. Part 2 asks open-ended questions about the drivers and constraints in the five strategic aspects. Part 3 derives the relative importance of the drivers and the relative significance of the constraints identified through the literature review. The interviewees were asked to rate the importance and significance of drivers and constraints, respectively, using a five-point Likert scale (with the scale from 1 for “not important/significant” to 5 for “very important/significant”).

A pilot study of the survey was carried out with three experienced researchers and two industry specialists to review the appropriateness, structure, readability and validity of the survey questions (Neuman, 2011). Their feedback was incorporated to revise the survey questions. The revised interview-based survey was then e-mailed to the interviewees before the interviews with ethics clearance. This approach provided the interviewees with necessary cognitive background on the drivers and constraints as well as their underlying institutional and socio-technical issues, which helped to effectively engage them in the discussion during the interview (Willis, 2005).

The completed questionnaires were analysed quantitatively to validate the qualitative analysis of the interview transcripts. The relative importance index (RII) was utilised to identify the relative importance of the drivers and the significance of the constraints. The RII is a process where weight is given to each type of response as per the judgment of the respondents, and has been widely used by researchers in the field of construction and project management (Gündüz et al., 2013).

The quantitative data collected through the questionnaires were analysed using SPSS 20.0 statistical software. The RII for each option was calculated using the following equation (Gündüz et al., 2013):

\[
\text{RII} = \frac{\sum W}{A \times N}
\]

where \(W\) is the weighting given to each driver and constraint by the respondents (ranging from 1 to 5), \(A\) is the highest weight given (i.e. 5 in this case), and \(N\) is the total number of respondents. The RII value ranged between 0 and 1, the higher the RII value, the more important/significant were the drivers and constraints. The RII value of 0.60 is the demarcation point. The RII value of less than and/or equivalent to 0.60 (\(\leq 0.60\)) is considered “not important”, and that larger than 0.60 (\(> 0.60\)) as “important/very important”.

**Results and analyses**

**Important drivers and significant constraints**

The average RII index values of the drivers and constraints in the five strategic aspects are over 0.60 (see Table II). The results suggest that all five aspects were perceived to be fairly important for construction productivity enhancement. This finding supports the suitability and relevance of the constructed systemic framework for examining construction productivity (Figure 1). The three most important drivers and the three most significant constraints in the five strategic aspects are presented in Table II in descending order. The detailed analyses in relation to the five strategic aspects are presented below.
For the policy formation aspect, the RII values indicate that “initiatives on labour training” (RII = 0.86) is the most important driver, followed by the drivers “flexibility in labour and capital markets” (RII = 0.81) and “transparent policies regarding construction industry” (RII = 0.74) (Table II). In contrast, the RII values indicate that “ageing workforce” (RII = 0.90) is the most significant constraint in the policy formation aspect, followed by the constraints “slow local authorities’ approval” and “impeding environmental sustainable construction” with their RII values of 0.82 and 0.70, respectively. The interviews revealed that at the time of this research the Hong Kong construction industry was facing a skilled labour shortage and an ageing workforce. The industry was demanding radical changes through promoting new sets of skills, knowledge and capabilities in order to improve performance and competitiveness. There was an urgent need to train non-active and semi-skilled workers, and attract young people to join the industry.
For the aspect of regulatory requirements, the RII values indicate that “qualification of contractors (e.g. Categories A, B, C and P for public works)” (RII = 0.77) is the most important driver, followed by “meeting the legal, quality control, aesthetic and functional requirements” (RII = 0.69) and “implementation of HSE regulations” (RII = 0.68). In contrast, the RII values show that “restriction on labour importation” (RII = 0.87) is the most significant constraint, followed by “compliance with new sustainability standards” (RII = 0.70) and “stringent HSE requirements” (RII = 0.65). The respondents commented that consultants and contractors’ technical capability and past performance should be assessed during tender evaluation stage. Further, labour importation might need to be considered as a short-term strategy to ease labour shortage. In line with the literature, compliance with HSE regulations was perceived as a driver and/or a constraint depending on specific construction contexts.

For the planning and design aspect, the RII values indicate that “improved buildability” and “increased collaboration between project partners” (RII = 0.90) are ranked as the most important drivers, followed by “effective planning and scheduling” (RII = 0.89) and “integration of design with supply chain” (RII = 0.82). In contrast, “frequent changes in design”, “incomplete design”, and “inaccuracies in the design” are ranked the highest (RII = 0.85) as the most significant constraints, followed by “bad working order planning” (RII = 0.80) and “architectural and engineering errors and omissions” (RII = 0.77). The interviewees welcomed the buildability assessment methods, which might be pilot tested on public sector projects by the government for improving construction efficiency. They also supported the application of the New Engineering Contract (NEC) to improve project collaboration.

For the project management and administration aspect, “good coordination with multi-layer sub-contractors” (RII = 0.89) is ranked the highest as the most important driver in this aspect, followed by “effective and efficient supervision system”, and “good management control of project team” (both RII = 0.88), and “good communication networks” (RII = 0.85). In contrast, “coordination problems between site personnel and the engineer or architect” (RII = 0.87) is ranked the highest as the most significant constraint, followed by “inaccurate working methods” (RII = 0.84), and “unclear instructions to workers” and “poor field management” (RII = 0.80). The interviewees argued that as the industry heavily relied on sub-contracting, good coordination and effective supervision were fundamental for smooth delivery of projects to enhance the productivity and efficiency of projects.

For the site construction aspect, “better management of concurrent operations at site” and “the use of automated production” (RII = 0.84) are ranked as the most important drivers, followed by “quality of craftsmanship” (RII = 0.82), and “quality control and quality assurance practices” and “effective labour time utilisation” (RII = 0.79). In contrast, “lack of skilled craftsmen” (RII = 0.87) is ranked as the most significant constraint, followed by “rework” (RII = 0.86), and “incompetent foremen” and “waiting for design interpretation/engineering information” (RII = 0.81). Most of the interviewees opined that skilled workforce, offsite construction as well as new technologies, methods and material can all enhance productivity of the industry. They urged the industry to adopt automated production technologies for managing severe challenges of skilled labour shortage and an ageing workforce.

*Interrelationships between the drivers and constraints*

The findings derived from the interview-based survey suggest that the drivers and constraints relating to the aspects of policy formation and regulatory requirements focus more at the industry level, while those factors relating to the aspects of planning and design, project management and administration are primarily related to the project level, and those factors relating to the site construction aspect are associated more with the activity level.
The discussions of FGMs revealed that actually all the factors interact across the three levels to impact construction productivity.

The insights into the interrelationships between the different drivers are depicted in Figure 2. For example, the FGMs revealed that at the industry level, policy incentive and regulations would drive the industry to adapt new construction technologies and methods (e.g., BIM and prefabrication). Electronic submission of designs would allow smooth submission and reduce conflict between public and private sectors. At the project level, early contractor’s involvement, closer coordination and fairer risk allocation enabled by NEC contracts would enhance productivity. “3S” concept (standardisation, simplification, and single integrated element) applied during the design stage would facilitate offsite construction. The adoption of offsite technologies and automated production would reduce labour intensiveness of site operations thereby improving the productivity at the site level. The findings derived from the FGMs support that the drivers in the five strategic aspects and at three industry working levels are interlinked with each other in enhancing productivity.

Similarly, the FGMs also revealed that the interdependence between the constraints could reinforce their negative influence on productivity (Figure 3). At the industry level, the lack of productivity measurement standards was perceived as a fundamental constraint that had caused difficulties for effective productivity evaluation. Funding approval delays by the Legislative Council of Hong Kong affected the continuity of some major public infrastructure projects and slowed project progress. Other constraints at the industry level such as skills shortage, lack of continuity of construction work, stringent statutory requirements, long planning approval processes and insufficient incentive for new technology application were also interconnected with each other and reduce the productivity of project delivery. Site productivity was decreased by over dependent on old techniques, delay in payment and high construction waste. Low retention rate of skilled labour and lack of skills training affect site work quality.

The analysis on the interrelationships between the important drivers and significant constraints in the five aspects and at the three levels disclosed the systemic nature of...
construction productivity enhancement (Figure 4). The findings suggest that workforce development, infrastructure planning, planning and design, project collaboration and management, and regulatory compliance could be potentially improved by leveraging the drivers and reducing the impact of the constraints. The FGMs revealed that the lack of certainty and continuity of infrastructure development clouds the stakeholders’ vision about future market evolution and thus causes difficulties in longer term planning for skilled workforce development. The impact of stringent statutory requirements on productivity is dynamic phenomenon depending on the resource allocation for meeting such requirements. Increasing labour market flexibility and training initiatives could ease skills shortages and improve quality of craftsmanship. Incorporating buildability into design solutions would increase design accuracy and minimise variation orders. Further control of sub-contracting layers could improve collaboration and coordination, thus achieve smooth operations on site.

Discussion
The important drivers and significant constraints identified by the study are in line with the findings of previous construction productivity studies (e.g. Dai et al., 2009; Palaneeswaran et al., 2008; Rojas and Aramvareekul, 2003). The analyses on the interrelationships between the drivers and constraints derived three CLDs, which unveil the insights from the construction context about the complex system and significance of innovation that underpin productivity growth being asserted by Porter (1998). The findings imply that the persistent challenges such as skills shortages and high construction cost could be resolved by upgrading both production and demand conditions through innovation. Joint forces of multiple drivers could be leveraged to amplify the impact of smart construction technologies, develop high-qualified human resources and cultivate sophisticated local demands for prefabricated construction.

Conclusions
The paper has identified the important drivers and significant constraints, which concern construction productivity in Hong Kong, and explored the interdependence of these factors
in driving or hindering productivity enhancements. The paper concludes that the overall productivity of the construction industry should be perceived as a latent entity, which is underpinned by a complex system of the five strategic aspects, i.e. policy formation, regulatory requirements, planning and design, project management and administration, and site construction, operating at three levels of focus, i.e. industry, project and activity. A wide range of drivers and constraints were found to co-exist and interlink to each other within that system. The interdependencies between the drivers and constraints were observed to evolve over time and contribute to the elusiveness of construction productivity in its
measurement and prediction. From a systemic perspective, single-factor productivity, which may help to address specific issues such as labour productivity within a given context, would fall short to elicit insights into the macro context in seeking for effective solutions.

**Recommendations**

The findings reveal the rationale underpinning construction productivity enhancement in Hong Kong and suggest that holistic strategies must be formulated to leverage the drivers and deal with the constraints systemically. To highlight, construction productivity measurement standards need to be developed to pave a foundation for objective productivity evaluations. Policy solutions are required to stabilise the supply of public infrastructure projects in order to provide the industry with a clear vision for workforce mobilisation. Labour training should strategically focuses on upgrading technological competence of the workforce. Smart and sustainable construction should be promoted by more integrated policy incentives and regulatory guidance and facilitated by better project collaboration and management.

**Future studies**

The authors have planned to develop SD models based on the three CLDs for simulating the evolution of drivers and constraints over time in succeeding study phases. The generalisability of the findings could be improved by future research into a wider context. For example, the systemic framework could be applied to examine the drivers and constraints in other regions. The CLDs also provide guidance for future SD investigations into the relationships between the drivers and constraints within a project context.

**References**


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Causes and mitigation for declining productivity in the Australian mid-rise residential construction sector

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Abstract
Purpose – The construction industry is a significant driver of economic activity in many countries. However, there has been a lack of growth in productivity within the Australian construction sector over recent years. The purpose of this paper is to gain an in-depth understanding of the causes for declining productivity within the Australian mid-rise residential construction network.

Design/methodology/approach – Two in-depth case studies have been conducted with a builder and developer, both significant entities of the Australian mid-rise residential construction network. Case study data collection comprised a five-stage process including semi-structured interviews and archival information review.

Findings – Drivers for declining construction productivity were identified under the categories of: industry-, firm- and project-level productivity. The drivers include: incomplete documentation, design changes, inefficient project management, supply chain fragmentation, among others.

Originality/value – The contribution of this study is the identification and categorisation of major issues impacting sector productivity along the mid-rise residential construction supply chain. The research identified that the substructure and superstructure are the construction phases during which most productivity losses occur. Mitigations are discussed in terms of systemic sector productivity increases at an industry, firm and project levels.

Keywords Australia, Case study, Lean production, Project management, Offsite construction, Building information modelling, Construction productivity, Complexity-reduction strategies, Mid-rise residential

Paper type Research paper

1. Introduction
The construction industry is a significant driver of economic activity in many countries. This holds true in Australia where the construction industry is the third largest industry, behind mining and finance, producing around 8 per cent of the country’s gross domestic product. It comprises over 330,000 businesses nationwide and directly employs over 9 per cent of the total workforce (AiGroup, 2016). However, productivity growth within the construction sector has been reported to be in decline (Slater and Cater, 2016). Productivity can be defined as the output produced as a proportion of the inputs required (OECD, 2001). In the context of the construction industry, outputs can be measured by the value of
buildings produced, whilst inputs include time, labour, plant, materials, energy, among others. There are many ways to measure productivity including: labour productivity, capital productivity, multi-factor productivity (MFP) and total factor productivity (TFP) (Loosemore, 2014). Labour and capital productivity are single factor measures. As such, they fail to provide a holistic representation of productivity. MFP combines these two hard-to-separate measures but fails to account for factors such as management practices and work environment (Loosemore, 2014). TFP provides a more holistic measure of productivity, but its use within the construction industry has been limited (Abbott and Carson, 2012).

Whilst labour productivity in Australia in the last 25 years has risen significantly in sectors like manufacturing and retail, in the construction sector it has remained virtually flat over this time. A 2014 report (Australian Government Productivity Commission, 2014, p. 2) determined that labour productivity growth within the Australian construction industry had been “sluggish” and that levels of productivity in construction were similar to those in other developed countries. There has been a gradual decline in construction productivity in the USA of 19 per cent since the 1960s. However, this is in the context of significant growth in productivity, of over 150 per cent, across other sectors (World Economic Forum, 2016). Similar trends are reported in the UK, where productivity growth in the construction sector was stagnant over the two decades to 2015 and fell below productivity growth across the whole economy during the same period (Farmer, 2016).

In 2017, the Reserve Bank of Australia reported that annual apartment construction numbers had tripled since 2009 (Rosewall and Shoory, 2017). This increased apartment construction activity has been focused in metropolitan areas for many reasons, including: population growth within cities, increased demand for affordable dwellings and greater employment opportunities. In 2016, individual houses accounted for only 30 per cent of all residential building approvals in Greater Sydney (Australian Bureau of Statistics, 2018) disaggregated figures for the remaining sub-sectors, including mid-rise apartments, are not available. The value of building projects in Australia during 2016 was over AU$103 billion; of this total, over 72 per cent was within the residential sector (Australian Bureau of Statistics, 2017). In the Australian context, it has been stated that the apartment sub-sector uses different materials and supply chains to those used for individual houses and is characterised by “longer and lumpier” construction timelines (Rosewall and Shoory, 2017, p. 9). It is therefore timely to explore the causes and potential mitigation for declining construction productivity through the lens of the growing mid-rise residential sector.

The aim of this study is to gain an in-depth understanding of the causes for declining productivity within the Australian mid-rise residential construction sector. In order to achieve this aim, the following research objectives were established: to identify the stage within mid-rise residential construction projects at which productivity is most affected, including the causes; and to develop mitigation strategies to address the declining productivity in this sector. Within the next section, the relevant literature is reviewed. A methodology is further described that yields insights into the Australian mid-rise construction context. The findings of the case studies are followed by discussion. The paper concludes with consideration of the study limitations and further research opportunities.

2. Literature review

2.1 Overview of construction industry: a supply network perspective

The construction industry is a global network of businesses with a strong domestic economic penetration due to many on-site activities. Most construction projects require a range of activities, relationships, organisations, knowledge and skills to achieve a particular outcome (Gosling et al., 2015) during the primary phases: design, construction and operation (Succar, 2009). The supply network is beset with problems due to high levels of complexity, which increases risk. Additionally, the supply network operates within policy and technical
contexts, comprising macroeconomics, social and regulatory influences, and industry-wide technical challenges.

In the traditional structure of the construction industry, with subcontracted trade specialisation, few individual businesses grow to a size that commands a substantial market share. In Australia, the industry is overwhelmingly comprised of small businesses with fewer than 20 employees (98.6 per cent) (AiGroup, 2016). This results in multi-tiered and complex supply networks, increasing the likelihood of supply chain disruption and productivity loss (Böhme et al., 2014; Gann and Salter, 2000).

2.2 Construction productivity
In the context of the construction sector, in which every project is bespoke, the measurement of productivity, with changing inputs and outputs, has proven problematic (Chancellor, 2015; Sezer, 2015).

Previous research has identified a range of productivity drivers within both the Australian construction industry and internationally. Ramanathan et al. (2012) conducted an extensive literature review on the topic and identified a total of 113 causes reported in the literature. Table I provides an overview of recent publications on construction productivity. Loosemore’s (2014) categorisation of the different levels within the construction industry (industry, firm and project) provided a useful framework for the review of this literature.

In a labour-intensive industry like construction, wages and unionisation contribute greatly to productivity and overall costs (Doucouliagos and Laroche, 2003). Towill (2003) investigated the total cycle time (total time from design to completion) reduction paradigm in the Australian construction sector. He reported on 40 case studies in which 25 per cent cost reduction has been consistently achieved by re-engineering the relevant construction process to compress cycle times by up to 40 per cent. Construction productivity issues have been consistently linked to construction time overruns (Towill, 2003; Toor and Ogunlana, 2008; Olawale and Sun, 2010 to name a few). Typically, construction delays result in cost overruns, poor quality, disputes and also lost revenue due to unavailability of the completed building (Toor and Ogunlana, 2008). Arguably, total cycle time, delays and associated cost (lost revenue) are useful indicators for productivity due to their wide-ranging impacts within the supply chain.

While the above studies provide a better understanding of the factors associated with cost and time overruns in construction projects, and ultimately productivity, there are some limitations: the studies identified are dated and predominantly quantitative; many studies identify laundry lists of factors, failing to identify causal relationships; there is limited research within the Australian context (Gurmu and Aibinu, 2017); and few studies are specific to a particular construction sub-sector, with none focusing on the mid-rise residential sector.

3. Methodology
The aim of this study is to gain an in-depth understanding of the drivers for declining productivity within the Australian mid-rise apartment construction network. Case study is an ideal methodology when a holistic, in-depth investigation is required (Feagin, Orum and Sjoberg, 1991). Due to limited existing empirical evidence in this particular sector, this research is exploratory in nature.

3.1 Case selection
Two in-depth case studies were conducted with leading entities in the Australian construction industry. The first case study focused on the customer end: the “Developer”. The Developer organisation is an Australian Stock Exchange listed organisation, one of the largest
developers in Australia. The second case study focused on the supplier of construction projects: the “Builder”. The Builder is one of Australia’s largest privately-owned construction companies, classified as a Tier 1 builder in the Australian context; meaning the company is able to engage in large-scale construction projects. The Builder is a critical node in the Developer’s construction supply chain. Studies along the construction supply chain are rare. Case selection was guided by diversity and the case’s potential to help contribute to the research objectives rather than by any concern for randomness (Yin, 1994). Stuart et al. (2002)

<table>
<thead>
<tr>
<th>Causes of declining productivity</th>
<th>Mitigation of declining productivity</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry</strong></td>
<td>Construction technology improvements</td>
<td>Li and Liu (2010)</td>
</tr>
<tr>
<td></td>
<td>Regulation and procurement strategies (e.g. mandated BIM)</td>
<td>Kenley (2014)</td>
</tr>
<tr>
<td>Unionisation (Australian states varied)</td>
<td>Apprenticeships, research and development</td>
<td>Chancellor (2015)</td>
</tr>
<tr>
<td>Industry fragmentation and inadequate interoperability</td>
<td>BIM and integrated project delivery; a project approach that integrates people, systems, business structures, and practices to improve project results, value to owner, and efficiency</td>
<td>Succar (2009)</td>
</tr>
<tr>
<td><strong>Firm</strong></td>
<td>Location-based planning, scheduling and control to enhance construction flow to simultaneously achieve good project flow, location flow and trade flow</td>
<td>Lowe et al. (2012), Sacks (2016)</td>
</tr>
<tr>
<td>Subcontracting and its impact (interruption) on material and information flows and the ability of construction managers to control work flow</td>
<td></td>
<td>Hughes and Thorpe (2014)</td>
</tr>
<tr>
<td><strong>Project</strong></td>
<td>Adjustments to resource allocation and scheduling, technology improvement (with an estimated impact of 30–40% on labour productivity), increased predictability of work flow</td>
<td>Loosemore (2014)</td>
</tr>
<tr>
<td>Rework, incompetent supervision, incomplete drawings, work overload, lack of material, poor communication, poor site conditions, poor site layout, overcrowding and inspection delay</td>
<td>Control models and techniques for data collection on construction performance</td>
<td>Kenley (2014)</td>
</tr>
<tr>
<td>Interruptions, size of labour force, continuous overtime, poor site management, fragmentation, no focus on productivity, poor productivity training, lack of detailed planning, contractual conflict, poor design, lack of commitment to continuous improvement, lack of trust, poor workforce consultation and poor monitoring productivity</td>
<td>Well-defined scope of work, health and safety policy/plan, hazard analysis, long lead-time material identification, safe work method statement and toolbox safety meetings</td>
<td>Gurmu and Aibinu (2017)</td>
</tr>
<tr>
<td>Internal: rework, level of skill and experience of the workforce, adequacy of method of construction, buildability issues, and inadequate supervision and coordination. External: statutory compliance, unforeseen events and external dynamics</td>
<td>Use of offsite construction to improve time and cost certainty, reduce health and safety risks and improve predictability and productivity</td>
<td>Pan and Goodier (2012)</td>
</tr>
</tbody>
</table>

Table I. Overview of recent publications on causes for and mitigation of declining construction productivity
stated that the case study method is often chosen to identify a relationship or effect, not to describe an average effect; hence, cases are aimed at being exemplary as opposed to representative. The selection of one specific market (mid-rise construction sector in Australia) allowed the researchers to control environmental variation, while the focus on large corporations constrained variation due to size differences among companies.

3.2 Research design and data collection
Case study research seeks causal relationships between variables and assumes that these relationships are relativistic (Burrell and Morgan, 1985). Therefore, correlations are studied from the inside, by analysing the activities and relationships between individuals directly involved with the problem, rather than taking an outside observer’s perspective (Denzin and Lincoln, 1994). The focus is to understand the research subject in its context (Frankel et al., 2005). Hence, the research team developed a holistic research design as presented in Table II. Prior to collecting any field data, the research team developed a research protocol for Stages 1-3 in order to enhance reliability of the case studies (Yin, 1994) including an overview of the case

<table>
<thead>
<tr>
<th>Stage</th>
<th>Objective</th>
<th>Case company</th>
<th>Archival data collection</th>
<th>Field data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current construction performance in the Australian context</td>
<td>Builder/Developer</td>
<td>Annual reports, organisational structure, Identification of 9-mid-rise residential projects, Planning, variance, progress and evaluation reports, project Gantt Charts of 9-mid-rise projects</td>
<td>Observations on 2 mid-rise apartment construction sites, Senior executive managers, Senior procurement manager, Senior project manager, Site project managers, Contract manager, Subcontractors</td>
</tr>
<tr>
<td>2</td>
<td>Identification of uncertainty sources from a customer/demand perspective</td>
<td>Developer</td>
<td>Process maps, Procurement strategy, Construction reviews, Site-visit (observations), Construction audits, Feasibility studies</td>
<td>Project managers, Contract manager, Designers, Supply chain manager, Cost planner, Procurement managers, Business development, Innovation manager</td>
</tr>
<tr>
<td>3</td>
<td>Identification of uncertainty sources from a supplier perspective</td>
<td>Builder</td>
<td>Process maps, Construction Gantt Charts, construction plans, Construction cash flows, Site visits (observations), Factory layouts, Supplier overview, People traffic on-site, construction audits</td>
<td>Project managers, Senior project manager, Contract manager, Designer, production manager, Team leader (BIM), Innovation manager</td>
</tr>
<tr>
<td>4</td>
<td>Verification of results</td>
<td>Developer</td>
<td>None</td>
<td>Various feedbacks from stakeholders who took part in the study</td>
</tr>
<tr>
<td>5</td>
<td>Verification of results</td>
<td>Builder</td>
<td>None</td>
<td>Various feedbacks from stakeholders who took part in the study</td>
</tr>
</tbody>
</table>

Table II. Research design and methods

Causes and mitigation for declining productivity
The research was carried out in five stages. In Stage 1, data were collected from the Developer and the Builder in order to be able to identify current construction performance. Observations took place at two distinct mid-rise apartment construction sites alongside semi-structured interviews with personnel, including subcontractors. Respondents were encouraged to talk about mid-rise apartment productivity as well as site specific issues (Rowley, 2012). Further, insights into mid-rise apartment construction productivity were gained through archival data of nine construction projects. Reports were collected on planned vs actual construction performance, as stated to be an indicator of construction productivity (Sezer, 2015). The insights from Stage 1 provided the guidance for Stages 2 and 3 and allowed for semi-structured interview guides to be developed using the funnel model (Rowley, 2012). Stage 2 focused on understanding the impacts on productivity; here, semi-structured interviews were conducted to clarify problems/delays in the nine projects. Stage 3 aimed at understanding the impacts on productivity from a builder’s perspective. The research conducted in Stages 2 and 3 followed purposive sampling (Silverman, 2010). Process maps were developed to better understand the construction process from the perspective of Developer and Builder. This allowed the research team to identify key personnel to be interviewed. The case study interviews ranged from 1 to 3 hours. Stages 4 and 5 were two separate feedback workshops to verify results and strengthen validity. The five-stage research design allowed the research team to gain an in-depth understanding of the Australian mid-rise apartment construction sector from the perspective of the two interrelated case organisations.

The research was designed so that data collection frequently overlapped with data analysis (Yin, 1994; Böhme et al., 2014). Detailed case study write-ups for each site assisted the research team to cope with large quantities of data/information (Tellis, 1997). Case study data analysis consists of examining, categorising, tabulating or otherwise recombining the collected evidence (Yin, 1994). Here, the initial deductive observations, interviews and analysis provide a solid foundation for an inductive process of identifying patterns and cause-effect relationships using thematic analysis (Böhme et al., 2014). Root cause analysis was also used; the resulting Ishikawa diagram enables the depiction of the predictor variables and causal interactions (Böhme et al., 2014). Most importantly, it also reveals the hidden problems and issues giving rise to often readily observable surface symptoms. Data were analysed using the framework established in the review of the literature; at industry, firm and project levels.

4. Findings
The findings of Stage 1 are first presented before the overall findings of the root cause analysis provide a more in-depth insight into contributing factors for declining productivity.

4.1 Investigation of construction productivity in mid-rise apartment construction
A review of nine completed Australian mid-rise apartment projects was conducted. All projects were completed between January and June 2017 with a contract value of AU$24-26.5 million. Data were provided by both the Developer and the Builder. The homogenous data set enabled a fair comparison between projects. The planned vs actual construction performance has been reviewed based on time and cost. The vast majority of mid-rise apartment buildings are constructed in situ, with a reinforced concrete frame, as was the case for all nine of the projects reviewed. These materials and methods are traditional and well-supported by existing supply chains but fail to foster innovation in terms of productivity. The dark grey shaded areas in Figure 1 represent the high-level planned activities, where the light grey shaded areas represent the actual performance (both means). On average, 1,122 inducted people worked on-site during 55 weeks of construction time for these mid-rise apartment developments. The mean construction completion delay was
Figure 1. Mean planned vs actual construction performance of nine mid-rise residential developments

| Weeks | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Site works |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Sub-structure |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Basement |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Ground floor |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Cranes |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Scaffolding |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 01 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 02 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 03 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 04 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 05 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Level 06 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Roof    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 01 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 02 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 03 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 04 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 05 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Fitout Level 06 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Lifts   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| External render and paint |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| External works |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

Causes and mitigation for declining productivity.
Eight weeks, and the mean time overrun was 195 days. However, not all time overrun activities were part of the critical path, hence the reduced impact on overall construction time.

Two of the nine projects achieved overall on-time completion, but only because the project managers recovered earlier delays during the services and finishes phase. The industry norm for time contingency is 12 per cent, of which more than 75 per cent is for structural works. For the analysed projects, more than 60 per cent of the total project delays occurred during the substructure and superstructure phases; in particular the formwork installation due to materials supply issues and inclement weather during concrete pouring. Hence, the phases with the largest contribution to productivity loss are substructure and superstructure, resulting in further productivity losses in the fit-out phase due to the efforts of time compression.

4.2 Root cause analysis on construction productivity performance

The research identified various contributing factors that impact on construction productivity. Figure 2 presents a visual representation of key identified causes for Australia’s declining productivity in residential construction projects within an Ishikawa Diagram (fishbone diagram) (Figure 2). The identified causes were common across the nine construction projects. The Ishikawa Diagram is structured according to the productivity categories used in Table I.

Project-level productivity. Most variables identified stem from the project level. Root causes are design related, which permeate the day-to-day operation of a construction site: incomplete designs, and frequent design changes. For example, the project manager (Builder) stated:

The structural engineers did not provide sufficient detail in places to undertake the construction, so details had to be developed along the way. Some aspects had to be designed as this was part of the contract. This led to time and cost overruns due to lack of clarity.

Frequent design changes and incomplete designs also result in inaccurate demand forecasting, especially around material and labour requirements. Forecast inaccuracy results in buffer capacities in terms of time, labour resources and inventory. Buffer capacities are built in at every stage of the construction supply chain, which negatively impacts on productivity. Additionally, site complexity is ever increasing. The project manager of the Builder stated:

It is an army of ants on an apartment construction site. Managing reliability and having trades there when you need them is the big issue.

The contract manager of the Builder added:

Trying to find skilled resources on site is a real issue. People are getting harder and harder to find. Just trying to get something from a loading dock to the workforce is difficult, which results in time evaporating on-site. In a working day the productivity hours are going and that is why things cost so much.

Construction sites are predominantly managed using experience, as opposed to facts. This results in a large amount of “firefighting” (on-the-spot problem solving) with limited awareness of cause and effect. Finally, not only the site layout, but also the traditional construction management approach, decreases the amount of construction process and subcontractor control. Problems in regards to supply of materials during formwork installation impacted on time overrun across the nine projects. However, inclement weather was identified as the major cause of delay; in particular during the concrete pouring stage (see Figure 1).

Firm-level productivity. The second productivity characteristic focuses on the firm level. IT deployment along the supply chain is in its infancy. Advanced construction design and management tools such as building information modelling (BIM) are currently experimented
Causes and mitigation for declining productivity

Figure 2. Ishikawa diagram showing findings categorised by level
The lack of IT deployment creates uncertainty throughout the construction life-cycle, starting at the design phase (incomplete designs) and carried through to the construction site (poor coordination); and finally building operation. A senior quantity surveyor expressed:

Computer based BIM models and 3D renderings are mainly used to communicate changes but final information is still conveyed to builders as 2D flat drawing. Some people are moving even completely away from BIM as it has not worked well for them.

The two case companies also face a shortage of highly skilled project managers and IT capabilities. Most project managers have no formal qualification in project management; their understanding has developed through experience. IT is poorly deployed by both builder and developer, which hampers visibility and results in a lack of construction control. The root cause, however, lies in the lack of interdisciplinary skills incorporating lean construction principles with IT-enabled project management.

Industry-level productivity. The final productivity characteristic is termed industry-level productivity. It is industry standard that builders operate construction sites establishing temporary supply chains for every one-off construction project. Temporary supply chains result in industry-wide supply chain fragmentation. The fragmentation affects project productivity through frequent firefighting due to a lack of long-term targets and commitments and a lack of joint investment in supply chain interface design and improvement. The lack of long-term collaboration perpetuates a “blaming” culture in the industry, and negatively impacts on trust and relationships. The lack of trust results in a high level of buffer capacity and rework, and hence, negatively impacts on construction productivity.

Both Builder and Developer asserted that most subcontractors would not have the appropriate capability to work on any forms of innovation. The Builder referred to supply chain innovation as follows:

To innovate, you have to make sure that your subcontractor is the right person to innovate with. However, the root cause lies in the oligopolistic structure of Australia’s construction market; a small number of firms have a large market share, and very few builders qualify to take on large construction projects. This market results in the Developer being heavily reliant on tendering policy in order to maintain a level of market competitiveness. However, the tendering policy also means that long-term relationships, resulting in joint investments, are difficult to develop.

5. Discussion
Reducing cost in relation to output, the essence of improving productivity, requires different and innovative approaches. The Australian residential construction industry requires efficiency gains within projects due to increased demand for homes. The research identified that the traditional Australian construction industry frequently experiences considerable time and cost overruns in the mid-rise residential apartment sector and hence suffers from high levels of productivity loss. Most delays occur during the structural stage of the build due to inclement weather and poor supply performance. Additional resources are required during fit-out in order to catch up from structural delays, which increases cost and decreases productivity.

Many causes have been identified that are contributing to the loss of productivity. The causes have been classified using project-, firm- and industry-level productivity. The Australian mid-rise residential construction sector requires transparency and better control of complex material and information flows across the supply chain throughout construction. This reflects previous research in which document control and project documentation were found to be factors which often impact negatively on construction productivity (Hughes and Thorpe, 2014; Loosemore, 2014). Complexity is present due to both the diversity of IT
systems required to manage a construction site and a lack of integration between the various systems. This isolation, fragmentation and poor integration of systems can often result in “multiple truths” and opinion-based decision making. Visual and effective real-time information management is required to coordinate site activities and supply chain members (Succar, 2009). Mitigation strategies at industry, firm and project levels are discussed next.

5.1 Mitigation strategies

Complexity can be addressed through two different means: reduction of complexity; and principles, tools and techniques applied to better manage complexity (Böhme et al., 2014). The key system capable of better managing complexity is BIM. Governments around the world, including those in UK, Scandinavia and Spain, are establishing BIM as an industry standard. The opportunities and potential impact that BIM can effect in the construction supply network are well established in the literature (e.g. Koskela and Leikas, 1997; Succar, 2009). Despite such significant potential impact, the know-how and motivation to truly engage with IT solutions in the Australian context is sporadic. Hosseini et al. (2016) identified that many Australian construction companies lack confidence that BIM can enhance construction performance and productivity. This lack of confidence is supported by our study. However, the root has been identified in the lack of interdisciplinary skills; contradicting Hosseini et al.’s (2016) findings, which claim that a lack of knowledge is not a major barrier. Understanding how to best harvest the benefits, especially when moving beyond BIM design modelling towards digitalised construction project management, is key to industry-wide uptake. In the Australia’s oligopolistic construction sector, the lack of competition paired with a non-compulsory implementation of BIM will further slowdown adoption for construction project management. A final hurdle for BIM adoption in the Australian mid-rise residential construction sector is the large number of SMEs (Hong et al., 2016) deterred by an uncertain return on investment (Olatunji, 2011; Hosseini et al., 2016).

Focusing on complexity reduction, many authors investigated the applicability of lean to the construction industry (e.g. Towill, 2003; Gosling et al., 2015) and the impact on productivity improvement (Towill, 2003). Applying lean to construction would require a re-design of supply chain practices (Ekeskär et al., 2016). Most construction activities in Australia follow project management principles and temporary supply chains leading to instability and fragmentation (Gosling et al., 2015). However, many construction tasks are repetitive and could follow process principles. In order for the construction industry to transition to a more process-driven environment, variety in construction typologies needs to be streamlined. Applying standardisation measures at the typology level increases predictability upstream in the supply chain (Towill, 2003).

Combining standardisation with construction techniques that support offsite construction allows for construction complexity to be moved to a controlled indoor environment, where lean principles can be implemented more effectively (Gosling et al., 2015). Another significant hurdle to overcome is the dominant tendering policy. Tendering treats every construction activity as a one-off project, ignoring manufacturing economies of scale (Vrijhoef and Koskela, 2000).

Overall, it can be argued that productivity enhancements need to occur at all three levels of productivity, namely industry, firm and project levels. Investment in interdisciplinary skills as well as IT and offsite manufacturing solutions is required at a firm level to drive project-level productivity. Additionally, government policy needs to positively influence productivity improvements in the industry. Mao et al. (2015) identified that absence of government regulations, high initial cost and dependence on traditional construction methods are major barriers to offsite construction in China. Similar holds true in the Australian context.
6. Conclusion
The research objective of this study was to gain an in-depth understanding of the causes for declining productivity in the Australian mid-rise residential construction sector. In order to address the objective, a case study research methodology was selected. The research revealed that substructure and superstructure are the phases at which most time delays, and ultimately productivity losses, occur. A manifold of causes negatively impacts industry productivity. Root causes were established in each of the sector levels: industry, firm and project. In particular, inclement weather, the lack of interdisciplinary skills, the lack of data accuracy and scientific decision making paired with frequent design changes all result in buffer capacities in terms of time and resources, negatively impacting overall construction productivity. Mitigation strategies including BIM, offsite and lean construction are identified as having potential to improve construction productivity in the mid-rise residential apartment sector.

Of course, a study of this scope has its limitations. The research findings presented in this paper are based on two in-depth case studies in the Australian context and more research is needed to validate these insights. Complexity-reduction strategies as well as complexity-management strategies identified in this paper warrant further exploration to determine impact and to identify optimal pathways to productivity improvement in this highly complex system.

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Using the learning curve theory in the investigation of on-site craft gangs’ blockwork construction productivity

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Abstract

Purpose – The purpose of this paper is to investigate how on-site blockwork craft gangs’ learning impacts productivity within the production environment on-site to optimise their productivity.

Design/methodology/approach – The research is adopting a quantitative method with the observation of seven craft gangs’ blockwork with an average of five members in each gang, using the learning curve model application in a 17-storey tri-tower construction project in Nigeria. The linear regression method was employed in the analysis stage of this study using labour-recorded productivity time input as the dependent variables.

Findings – The paper provides empirical insights about the significance of on-site craft gangs’ learning. The overall blockwork craft gangs learning observed at the site level shows an average learning rate of 94.21 per cent resulting in 5.79 per cent improvement gains.

Research limitations/implications – Due to the nature of the study and the research question, the observations in this research study were limited to FCDA construction project in Nigeria. The limitation of this scenario is that the research results may lack generalisability. Therefore, there is the need for further study on the learning rate.

Practical implications – This research study includes the implications for the development of on-site blockwork craft gangs learning; the significant impact of learning rate of 94.21 per cent resulting in 5.79 per cent improvement gain can be used in the planning and to fast track the productivity of craft gangs’ construction.

Originality/value – This paper identified the need to improve construction productivity through craft gangs’ on-site learning with the application of the learning curve theory.

Keywords Construction productivity, Blockwork, Craft gangs’, Learning curve theory, On-site learning, Quantitative research method, Standard observation

Paper type Research paper

Introduction

Construction is a challenging industry that uses many capitals; it accounts for an important amount of gross domestic product (GDP) of some advanced and emerging countries (Tucker et al., 2005). In advanced European countries, the building industry accounts for 10 per cent of the GDP and even more in emerging countries (Chen et al., 2009; Hassan and Mccafferr, 2002). The provision of infrastructure is an important measure of growth and improving infrastructure to provide for the varying demands of a fast-evolving world is important for economic activity and growth (Attar et al., 2012).

Labour costs contribute to a large portion of the total contract cost of a construction project compared to other cost elements such as equipment and material; the labour contract costs have the probability of being reduced by the appointment of a competent...
building team (Odesola and Idoro, 2014). An upturn inefficiency tends to reduce the overall workforce productivity of the construction project (Hanna et al., 2008).

Craft gangs’ learning systems perform a significant function in enhancing construction workforce productivity (Wong and Neck, 2010). The conventional learning platforms occur in the construction industry union sectors in the USA (Wong and Neck, 2010). However, these conventional programmes are unreliable and enjoy insignificant support from the government (Wong and Neck, 2010). The official traineeship platforms in Canada are regulated and maintained by the management in the relationship with the unions and private organisations and related formal preparation learning programmes exist in other developed countries of the world. This problem associated with the deficiency of building craftsmanship learning in the USA can be related to the likely cause for discouraging US production growth in the building engineering industry (Wong and Neck, 2010).

In Nigeria, construction projects’ failure is a result of contractor’s poor performance which is characterised by the poor skill of workers, rework, low output, late accomplishment, cost overruns, high accident rate, poor labour practice and conflict (Usman et al., 2012). Qualitative and quantitative studies were carried out in Nigeria by Usman et al. (2012); the study identifies the inadequacy of knowledge in the skill of workers as a part of the factors affecting the success of productivity in the Nigerian building industry. Furthermore, the construction industry is concentrating on the company profit and undermining the workers who perform the work (Usman et al., 2012). Construction labour productivity has become one of the major concerns of the building industry as it is generally labour-demanded and enhancing labour performance will be advantageous for the construction industry (Tran and Tookey, 2011).

The last decade in Nigeria has experienced a boom in construction output; there has been an expansion in public sector developments such as rehabilitation of infrastructures, highway and public housing schemes (Oluwakiyesi, 2011). However, despite these construction projects in the country, the construction sector is still struggling with many fundamental issues. The issues include the incompetent skill of workers, inadequate technology and poor supervision. Other issues include the adoption of basic hand tools and delay in supply of materials during construction process (Oluwakiyesi, 2011; Usman et al., 2012; Isa et al., 2013; Odusami and Unoma, 2011; Odesola, 2012).

Previous studies on construction labour productivity have been limited to identifying the factors affecting labour productivity and determining their impact on performance (Oluwakiyesi, 2011; Usman et al., 2012; Isa et al., 2013; Odusami and Unoma, 2011; Odesola, 2012). These studies have mainly utilised perception surveys and interviews, focusing on the key constraints and attempting to quantify the performance of the craftsmen. One would expect that craft gangs’ learning impacts on the productivity subject to the inevitable problems that arise on site. However, no studies have been conducted on how blockwork craft gangs’ learning impacts productivity within the production environment.

The question then becomes:

**RQ1.** How can the impact and relative influence of on-site learning be measured on blockwork craft gangs’ productivity within the production environment?

To date, research studies with the objective of shedding light on this area are scarce. In view of the above, the study purpose is to investigate the impacts of on-site blockwork craft gangs’ learning on productivity within the production environment in order to improve productivity in the construction industry.

In order to develop an understanding of previous research conducted on construction productivity improvement and the progress developed in this area, the paper starts with a literature review of factors affecting construction productivity. It also briefly introduces an
overview of the learning curve theory (LCT), presents the research method and analysis and
finally provides the result discussion including conclusion and recommendations geared
towards further enhancing the investigation of on-site craft gangs' construction
productivity using LCT.

Literature review
Factors affecting construction productivity
Inadequate knowledge in workmanship is one of the factors affecting the success of
productivity in the Nigerian building industry (Usman et al., 2012). A qualitative and
quantitative study carried out shows that the construction industry is concentrating on the
company profit and undermining the workers who actually perform the work (Usman et al.,
2012). Furthermore, Usman et al. (2012) classified the causes of construction projects failure
in Nigeria as contractor’s poor performance which is characterised by poor workmanship,
rework, low output, late accomplishment, cost overruns, high accident rate, poor labour
practice and conflict. Darnton (2006) stated that the construction industry is affected by the
following problems: supply of improved manpower capable of greater productivity in
carrying out simplified sequential operations, maintaining several craftsmen capable of
experienced, skilled work and inadequate training of craftsmen.

A number of researchers have noted that there is a recent deficiency of experienced
manpower and this is giving many building industry difficulties in dealing with the recent
improvement in building work and the full amount of work they now have (Alinaitwe et al.,
2007; Ciob, 1987; Odusami and Unoma, 2011). Hanafi et al. (2010) stated that competency of
site supervisors is an important contributing factor that influences on-site labour productivity.
In a related study, Chigara and Mangore (2012) noted that inadequate skilled manpower and
inexperienced labour negatively influence construction labour productivity in Zimbabwe.

Alinaitwe et al. (2007) ranked deficiency in crafts worker’s knowledge and incompetent
supervision as top two significant factors causing differential productivity of craft workers
in developed and developing countries. In the same way, Odusami and Unoma (2011) noted
that the differential output in productivity could relate to inadequate and poor knowledge of
workers in the construction industry. Moselhi (2010) identified the following constraints that
can influence productivity daily: craft gangs training, crew composition, and weather,
the height of work and construction method. Enhancing the skill of craftsmen will assist in
addressing these problems in project delivery in Nigeria.

LCT
The LCT has its origin in the aircraft industry in 1936 when Wright conducted a research
and published an article in Aeronautical in February 1936, according to Norfleet (2004).
The presence of diverse terms for the theory of learning curve, at the elementary level,
explains the same phenomenon: the unit’s rises, the capitals necessary to complete the
production unit per man-hour or cost decline (Norfleet, 2004). Couto and Teixeira (2002)
noted that the period necessary to achieve same activities sequentially and in the same
environments is anticipated to decline to a definite significance value. Therefore, it is
feasible to introduce this learning effect in construction repetitive work planning processes,
hence bringing about an expected productivity rise after the first repetitive work experience.

Granerud and Rocha (2011) stated that learning comprises of the enhancement of
innovative experience, expertise and performance, the corrections of errors and
enhancement of modern method, and also the improvement of recent standards. Arashpour et al. (2012) carried out research on organisational learning and noted that it
is projected to lead to constant development. The study also suggested that opinion,
methods and knowledge from inside or outside the industry are combined to enhance the
company performance.
A research study conducted by Parker and Oglesby (1972) on building construction work shows that the projected percentage of learning in most construction work falls within the range of 90-30 per cent, it means that if a craft gang or worker follows the 70 per cent learning model and it is expected that the time to build the first unit is 1,000 man-hours, it implies that in order to build the next two unit, it will require 70 per cent of 1,000 man-hours or 700 working hours, then the time to erect the subsequent units will be 70 per cent of the previous units. However, the LCT states that as the units number rises the production rate of construction stabilises, since the workers or gangs are becoming more familiar with the procedure of work (Parker and Oglesby, 1972).

Couto and Teixeira (2005) stated that applying the learning curve model in the building engineering is complemented with some challenges because building activities generally take place in diverse and unique environmental condition. In addition, their study observed that the construction industry works are different and are not repetitive, unlike the manufacturing industry where the workers could perform their work repeatedly. However, their study argued that the main reason why building engineering shows a low level of productivity compared to other manufacturing industry is that the building tasks are characteristically different and not repetitive.

In a related study investigated by Thomas et al. (1986) on 65 different labour-intensive productivity data from construction activities shows great coefficients of determination in the relationship among the cycle numbers and the time. However, notwithstanding the low response rate of the building industry in the application of the LCT, prior research work has shown the significance of this model to construction productivity (Norfleet, 2004; Couto and Teixeira, 2005). Thomas et al. (1986) noted that to achieve the most profits from the development of the LCT, investigators should focus on evolving scientific models of learning curves; this model illustrates the time per cycle of repetitive activity. The purpose of the scientific technique is to forecast the increased output in the repetitive work. The development of straight line unit model has assumed that the rate of learning is constant (Jarkas, 2010). However, the theory considers the adjustment of previous experience.

An investigation was carried out into rebar fixing labour productivity using the application of the LCT to quantify the effect of learning on the rebar fixing productivity; the study found an important relationship between learning and productivity improvement due to the repetition in rebar construction (Jarkas, 2010). However, Jarkas (2010) noted that it is significant to distinguish between production increase arising from the effect of learning due to the repetition of material. The earlier may be referred to as the phenomenon of learning, while the latter can be described as material repetition effect.

Several studies have investigated the application of the LCT in the construction industry; these studies have revealed that the benefits of the LCT to construction labour productivity are very significant (Parker and Oglesby, 1972; Couto and Teixeira, 2005; Thomas et al., 1986; Long et al., 2013; Jarkas, 2010).

Research methodology
The researcher employed a quantitative research method using the application of the theory of learning curve. A standard observation form was used in the collection of data from the seven craft gangs observed on the 17-storey tri-tower construction site located in Abuja, Nigeria. The observation form in Figure 2 was used to record the observed productivity time inputs and the associated productivity output of the seven craft gangs’ blockworks. The forms were designed to include general site information. The observation form or sheets were recorded for each working day of the craft gangs’ blockwork observed in the on-going construction project. The observation of the craft gangs’ repetitive blockwork activities took a period of 12 weeks for a total of 16-26 observations among the
blockwork craft gangs. In addition, selected craft gangs’ blockwork activities which are repetitive in nature within the observed projects sites were also monitored to complement the required productivity data.

Data analysis
The linear regression technique which is also known as the ordinary least square technique was used with the straight-line learning curve model in the analysis of this study. Craft gangs’ productivity time recorded input was used as the dependent variable for predicting the regression model. PHStat Microsoft Excel software add-in was also used to aid the regression analysis. The following steps were adopted in the analysis phase: first, the basic assumptions of the regression model were verified in order not to violate the assumptions by quantifying the regression model coefficients. Second, the overall usefulness of the predictive regression model was statistically determined to assess the importance of the result. In addition, the standardised regression model was quantified to determine the impact of learning on the craft gangs and finally, the learning rate of each craft gang and the overall average learning rate were determined.

Table I represents a sample detail of the correlation coefficient which was used to generate the regression model in Table II. The correlation coefficient is the relationship between the average difference in craft gang blockwork productivity between first and repeated cycle numbers of blockwork. Table II represents a sample regression model for craft gang productivity. The relationship between the cycle numbers and the craft gangs’ productive time input was determined at a level of 5 per cent significance by substituting the observed, recorded productive time input into the linear regression equation, as presented in the following equation:

$$ Y = \alpha + \beta X $$

From the regression equation, $\alpha$ and $\beta$ indicate the intercept and the slope of the linear regression model. The slope and the intercept are thus estimated:

$$ \beta = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2} $$

(2)

$$ \alpha = \bar{Y} - \beta \bar{X} $$

(3)

From Equations (2) and (3) and Table II, we get a sample regression model with $\alpha = 6.27$, $\beta = -0.14$, $\gamma = -0.77$. Where $\alpha$ is the intercept, $\beta$ is the slope of the linear curve, and $\gamma$ is the correlation coefficient of the observed gangs. Hence, the general regression model for the observed sample blockwork craft gangs is as given below:

$$ Y = 6.27 - 0.14X $$

where $Y$ is man-hours = $6.27 - 0.14$ cycle numbers.

Table III represents the overall regression model for blockwork craft gangs. In the regression equation, $\alpha$ and $\beta$ indicate the intercept and the slope of the linear regression model. The slope and the intercept are estimated with the regression model:

$$ \beta = \frac{n \sum xy - \sum x \sum y}{n \sum x^2 - (\sum x)^2}, \text{ and } \alpha = \bar{Y} - \beta \bar{X} $$

(4)

where $Y$ is Man-hours and $X$ is the cycle numbers.
### Table I. Sample craft gangs' correlation coefficient

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**SUM**: 33.5155 199.69 76.1878 612.2019
Sample regression model for blockwork craft gang

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Table II. Sample regression model for blockwork craft gang.

GANG 1605 regression model for blockwork

Learning curve theory
From the overall regression model in Tables III, $\alpha = 6.17$, $\beta = -0.09$, and $\gamma = -0.82$. Where $\alpha$ is the intercept, $\beta$ is the slope of the linear curve, and $\gamma$ is the correlation coefficient of the observed gangs, as presented in Tables I and II sample craft gangs’ correlation coefficient and regression model. Hence, the general regression model for the observed blockwork craft gangs is given as follows:

$$Y = 6.17 - 0.09x$$ \hspace{1cm} (5)

That is, man hours = 6.17−0.09 cycle numbers.

The LCT states that whenever the production quantity/number or unit doubles, the cumulative productive hour or cost required for the production declines with a percentage of the previous quantity. These declines in percentage are known as the learning rate. It determines the rate of learning achieved in the production process (Thomas et al., 1986; Long et al., 2013; Jarkas, 2010). In the learning curve, the rate of learning is established by the slope. The lesser the percentage of learning, the more is the learning achieved, i.e. 100 per cent rate of learning means that learning has not taken place but a learning less than 100 per cent indicates that learning has taken place (Jarkas, 2010; Long et al., 2013).

From the overall craft gangs’ blockwork regression model in Table III, the craft gangs’ regression model shows a negative relationship between the blockwork gangs’ inputs and the cycle numbers. These indicate that there is a relationship with the learning curve model. It also means that as the cycle numbers increases, man hour inputs decrease.

The research question is as follows:

**RQ1.** How can the impact and relative influence of on-site learning be measured on blockwork craft gangs’ productivity within the production environment?

As a result of answering the question on the observed blockwork craft gangs, the productivity learning impact was analysed using the “straight-line unit learning model, and it is expressed as a power function” (Jarkas, 2010; Couto and Teixeira, 2005; Thomas et al., 1986). The logarithmic mathematical model underlying the straight-line learning curve expressions is:

$$Y = T_i \times (x)^b$$ \hspace{1cm} (6)

where $Y$ is the cost, man-hours, or time required to perform the repeating unit; $T_i$ the cost, man-hours, or time necessary to perform the first unit; $x$ the cycle number of the unit; and $b$ represents the slope of the logarithmic curve (Couto and Teixeira, 2005). This can be explained as:

$$b = \frac{\ln S}{\ln 2}$$ \hspace{1cm} (7)

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**Table III.** Overall regression model for blockwork craft gangs

**Notes:** The overall regression in Equation (2) and (3): $\alpha = 6.17$, $\beta = -0.09$, $\gamma = -0.82$. Where $\alpha$ is the intercept given by the standard linear equation, $\beta$ is the slope of the linear curve, and $\gamma$ is the correlation coefficient of the observed gangs, as illustrated in Tables I and II sample craft gangs’ correlation coefficient and regression model.
In Equation (7), \( S \) = learning rate and it is described as the percentage reduction in the cost of man hours. Equation (7) can be re-expressed as:

\[
S = \left(2^{b}\right) \times 100
\]  

(8)

**Discussion of results**

**Blockwork craft gangs on-site learning impact on productivity**

Table IV and Figure 1 summarise the observed results obtained from the seven craft gangs’ blockwork learning rate productivity. The rate of learning (\( S \)) is determined by substituting the slope (\( b \)) into Equation (8) as presented in Table IV that is \(-0.09\), into the learning rate Equation (8) as follows: \( S = \left(2^{-0.09}\right) \times 100 = 94.21 \) per cent. The influence of learning rate from the summary in Table IV shows average learning of 94.21 per cent resulting in 5.79 per cent productivity improvement. However, craft gangs’ number G1601 and number G1602 show insignificant learning ranging from 98.14 to 96.08 per cent.

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<td>16.00</td>
<td>5.99</td>
<td>-86.26</td>
<td>94.65</td>
<td>5.35</td>
<td>Significant</td>
</tr>
<tr>
<td>G1604</td>
<td>17.00</td>
<td>5.99</td>
<td>-87.32</td>
<td>93.76</td>
<td>6.24</td>
<td>Significant</td>
</tr>
<tr>
<td>G1605</td>
<td>17.00</td>
<td>6.00</td>
<td>-70.83</td>
<td>90.95</td>
<td>9.05</td>
<td>Significant</td>
</tr>
<tr>
<td>G1606</td>
<td>17.00</td>
<td>5.97</td>
<td>-96.75</td>
<td>92.36</td>
<td>7.64</td>
<td>Significant</td>
</tr>
<tr>
<td>G1607</td>
<td>18.00</td>
<td>6.02</td>
<td>-82.61</td>
<td>93.54</td>
<td>6.46</td>
<td>Significant</td>
</tr>
<tr>
<td>AVERAGE</td>
<td></td>
<td></td>
<td>-82.49</td>
<td>94.21</td>
<td>5.79</td>
<td>Significant</td>
</tr>
</tbody>
</table>

**Notes:** The learning rate (\( S \)), expressed as a percentage, is quantified by substituting the slope (\( b \)) shown in Equation (6), that is \(-0.09\), into the learning rate equation as follows: \( S = \left(2^{-0.09}\right) \times 100 = 94.24 \) per cent, this is approximately 94 per cent as illustrated in Table IV. A learning rate value of 100 per cent indicates that no learning has taken place. A value lower than 100 per cent indicates the justification of the learning curve theory, a negative relationship between man-hours and cycle numbers is determined, that is, man-hours decreases as the cycle numbers increases. In both cases, the learning theory is applicable to the blockwork craft gang observed.
Long et al. (2013) carried out an observational study on the relationship between building floor and productivity using LCT and found an increase in the first five floors construction. These findings are related to the finding of Long et al. (2013). Like the building floor and labour productivity of the structural work together with formwork installation and rebar fabrication activity, the decrease in productivity of craft gangs’ number G1601 and G1602 blockwork activity from the observed factors might be due to the craft gangs’ crew composition and deficiency in crafts gangs’ knowledge of construction method. These factors relate the study conducted by Usman et al. (2012), stating that inadequate knowledge in workmanship is one of the factors affecting the success of productivity in the building construction industry. These factors are also in association with previous studies that acknowledge a deficiency in craft gangs’ knowledge as one of the key factors affecting construction labour productivity (Chigara and Mangore, 2012; Oluwakiyiyesi, 2011; Alinaitwe et al., 2007). This factor on construction method is related to the study conducted by Moselhi (2010) and found that construction method is one of the key factors that can influence labour productivity daily.

The learning rate found in craft gangs’ G1601 and G1602 is in relation to the findings of Jarkas (2010). The researcher investigated the application of the learning curve model to reinforcement bar and formwork labour productivity of building floors and found little evidence in the productivity. The study further mentioned four reasons to support their findings: the nature of the formwork/rebar operations, distinction between productivity improvement due to “trade learning” and “site acquaintance”, psychological effect and the influence of learning that may have been overshadowed by other project-related and/or human factors (e.g. change in working methods). However, the factors that may have affected G1601 and G1602 learning rate are crew composition, inadequate knowledge in workmanship and construction method (e.g. variation in blockwork course arrangement: variability in wall stiffener, variability in wall joints, variation in blockwork re-bar and variability of wall columns).

The overall learning rate found in Figure 1 and Table IV shows a significant learning rate of 94.21 per cent. These craft gangs’ significant learning in this project could be attributed to the craft gangs’ composition of gangs’ members, adequate knowledge in workmanship and experience in construction method. The overall learning rate found in this study concurs with the study carried out by Couto and Teixeira (2005) and observed a significant rate of learning not less than 85 per cent. However, these findings contradicted the findings of Jarkas (2010) on the application of the LCT to rebar-fixing labour productivity and observed that majority of buildings investigated exhibited either an increase or a negligible reduction in labour inputs as the cycle number of recurring floors increased (Figure 2). Furthermore, these findings support the findings of Long et al. (2013) on the relationship between building floor and labour productivity of structural work adopting the application of LCT and found that formwork labour productivity increased significantly in the construction. Thomas et al. (1986) stated that labour inputs are expected to decrease by a certain percentage as cycle numbers of work activity increases, these results extend these findings. The overall learning rates found in this study are in a relationship with the findings from previous researches in Vietnam, UK, Kuwait, Zimbabwean and USA (Jarkas, 2010, 2012; Long et al., 2013; Thomas et al., 1986; Couto and Teixeira, 2005).

**Conclusion**

Construction labour productivity has become one of the major concerns in the building industry, as it is generally labour-demanded and enhancing the performance of labour in the construction industry will improve the productivity in the construction industry. An understanding of the importance of on-site craft gangs’ learning would provide insight into its impact
This paper reports the research that observed the productive time of seven craft gangs’ blockwork construction in Nigeria and analysed the productive time input to determine the significance of the learning rate. The observed productive time input was analysed using the linear regression technique which is also known as the ordinary least square technique with the application of the learning curve model. Craft gangs’ productivity time recorded input was used as the dependent variable for predicting the regression model.

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**Figure 2. Observation sheet**

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on labour productivity. This paper reports the research that observed the productive time of seven craft gangs’ blockwork construction in Nigeria and analysed the productive time input to determine the significance of the learning rate. The observed productive time input was analysed using the linear regression technique which is also known as the ordinary least square technique with the application of the learning curve model. Craft gangs’ productivity time recorded input was used as the dependent variable for predicting the regression model.
The result shows an average learning rate of 94.21 per cent resulting in 5.79 per cent improvement in labour productivity. The empirical evidence shows that on-site craft gangs’ learning offers the platform for enhancing labour productivity and contributes to improving productivity in the construction industry. Among the seven craft gangs observed, the summary shows significant learning rate. This finding contradicts the previous study of Jarkas (2010) on the investigation into the application of the learning curve model to reinforcement bar and formwork labour productivity of building floors that found little evidence in the productivity. However, this study supports the previous research carried out by Long et al. (2013) on the relationship between building floor and labour productivity of structural work adopting the application of LCT that found an increase in formwork construction labour productivity.

This study extends previous studies that investigated the application of the LCT in construction labour productivity. The overall significant learning rate found in this study is related to the findings from previous research studies in Vietnam, UK, Kuwait, Zimbabwe and USA. The factors that may have contributed to the significant learning rate that resulted in improvement in the observed craft gangs’ blockwork productivity are as follows: crew composition, knowledge in workmanship and experienced in construction method (e.g. ability to deal with following issues: variation in blockwork course arrangement, variability in wall stiffener, variability in wall joints, variation in blockwork re-bar and variability of wall columns).

The strength of this research is its comprehensive investigation and the application of the LCT in investigating the impact of on-site craft gangs’ blockwork learning on construction productivity. Although this research study focused on blockwork construction, applying other types of construction materials like concrete, formwork, tilling, rendering and reinforcement steel can also have a positive impact on improving construction productivity.

Construction supervisors, project managers and other industry practitioners can also introduce this method as an important tool in the planning stage of construction to fast track the effective utilisation of construction work and improve the construction labour productivity. This will enable clients and those in the supply chain access to a possible means of changing their methods and practices of improving productivity.

Due to the nature of the study and the research question, the observations of this research study were limited to FCDA on-going government office building located in Nigeria. The limitation of this scenario is that the results generated from this study may not be generalised. In addition, this research investigation was limited to straight or linear block walls due to the limited number of curved walls encountered during the observed project. It is recommended that the influence of curved block walls on craft gangs’ labour productivity be investigated further.

References


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International comparison of performance of public projects

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Abstract
Purpose – The purpose of this paper is to investigate the performance of public projects in Beijing, Hong Kong, Singapore and Sydney to uncover which areas project managers should focus on when managing public projects in different countries.

Design/methodology/approach – Based on the literature review, a structured questionnaire was designed to collect data of completed public projects. In total, 244 sets of data of completed public projects were collected.

Findings – Significant cost and schedule overruns are found in all four cities. Hong Kong’s public projects have the highest cost and schedule overruns. Singapore’s public projects have the lowest cost overrun and Beijing’s projects have the lowest schedule overrun. Public projects in all four cities recorded significantly good project quality.

Research limitations/implications – The findings are not easily generalizable due to the relatively small sample size in Sydney, low response rate and data being collected from only four cities. The research implication is that the plethora of project management strategies does not seem effective in preventing cost and schedule overruns in public projects.

Practical implications – This study found that across the four cities, there are significant cost and schedule overruns. Projects in Hong Kong perform the worst in terms of cost and schedule, when compared to Beijing, Singapore and Sydney. The implication is that more attention should be paid to managing cost and schedule, especially in Hong Kong.

Originality/value – The originality is that the study discovered which areas project managers should focus on when managing public projects in different countries. In laissez-faire or free market economies, more attention should be paid to managing project cost and schedule. When a country has lower transparency index, more attention should be paid to controlling project quality. Project team members should focus on delivering public projects to the highest level of quality in developed countries.

Keywords China, Public sector, Quality, Time, Cost efficiency, Performance levels

Paper type Research paper

Introduction
Public projects need to be managed efficiently and productively because they are funded using taxpayers’ money, which comes with a high level of accountability. Comprehensive project management guidelines such as those issued by APM (2012), PMI (2013) and CIOB (2014) are available. However, even when project managers abide by these guidelines, projects display varying outcomes in terms of cost, schedule and quality.

The aim of this research is to compare the performance of public projects in China, Singapore and Australia. The specific objectives are to: investigate the performance of public projects in Beijing, Hong Kong, Singapore and Sydney in terms of cost, time and quality; compare the performance of public projects to find out which cities’ projects perform the best or worst; and deduce how the differences in performance may be attributed to the variations in national culture, economic performance and size of construction industries.

China is chosen for study because it has a large construction market, which is estimated at CNY25 trillion (US$3.77 trillion) by end of 2017 (ConsTrack 360, 2017). However, due to China’s large geographical area, the scope of this study is confined to public construction projects in Beijing and Hong Kong. The capital city of Beijing was chosen for study as it has a significant number of completed public projects for the 2008 Olympics and also because it is representative of how a centrally planned economy operates. Hong Kong, a former British colony and now a Special Administrative Region, was chosen for study because its
construction practices are closer to those adopted in free market economies. Singapore was chosen for study because it is in many ways similar to Hong Kong in having a free market and adopting western project management practices, and yet it is different because it is a much smaller market and a sovereign country. Australia is chosen for study because it has a free market economy and practices western project management, but is very different from Singapore and Hong Kong in terms of national culture and geographical size. Due to Australia’s large size, only public projects in Sydney were investigated.

The geographic-specific findings of Beijing could be applied to centrally planned economies while the findings of the other three cities may be more applicable to free market economies in the context of the broader global community. Findings about Singapore, Hong Kong and Australia may have some application to small, medium and large construction industries, respectively, in developed countries that practice western project management practices. The contrast between the four cities may inform architectural, engineering and construction (A/E/C) firms on how to manage their overseas projects more efficiently and productively by studying the national culture and industry characteristics.

**Brief literature review**

*Measures of project performance*

Among the several performance metrics, cost performance and schedule performance are selected for comparison as objective measures could be obtained, and are regularly used in construction management research (e.g. Krajangsri and Pongpeng, 2017). Konchar and Sanvido (1998) defined cost growth as the percentage gap between the actual cost and the estimated cost, and this is represented in Equation (1). The most common definition for time overrun is a delay beyond the agreed contract deadline (Lo et al., 2006), and the percentage gap between total time and as-planned time (Konchar and Sanvido, 1998) is shown in Equation (2):

\[
\text{Cost performance} = \frac{\text{Final cost} - \text{Initial cost} \times 100\%}{\text{Initial cost}}
\]

A positive value and negative value indicate cost overrun and cost savings, respectively. When the value is 0, the project is on budget:

\[
\text{Time performance} = \frac{\text{Actual duration} - \text{Planned duration} \times 100\%}{\text{Planned duration}}
\]

A positive value and negative value indicate schedule overrun and early completion, respectively. When the value is 0, the project is completed on time.

The third performance metric is quality which may be measured on a Likert scale (e.g. Chan and Chan, 2004). This study adopted a five-point scale, where 1 = very unsatisfactory, 2 = unsatisfactory, 3 = neutral, 4 = satisfactory, and 5 = Very satisfactory.

It is argued that projects may be considered to have good performance if they are completed below budget (do the same work with less resources), ahead of schedule (taking shorter time to do the same amount of work) and to an acceptable level of quality (time and money saved in reworks).

*National cultures and transparency*

A comparative study of the four cities may be approached from their national cultures. The differences in national cultures have effects on how individuals and organizations behave in construction projects. Hofstede (2001) proposed a national culture framework comprising these dimensions: power distance, individualism, masculinity, uncertainty avoidance, long-term orientation and indulgence. These six dimensions of national culture are used to underpin this comparative study. There are, however, limitations to Hofstede’s national culture dimensions.
These include one nation could have several types of culture (Knudsen and Froholdt, 2009), and culture and nationality are not synonymous (Baskerville-Morley, 2005).

Power distance dimension describes the culture’s attitude toward power distribution inequalities (Hofstede, 2001). The power distance scores in descending order are 80, 74, 68 and 36 for China, Singapore, Hong Kong and Australia, respectively (Hofstede et al., 2010). This indicates that the Chinese society has more respect or fear for high authority compared to Australia.

Individualism dimension measures the degree of interdependence among people (Hofstede, 2001). Australia has the highest individualism score at 90 indicating a highly individualistic culture where people are expected to be self-reliant and display initiative. The other three cities hover around the 20s (China = 20; Hong Kong = 25; Singapore = 20), indicating a more collectivism culture where commitment, loyalty and responsibility for fellow members of the group are important (Hofstede et al., 2010).

Masculinity dimension explains whether a culture is driven more by competition, achievement or caring for others (femininity) (Hofstede, 2001). The masculinity vs femininity scores in descending order are 66, 61, 57 and 48 for China, Australia, Hong Kong and Singapore, respectively (Hofstede et al., 2010). This suggests that Singaporeans are more likely to embark on negotiation and cooperation, while the Chinese are more inclined toward competition, achievement, and assertiveness.

Uncertainty avoidance measures a culture’s intent to avoid uncertainty (Hofstede, 2001). The scores are 8, 29, 30 and 51 for Singapore, Hong Kong, China and Australia, respectively (Hofstede et al., 2010). Singapore’s low score suggests it is more relaxed about uncertainty. In comparison, Australians are more likely to feel threatened by ambiguous or unknown situations and have created rules and regulations to try to avoid these.

Long-term orientation indicates how a culture maintains links with the past while dealing with present and future challenges (Hofstede, 2001). In descending order, the scores are 87, 72, 61 and 21 for China, Singapore, Hong Kong and Australia, respectively (Hofstede et al., 2010). A higher score for China implies that its people encourage thrift, see modern education as a way to prepare for the future, are more pragmatic, practical and tend to keep options open. Australia’s low score suggests that it has a relatively small propensity to save for the future, and a focus on achieving quick results.

Indulgence measures the extent to which people try to control their desires and impulses (Hofstede, 2001). The scores are 17, 24, 46 and 71 for Hong Kong, China, Singapore and Australia, respectively (Hofstede et al., 2010). The low score for Hong Kong suggests that is a more restrained society where there is more pessimism, and the people control the gratification of their desires. The high score for Australia suggests that people may exhibit a willingness to realize their impulses and desires with regard to enjoying life, possess a positive attitude and have a tendency toward optimism.

Besides, the six dimensions of national culture, countries are rated by corruption perception index. The scores for China, Hong Kong, Australia and Singapore are 40, 77, 79 and 84, respectively (Transparency International, 2017). China’s score is below the global average of 43, where 0 is highly corrupt and 100 is very clean.

The review above shows that the four cities that are investigated have different national culture and different transparency level. It is worthwhile to investigate how these differences influence the performance of public projects.

Market structures
Australia operates a free market economy. Individual consumers and businesses act in their own rational interests while producers produce what consumers need and want (Bollen, 2007). The open market competition in Australia encourages economic benefits in its building and construction industry, which plays a significant role in the economic prosperity of the country
The value of construction work done was about A$188.2 billion (≈ US$148 billion) in 2016 (ABS, 2017) while the GDP per capita is US$49,928 (Trading Economics, 2017). Australia has a population of 24.13 million (Trading Economics, 2017).

China has a centrally planned economy, which is sometimes called “authoritarian capitalism” (McGregor, 2012). The Government Procurement Law of the People’s Republic of China (“GPL”), last revised in 2014, and the Bidding and Bid Law of the People’s Republic of China (“Bidding Law”) of 2000 are the major laws that frame the public procurement in China (Liang, 2016). GPL sets several approaches for government procurement and the major approach is open tendering while the Bidding Law further provides more details regarding the tendering procedures (Liang, 2016). China’s population is 1.37 billion, its GDP from construction in 2016 is US$717.8 billion, while the GDP per capita is US$6,498 (Trading Economics, 2017).

Hong Kong is a special administrative region of China. It is highly developed and practices many of the western management principles such as open tendering. Hong Kong has a population of 7.37 million, its GDP from construction in 2016 is US$13 billion while the GDP per capita is US$36,726 (Trading Economics, 2017).

Singapore is a highly developed, small and trade-oriented market economy where the market is open (Wong and Ho, 2007). The Government Procurement Regulations 2014 issued under the Government Procurement Act Chapter 120 state that the general rule regarding procurement of public projects is via open tendering. Singapore has a population of 5.6 million, its GDP from construction in 2016 is US$3.3 billion while the GDP per capita is US$51,855 (Trading Economics, 2017).

From the brief review above, the differences in performance outcomes of public projects in these four cities are hitherto not known. The gap in knowledge is that international project managers do not know which performance metrics to focus on when managing public projects in countries that have different characteristics such as method of managing the economy, level of corruption, national culture, size of country, stage of development, etc. The review shows that in terms of population and geographical size, the ranking in ascending order is: Singapore, Hong Kong, Australia and China. In terms of GDP per capita, it is: US$6,498; US$36,726; US$49,928 and US$51,855 for China, Hong Kong, Australia and Singapore, respectively. Singapore, Australia and Hong Kong have open market economies while China is a centrally planned economy. The vastly different sizes of these construction industries and economic performance of these countries make it meaningful to investigate how these influence the performance of public projects.

Research method
A large study on the drivers and barriers of relational contracting, relational contracting practices and how these affect the performance of public construction projects in China, Australia and Singapore had been conducted. This paper reports on a part of the study, focusing on performance of public projects in Beijing, Hong Kong, Sydney and Singapore in terms of cost, schedule and quality outcomes.

The unit of analysis is a completed public sector project. The target population is completed public projects, and the sampling frame is completed public projects in these four cities. In order to collect the data, multiple stakeholders comprising public sector clients and consultants, private sector consultants (e.g., architects, engineers, quantity surveyors, and project managers) and contractors, who had been involved in public construction projects in these four cities, were approached.

Due to the lack of a national registry of officials/firms involved in public construction projects, the contact details of public officials were obtained from government directories. Questionnaires were then sent to all of them because the number is not large. The contact details of private consultants and contractors were derived from the respective professional and trade institutions, and randomly selected. As this group may contain those who have
not handled public projects before, the questionnaire clearly stated that only those who had completed public projects should fill up the questionnaire. Data were collected using a specially designed structured questionnaire. The questionnaire requested information on the completed public sector project, extent to which contractual and relational practices were adopted, and demographic characteristics of respondents and their companies. The questionnaire survey was adopted for the study to ensure the same set of questions was asked in every country for every project, so that the same information is gathered for cross-country comparison. The data from the questionnaire allow generalizations to be made.

This paper reports on the project performance in three areas: cost performance (Y1), schedule performance (Y2) and quality of completed facility/project (Y3). The measurement methods were described in the literature review section. Before an industry wide survey, a pilot study was done by asking three subject matter experts from each city to go through the questionnaire carefully to verify that the questions are relevant and the wordings are clear.

The data were analyzed using the Statistical Package for Social Sciences (IBM SPSS Statistics 24) software. The main statistical methods used were descriptive statistics, one sample t-test and independent samples t-test. The one sample t-test procedure was performed on the three performance metrics (Y1-Y3). Independent sample t-test was conducted to check if there is significant difference between the performance of the projects in each pair of cities. The confidence interval was set at 0.95.

Characteristics of respondents and their projects
More than 2,600 questionnaires were sent out and 244 completed and usable sets were received, giving the overall response rate as 9.2 % (see Table I). While the response rates in each city is not high, sufficient samples were obtained to enable robust statistical analysis to be carried out.

Table II shows the characteristics of the respondents. The majority of the respondents in Beijing have more than 10 years of industry experience, while the majority in the other cities have more than 15 years of experience. The majority of the respondents are contractors. Singapore’s respondents are divided almost equally among public clients, consultants and contractors. The majority of the respondents’ firms have a workforce of more than 200 employees. On the average, Beijing firms have much larger workforce, while Hong Kong firms have relatively smaller number.

The characteristics of the projects reported by the respondents are given in Table III. This sample comprised public housing, infrastructure (transportation, water plant and power plant), and other buildings (offices, hospitals and schools). The project types show that the results are based on a wide range of public construction projects. The majority of the clients have constant on-going projects, indicating that the clients have knowledge and experience in project management and would be able to add value to projects.

Table III shows that the traditional design-bid-build is still the most frequently used delivery method. The common approach adopted to procure construction services is open and competitive bidding in Beijing, Hong Kong and Singapore, reinforcing the notion that government procurement for construction and engineering services from contractors is generally transparent. In Sydney, selective bidding is the most frequently used method. In the bid evaluation for selecting a contractor, Table III shows that bid price still plays an important role.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Beijing</th>
<th>HK</th>
<th>Sydney</th>
<th>Singapore</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sent out</td>
<td>259</td>
<td>645</td>
<td>322</td>
<td>1,440</td>
<td>2,666</td>
</tr>
<tr>
<td>Received</td>
<td>59</td>
<td>51</td>
<td>30</td>
<td>104</td>
<td>244</td>
</tr>
<tr>
<td>Response rate (%)</td>
<td>23</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>9.15</td>
</tr>
</tbody>
</table>

Table I. Sampling and response rates
For the selection of consultants, selective bidding and negotiation are used in 33 percent (Singapore) to 77 percent (Sydney) of the projects (see Table III). This suggests that technical capability and past experience may be more important for consultants in winning a contract than for contractors. The results also show that government in-house consultants play a part in providing architectural and engineering professional services (i.e. about 20 percent in Hong Kong and Singapore). As shown in Table III, bid price does not play an important part in selecting consultants.

Results and discussion
Objective 1 of the study was to investigate the performance of projects in Beijing, Hong Kong, Singapore and Sydney in terms of cost, time and quality. Table IV shows the project performance in each of the cities.

Objective 2 was to compare the performance between cities to find out which cities’ public projects fared significantly better or worse. The pair-wise comparison between the cities was conducted using the independent samples $t$-test and the results are shown in Table V.

Cost performance
In terms of cost performance, Table IV shows that the mean cost overrun ranged from 5.3 percent (Singapore) to 12.5 percent (Hong Kong) and the $t$-test results show that there is significant cost overrun in each city. In the pair-wise comparisons, Table V shows that cost
overrun in Hong Kong is significantly higher than that in Singapore. Singapore has the smallest cost overrun in its public projects perhaps because there is strong financial discipline and good project governance, which is consistent with it having the highest transparency index among the four cities (Transparency International, 2017). In a small

<table>
<thead>
<tr>
<th>Description</th>
<th>Beijing (%)</th>
<th>Hong Kong (%)</th>
<th>Sydney (%)</th>
<th>Singapore (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of facility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>24</td>
<td>27</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>56</td>
<td>57</td>
<td>23</td>
<td>44</td>
</tr>
<tr>
<td>Other buildings</td>
<td>20</td>
<td>16</td>
<td>57</td>
<td>30</td>
</tr>
<tr>
<td>Type of client</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>One-off client</td>
<td>12</td>
<td>14</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>On-off client</td>
<td>19</td>
<td>14</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>On-going client</td>
<td>69</td>
<td>72</td>
<td>70</td>
<td>69</td>
</tr>
<tr>
<td>Contractual arrangement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design-bid-build with bills of quantities</td>
<td>40</td>
<td>51</td>
<td>46</td>
<td>17</td>
</tr>
<tr>
<td>Design-bid-build based on lump sum (without</td>
<td>37</td>
<td>25</td>
<td>30</td>
<td>56</td>
</tr>
<tr>
<td>quantities)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design and build</td>
<td>18</td>
<td>14</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Others</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td>71</td>
<td>20</td>
<td>83</td>
</tr>
<tr>
<td>Selective bidding</td>
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<td>24</td>
<td>57</td>
<td>10</td>
</tr>
<tr>
<td>Negotiation</td>
<td>21</td>
<td>4</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>Price : quality ratio (contractor)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:0</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9:1</td>
<td>0</td>
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<td>5</td>
<td>3</td>
</tr>
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<td>8:2</td>
<td>10</td>
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<td>14</td>
<td>31</td>
</tr>
<tr>
<td>7:3</td>
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Table III. Characteristics of respondents’ public projects
construction industry like Singapore, contractors are less likely to pursue monetary claims aggressively, especially when public projects take up almost half of the total contracts awarded. By not pursuing the monetary claims, the chance of a large budget overrun is also reduced in Singapore. This behavior is consistent with Singapore’s very low individualism
score (20) – indicating a more collectivistic society where people belong to “in groups” which take care of them in exchange for loyalty, instead of relentlessly pursuing their rights.

Table III shows that public contracts in Hong Kong are predominantly based on bills of quantities (BQ) while those in Singapore are based on lump sum (without quantities). In BQ contracts, if the actual quantity is different from the measured quantity in Hong Kong projects, adjustments are made to the contract price. In Singapore’s “without quantities” contracts, quantification risk lies with the contractor. Having BQs may lead to re-measurement and cost overrun. Cost overrun may also be due to premature tender documents at the point bids are invited, too many changes in owners’ requirements and tender winning prices that are unrealistically low (Rosenfeld, 2014).

Schedule performance
In terms of schedule performance, Table IV shows that the mean schedule overrun ranged from 8.4 percent (Beijing) to 17.8 percent (Hong Kong). The t-test results show that there is significant schedule overrun in each city. In the pair-wise comparisons, Table V shows that schedule overrun in Hong Kong is significantly higher than that in Singapore. The reasons for schedule overrun in Hong Kong may be traced to inadequate resources due to contractors’ lack of running capital, unforeseen ground conditions and exceptionally low bids (Lo et al., 2006).

Quality performance
For quality performance measured on a five-point scale, Table IV shows that the mean quality ranged from 3.19 (Beijing) to 4.27 (Sydney). The t-test results show that the public projects have significantly high quality (above mid-point 3, $p < 0.05$) in each city. Sydney’s highest quality performance coincides with it having the most matured construction industry that adopts western project management practices. Australia has the lowest power distance score (36, as compared with the rest that are above 65), suggesting that project leaders are generally accessible, managers rely on employees and teams for their expertise, both managers and employees are usually consulted, information is shared frequently, and communication is informal, direct and participative (Hofstede et al., 2010). This environment makes it conducive for projects to be completed to a high level of quality. Among the four countries, Australia has the highest uncertainty avoidance index. This suggests a normative culture where people have a strong concern for establishing rules, regulations and laws, which may have led to excellent work culture and consequently high quality built facilities. In the pair-wise comparisons, Table V shows that quality performance in Beijing is significantly lower than public projects in all the other three cities. Table IV shows that Beijing had the best schedule performance (8.4 percent) and the lowest quality performance (3.19). Beijing’s lowest schedule overrun may be explained by public owners who put pressure on contractors to complete projects quickly, even if this is at the expense of quality. Public owners’ behavior may be explained by the high power distance index in China (80), suggesting that the society believes that inequalities amongst people are acceptable, there is polarization of subordinate-superior relationship and individuals are influenced by formal authority and sanctions (Hofstede et al., 2010). In a high power index culture, people would go out of the way to satisfy their superiors’ command to meet the quantitative targets. Among the four cities, China also has the lowest GDP per capita – suggesting that China is a developing country. One of the characteristics of projects in developing countries are low quality (Long et al., 2004), as is the case of China. Low quality may be attributed to tight project schedule, contractors’ poor management ability and unavailability of sufficient amount of skilled labor, professionals and managers (Zou et al., 2007). Other reasons include errors or omissions in construction works, political focus on reduced project costs or time,
unsettled or lack of project planning, and errors or inconsistencies in project documents (Larsen et al., 2016).

Public projects in Hong Kong seem to fare the worst in terms of having highest cost overrun (12.5 percent) and highest schedule overrun (17.8 percent). The “race to the bottom” in terms of cost and schedule may be due poor site management and supervision, unforeseen ground conditions, low speed of decision making involving all project teams, client-initiated variations and necessary variations of works (Chan and Kumaraswamy, 1997).

The main limitation of the study is that the response rate is not high. However, this should not nullify the findings because in each city, at least 30 sets of samples were obtained, suggesting that the sampling distribution will approximate a normal distribution (Cohen, 1992). Notwithstanding this, the findings should be generalized carefully. In future, more sets of data could be collected, especially from Sydney. In-depth case studies of projects in these cities could also be conducted to discover the causes of poor project performance or enablers for superior performance.

Conclusion

This study adopted the survey questionnaire method to collect data of completed public projects in Beijing, Hong Kong, Singapore and Sydney to compare their performance in terms of cost, schedule and quality. The main finding is that in all four cities, there are significant cost and schedule overruns, and quality is perceived to be significantly good.

Among the four cities, it is found that Singapore public projects have on average the lowest cost overrun, while Hong Kong projects the highest cost overrun (see Table IV). It is recommended that more time be given to develop the design and prepare the tender documents so that there are fewer changes after the contract is awarded. It is suggested that the Hong Kong government investigate the appropriateness of using BQ contracts as the quantification risk is quite heavily borne by the public owner. The implication of the finding is that a larger contingency sum should be set aside for public projects in Hong Kong.

Public projects in Beijing, on average, have the lowest schedule overrun, while those in Hong Kong have the highest (see Table IV). The finding suggests that projects in Hong Kong may suffer from low productivity since more time and hence more man-days are needed to complete the project. It is recommended that public contracts be awarded to contractors with superior management capability, strong financial resources and competent professionals and workmen. The implication is that better project planning and control should be practised.

The findings show that Sydney’s public projects have the highest quality while projects in Beijing have the lowest quality (see Tables IV and V). The implication of the finding is that A/E/C firms working in Australia must be prepared to give the highest level of quality to meet public owner and stakeholders’ expectations. The suggestion to public owners in China is to avoid announcing facility opening date until the completion date is more certain. This is to avoid losing face and to allow time for the project to be properly executed. It is recommended that public owners avoid awarding projects to bidders who offer unrealistically low prices so that contractors have sufficient resources to produce high quality facilities.

The research implication of this study is that the plethora of project management strategies does not seem effective in preventing cost and schedule overruns in public projects regardless of the state of development of a country or size of construction industry. It is concluded that developed countries are likely to have better project quality. Unfortunately, lower schedule overrun may also lead to lower quality in developing countries.

This study contributed to knowledge by discovering the areas that project managers should focus on when managing public projects in different countries. In laissez-faire or free market economies, more attention should be paid to managing project cost and schedule.
When a country has lower transparency index, high power distance or high masculinity, more attention should be paid to controlling project quality. Project team members should focus on delivering public projects to the highest level of quality in developed countries that have low power distance, high individualism or high uncertainty avoidance index.

Acknowledgment
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References


Further reading


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Labour productivity motivation framework for Iskandar Malaysia
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Department of Civil Engineering, Swinburne University of Technology, Kuching, Malaysia, and Russell Kenley
Department of Management and Marketing, Swinburne University of Technology, Melbourne, Australia

Abstract
Purpose – The purpose of this paper is to develop a motivation framework that will enhance labour productivity for Iskandar Malaysia (IM) construction projects. The vision of IM development corridor is to become Southern Peninsular Malaysia’s most developed region by the year 2025. IM cannot realise this foresight without effective labour productivity. Previous studies have reported that the labour productivity of IM construction projects was six times lower than the labour productivity of Singapore construction projects, due to lack of motivation among IM labourers, and a shortage of local skilled labour. Therefore, there is a need to study how to motivate IM construction labourers, so as to increase their productivity.

Design/methodology/approach – A quantitative research method was used to collect data from IM construction skilled labourers and construction professionals, using two sets of questionnaire. The respondents were selected using a purposive sampling technique. In total, 40 skilled labourers and 50 construction professionals responded to the questionnaire survey, and the data were analysed using Statistical Package for Social Science software (version 22).

Findings – The analysis revealed the major factors that motivate labourers participating in IM construction projects. The factors were ranked hierarchically using Relative Importance Index (RII) and the outcome of the ranking indicated that effective management, viable construction practices, financial incentives, continuous training and development, and safe working environment were the most significant motivation strategies that positively influence IM construction labourers.

Originality/value – The study developed and validated a framework that can be used to boost the morale of IM construction labourers, so that their productivity can be increased. Implementation of the established motivation framework will also lead to career progression of IM construction labourers, based on the training elements in the framework. This career prospect will attract local skilled labourers to participate in IM construction projects.

Keywords Development, Motivation, Productivity, Labour, Framework, Iskandar Malaysia

Paper type Research paper

1. Introduction
Iskandar Development Region is a regional development corridor, currently known as Iskandar Malaysia (IM). It is located in Johor, Southern region of Peninsular Malaysia and it covers a total area of 2,300 square kilometres which is approximately three times the size of Singapore (IRDA, 2017). The vision of IM is to establish a strong and continuous developing metropolis of international standard (Elisabetta, 2017). As a result of increasing number of labourers participating in IM construction projects, the management of IM alongside Malaysian construction industry governing bodies has initiated several strategies to enhance the output of their construction labourers.

Among the strategies is the establishment of Iskandar Malaysia Human Capital Blueprint (IMHCB) with the essence of initialising, establishing, and implementing motivational strategies that will improve the overall output of IM. Notwithstanding, many construction stakeholders have questioned the efficiency of the IMHCB. They are of the view that the IMHCB is limited to only four sectors, thereby ignoring other sectors.
The construction labour, for example, has experienced little or no motivational packages from IMHCB; and this has resulted to problems, such as work delay, shortage of skilled labour, and workplace accident (IRDA, 2014). Another effort by Construction Industry Development Board (CIDB) to enhance labour productivity in Malaysian construction industry was the launching of Construction Industry Master Plan (CIMP). The aim of CIMP is to improve the skills of Malaysian construction industry workforce in general. However, one of the major challenges faced by CIMP is low allocation of training funds (IRDA, 2014). This has led to skilled labour shortage, and time and cost overrun. Just recently, the Comprehensive Development Plan ii Iskandar Malaysia Executive Summary (CDP 2014-2025) was launched to review the earlier Comprehensive Development Plan (CDP 2006-2025). The CDP (2014-2025) was developed after assessing the performance of IM ten years after its existence. One of the major recommendations by the recent review was on improving productivity by developing highly skilled cluster-driven human resources (IRDA, 2017).

Irrespective of these efforts, labour productivity of IM construction projects has not been able to meet to international standard (IRDA, 2014). The *New Straits Times* (2014), a local newspaper, reported that labour productivity of IM construction projects is six times lower than the labour productivity of Singapore construction projects. In addition, it reported that the situation might worsen by the end of 2017, probably due to the influx of inexperienced foreign labour, and lack of motivation among the labourers. In the same vein, CITP (2016) reported that labour productivity of IM construction projects has been ineffective due to lack of motivation among their labourers. Although some researchers have argued that motivation has an insignificant effect on labour productivity, still scholars such as Ahsan (2015) have affirmed that the inability of IM management to motivate their labourers has resulted to site accident, project delay, and lack of interest among Malaysian youths. Additionally, the local youths are not motivated to participate in IM construction projects due to lack implementation of motivation factors. Thus, they term it dirty, dangerous, and difficult.

However, few researchers have suggested ways of improving overall output of IM projects. Rabe *et al.* (2017) in their study suggested effective communication and management at all phases of IM projects. Their study did not put construction labourers into consideration, rather it focussed on the IM stakeholders. Rizzo and Glasson (2012) carried out a review on the vision and future of IM without any empirical survey. Ohueri *et al.* (2016) proposed the Continuous Training and Development Model to the management of IM. There were a few other studies conducted on strategies for improving construction workers output in the context of IM but they lacked empirical backing and thus cannot be ascertained (Rizzo and Glasson, 2012). Therefore, there is lack of research and development in the aspects of enhancing labour productivity of IM construction projects using motivation concept. Hence, the aim of this study is to develop a motivation framework that can be used to increase labour productivity of IM construction projects.

### 2. Factors that affect labour productivity in construction industry

Labour productivity is measured by the unit of output per unit of labour (Akindele, 2013; Frank, 2013; Jarkas and Bitar, 2012). According to Jayasinghe and Fernando (2017), enhanced productivity satisfies clients, attracts investment, and contributes to economic growth and well-being (Ameh and Osegbo, 2011; Baloyi and Bekker, 2011). However, this research reviewed previous studies in order to identify the major factors that affect labour productivity in the construction industry. This is illustrated in Table I.

From Table I, majority of the researchers strongly believe that motivation factors, such as management and supervision, financial incentives, and continuous training, have a very high impact on labour productivity. However, only one researcher acknowledged the fact that weather condition affects labour productivity. Therefore, it is necessary to establish strategies for enhancing labour productivity based on the significant motivation factors.
2.1 Motivation in the construction context

Motivation is defined as the internal and external factors, which prompt the desire and energy in people to be continually interested and committed to a job, role, or subject (BOD, 2017). Several studies and numerous theories (Vroom’s Expectancy Theory, Maslow’s Hierarchy of Needs theory, etc.) have been proposed to explain the nature of motivation at work (BOD, 2017). However, the uniqueness of the construction industry needs to be recognised in order to effectively apply the theories of motivation in the industry. Earlier research on motivation in the construction context lacked empirical support whereas those with empirical data lacked clarity, with a limited number of factors. For instance, instead of conducting an empirical survey, Wiley (1997) compared the results of four motivation surveys conducted over four decades ago. Similarly, Shoura and Singh (1999) conducted a study on motivational parameters of engineering managers without providing any empirical data analysis.

Recently, researchers have investigated motivational factors relating to specific types of employees in the construction industry. For example Cox et al. (2006) identified factors that promote positive motivational behaviour in construction subcontractor crews. Siriwardana and Ruwanpura (2012) summarised previous research works on construction labourers, identifying factors affecting their motivation and loyalty. However, all of these studies include a limited number of factors with no ranking between the different categories of factor and they were not based on job-site data collection (Akindele, 2013). Moreover, there is little or no research on the need to motivate IM construction labourers (Ohueri et al., 2016). Thus, it is paramount to conduct a more detailed empirical research on labourer’s motivation in the construction industry, especially in IM, so as to establish a framework that can be used to raise the morale of labourers.

3. Frameworks for improving labour productivity in the construction industry

Some of the prominent frameworks for improving labour productivity in construction industries are reviewed in this study as shown below. This is to enable us to adapt a suitable framework that can be used to increase labour productivity of IM construction projects.

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Table I. Factors affecting labour productivity in construction industry
3.1 **Construction productivity and capability framework (CPCF)**

CPCF was introduced by Building and Construction Authority (BCA) (2017). The CPCF is categorized into three major sections and several sub-sections. Furthermore, the sub-section indicates the modus operandi of this framework, and the primary goal is to enhance labour productivity of Singapore construction projects. Although the framework has effectively contributed to the improvement of labour productivity of Singapore construction projects, yet it has been heavily criticised by construction experts because it requires a huge amount of money to actualise.

3.2 **Malaysia productivity corporation framework (MPCF)**

According to MPCF, productivity can be improved by five inter-linked catalysing factors which include: organisational development, human capital management, capability to innovate, to acquire and use of technology, and efficient management system (MPC, 2017). The MPCF emphasises that human capital development and efficient management are paramount in realising enhanced labour productivity in Malaysian construction projects. Nevertheless, scholars have argued that the framework did not give any details on how to manage human capital for maximum performance. According to Bin Zakaria et al. (2013), the MPCF did not specify how the “five inter-linked catalysing factors” could be achieved.

3.3 **Model for continuous improvement of construction productivity (MCICP)**

The MCICP was proposed to the construction industry by Harris and McCaffer (2013). The MCICP was developed to enhance timely delivery of construction projects, at budgeted costs, and expected quality standards. Their study stresses the need for regular training and development of labour, and continuous improvement of the construction process. The expected outcome of this framework is quality performance, on time completion of construction project, viable construction practice, and increased number of skilled labourers. Due to its relevance in the construction context, MCICP is adapted in this study for the purpose of establishing a motivation framework for improving labour productivity of IM construction projects.

4. **Motivation framework for improving labour productivity of IM construction projects**

The motivation framework developed in this research is adapted from the MCICP. The framework was adapted due to its concept of quality management and continuous improvement of labour productivity. The MCICP framework addresses the critical factors that affect labour productivity in the construction industry (Harris and McCaffer, 2013). The established motivation framework has it bases from the findings of this empirical research and operates under the prominent theories of motivation.

5. **Research method**

This research adopted a quantitative method research which comprises of two sets of closed-ended questionnaire. According to Tashakkori and Teddlie (2010), quantitative method research is important because it increases response rates and greatly enhances the summary and analysis of collected data. The population of this research includes: IRDA, contractors, consultants (i.e. architects, builders, construction engineers, quantity surveyors, project managers, and site supervisors), and skilled workers in IM. Prior to the actual data collection, a pilot survey was conducted to assess the reliability of the research instrument. Pilot survey involves testing the phrasing of the questions, identifying ambiguous questions, testing the technique used for collecting data, and measuring the effectiveness of the respondents (Naoum, 1998).
In order to ensure the reliability of the pilot questionnaire, ten samples of the population were selected using the purposive sampling technique. However, five pilot questionnaires were returned. The answered pilot questionnaires were tested for reliability, to measure how stable the instruments are. Reliability ensures consistency in findings when continually used (Struwig and Stead, 2007). For this research, reliability was validated by testing the pilot questionnaire with Cronbach’s $\alpha$ coefficient in Statistical Package for Social Science (SPSS) software (version 22). This is a coefficient number that is used to rate the homogeneity or correlation among tested items (Cronbach, 1951). The Cronbach’s $\alpha$ values range from 0 to 1. Any scale below 0.4 is either modified or deleted completely; while scale of 0.65 and above is considered reliable and consistent (Cronbach, 1951). Hence, the consistency scale used to denote minimum reliability in this research is 0.65.

The Cronbach’s $\alpha$ reliability analysis for the pilot survey indicates that each variable in the pilot Questionnaire Set A has a Cronbach’s $\alpha$ value that is above 0.65. Also, the average Cronbach’s $\alpha$ value for the 14 items in the pilot Questionnaire Set A is 0.83. Also, the reliability test of pilot Questionnaire Set B shows that all the variables in this pilot questionnaire have a Cronbach’s $\alpha$ value that is above 0.65. Moreover, the average Cronbach’s $\alpha$ value for all the variables is 0.93. Thus, the pilot Questionnaire Set A and Set B were considered reliable.

After the reliability analysis, the main questionnaires were drafted and distributed to the samples. Purposive sampling technique was used to select the samples for this study which include: 100 skilled labourers and 100 construction professionals in IM. Purposive sampling technique was used in selecting the samples because the researcher was not able to get the exact number of the research population. This is in line with Struwig and Stead’s (2007) suggestion that purposive sampling technique is a non-random technique that does not need underlying theories or a set number of participants.

Two sets of closed-ended questionnaire were used in this survey. Each of the questionnaire comprised of Section A and Section B. However, Questionnaire Set A, which was specifically used to survey the skilled labourers in IM recorded 40 per cent response rate, while Questionnaire Set B which surveyed construction professionals witnessed 50 per cent response rate. In all, a total of 200 questionnaires were distributed, and 45 per cent response rate was achieved. This is suitable, and in line with the study conducted by Babbie (2007) which opined that any response rate above 30 per cent can be reported as statistically adequate. The factors used in the questionnaires were selected from review of previous publications because several researchers have considered them significant as shown earlier in Table I.

However, the data collected from the two sets questionnaire were analysed using SPSS software (version 22). Afterwards, it was triangulated for a more cohesive interpretation. According to Fielding (2012), triangulation is a means of convergent validation of multiple data. However, constant comparative method was used to triangulate the data from the two sets of questionnaire. Constant comparative method is a process whereby data collected from different research instruments or from previous research are continuously collated by coding the similarities in the collected data, to ensure consistent research output (Hertfordshire, 2017).

In this study, the results from Questionnaire Set A and Set B were compared to highlight the factors that are ranked high and at the same time reoccurred. Then, the reoccurred factors with high ranking are given priority in establishing the framework. Subsequent factors that did not appear in both questionnaires are also included in the framework based on their Relative Important Index (RII) value. However, factors with low RII value and mean value less than 3 are not included in the motivation framework. According to the Likert scale used in the questionnaires, any factor with mean value below 3 is not a significant factor. Finally, the motivation framework was validated, and recommended to IM for improving their labour productivity.
5.1 Validity process of established motivation framework

The established motivation framework was validated via face validity method. Face validation of framework by stakeholders will enable the researcher to know whether the framework will serve its purpose of establishment or not (Sushil and Verma, 2010). Two construction professionals were selected via purposive sampling technique in order to validate the established framework. This was due to numerous factors that hindered the researchers from meeting a larger group of IM construction professionals. Nevertheless, scholars such as Tongco (2007) have reiterated that there is no specific number of construction professionals required in the validated of any established framework, provided the selected construction professionals are experienced, and have the required information for meaningful feedback.

6. Data analysis and discussion

Data from the two sets of questionnaire are analysed and discussed in this section.

6.1 Questionnaire Set A

Section A of Questionnaire Set A was used to sought the background information of 40 skilled labourers that responded to the survey. Their response was analysed using SPSS descriptive statistics. The gender analysis shows that 77 per cent of the respondents were male, while 23 per cent were female. Bangladesh recorded the highest percentage (40 per cent) of skilled labourers surveyed in IM, while Myanmar has the lowest percentage (8 per cent). However, the percentage of skilled labour from Malaysia and Indonesia were 25 and 27 per cent, respectively. In total, 75 per cent of the skilled labourers have worked for less than 10 years, while 25 per cent have worked between 11 and 20 years.

Section B was used to evaluate the major factors that motivate IM labourers. It was structured using a five-point Likert scale: (1 = not important; 2 = slightly important; 3 = moderately important; 4 = very important; 5 = extremely important). This enabled the respondents (IM construction skilled labourers) to rate the listed motivation factors based on their level of importance on labour productivity of IM construction projects. As stated by Boone and Boone (2012), Likert Scale is usually a five-, seven-, or nine-point agreement scale used to measure respondents’ agreement with a variety of statements.

The data obtained from this section were systematically entered into SPSS software and analysed with descriptive statistics. Consequently, the mean and the standard deviation of each item were calculated. Meanwhile, the mean value of 3 was used as cut-off point to eliminate the insignificant factors because according to the Likert scale used in the questionnaire, any factor below 3 is not a significant factor. The use of mean in research is paramount as it minimises error and also determines the overall trend for the research (Loether and McTavish, 2014). However, the Relative Importance Index (RII) was used to rank them according to their level of importance. The formula for Relative Importance Index (RII) is as follows:

$$\text{RII} = \frac{\sum W}{A \times N} (0 < \text{RII} < 1)$$

where $W$ is the weight given to each factor by the respondents; $A$ the highest weight (i.e. 5 in this case); and $N$ the total number of respondents. After the analysis the major factors that motivate IM labourers were identified as shown in Table II.

Table II shows that effective management and supervision (RII = 0.96) has been ranked as the most important motivation factor that positively affects labour productivity in IM. In total, 80 per cent of the respondents believe that educated and experienced manager is extremely important in terms of labour productivity. Moreover, financial incentives strategy
Factors that motivate IM labourers | 1 | 2 | 3 | 4 | 5 | Total No. | Weight | Mean | SD | RII | Rank
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
Effective management and supervision | 8 | 32 | 40 | 192 | 4.80 | 0.41 | 0.96 | 1
Financial incentives | 15 | 25 | 40 | 185 | 4.63 | 0.49 | 0.93 | 2
Training and development | 8 | 24 | 40 | 176 | 4.40 | 0.81 | 0.88 | 3
Safe and friendly working environment | 10 | 10 | 20 | 40 | 170 | 4.25 | 0.84 | 0.85 | 4
Career progression | 11 | 12 | 17 | 40 | 166 | 4.15 | 0.83 | 0.83 | 5
Job satisfaction | 10 | 12 | 14 | 40 | 162 | 4.05 | 0.75 | 0.81 | 6
Information and communication | 12 | 11 | 16 | 40 | 159 | 3.97 | 0.77 | 0.79 | 7
Well-established goals | 14 | 18 | 8 | 40 | 154 | 3.85 | 0.74 | 0.77 | 8
Availability of machines and equipment | 15 | 20 | 5 | 40 | 150 | 3.75 | 0.67 | 0.75 | 9
Recognition | 2 | 18 | 20 | 40 | 138 | 3.45 | 0.60 | 0.69 | 10
Job security | 23 | 17 | 4 | 40 | 137 | 3.43 | 0.50 | 0.68 | 11
Interpersonal relationship | 5 | 18 | 16 | 1 | 40 | 133 | 3.33 | 0.73 | 0.66 | 12
Achievement and responsibility | 5 | 20 | 15 | 40 | 130 | 3.25 | 0.67 | 0.65 | 13
Company’s reputation | 15 | 15 | 10 | 40 | 115 | 2.88 | 0.79 | 0.57 | 14

was ranked second with RII = 0.93. This is a notable motivation factor because 63 per cent of respondents believe that fair wages for construction labourers are extremely important in increasing the output of labourers participating in IM construction projects. Other significant factors that increase labour productivity in IM include training and development (RII = 0.88), safe and friendly working environment (RII = 0.85), and career progression (RII = 0.83). Nevertheless, factor such as company’s reputation with low RII = 0.57, and low mean value 2.88 is insignificant and eliminated as major motivation factor. The Likert scale used in the questionnaires considers any factor that has a mean value less than 3 as insignificant. Loether and McTavish (2014) stated that the use of mean in research is paramount as it minimises error and also determines the overall trend of the research.

After the analysis, the Relative Importance Index (RII) was used to identify the major factors that motivate IM labourers. Effective management and supervision, financial incentives, training and development, safe and friendly working environment, career progression, job satisfaction, information and communication are the most significant factors that motivate IM labourers. The success of any organisation depends on the effectiveness of the management, safety, proper dissemination of information, and career progression (Nguyen and Hadikusumo, 2017). Furthermore, the need for a safety working environment cannot be underestimated (Almén and Tore, 2013). In order to probe further into strategies for improving labour productivity in IM, the construction professionals were investigated.

### 6.2 Questionnaire Set B

Section A of Questionnaire Set B surveyed the demographic information of 50 IM construction professionals who responded to the survey. SPSS descriptive statistics was also used to analyse the information collected. The analysis indicated that 77 per cent of the respondents were male while 23 per cent were female. In total, 66 per cent were consultants, 14 per cent of the respondents were contractors, and 20 per cent were IRDA staff. In all, 55 per cent of the professionals have worked for over 20 years, while 45 per cent worked for less than 20 years.

Section B was used to investigate the strategies that can be used to improve the productivity of IM labourers. It was designed using a five-point Likert scale (strongly disagree = 1, disagree = 2, neither agree nor disagree = 3, agree = 4, strongly agree = 5). According to QuestionPro (2017), Table III shows the analysis of the data.

After the analysis, the strategies that can be used to increase the productivity of IM labourers were highlighted. The analysis shows that 92 per cent of the respondents...
strongly agree that experienced and competent management is the most important technique in terms of motivating IM labourers for higher productivity. In addition, 87 per cent of the respondents strongly agree that the viable construction process is vital towards improving labour productivity of IM construction projects. In total, 79 per cent of the respondents strongly agree that increasing the wage of construction labourers will enhance labour productivity of IM construction projects. Furthermore, 65 per cent of the respondents strongly agree that training young labourers will enhance labour productivity of IM construction projects. Although strategies such as setting precise goals, and use of modern equipment’s and machines were ranked low, with average RII value of 0.76 and 0.69, respectively, they were still included in the framework because they have mean value above 3.

Based on this analysis, the major strategies that can be used to increase labour productivity of IM construction projects were identified, and ranked hierarchically based on their Relative Importance Index (RII). Hence, quality management, viable construction practices, sufficient reward system, and continuous training were identified as strategies that can be used to enhance labour productivity of IM construction projects. The findings accorded the quality management concept proposed by Harris and McCaffer (2013).

After analysis of the two questionnaires, the outcome was triangulated in order to identify any form of correlation. This was achieved via constant comparative method. This method compared the results from Questionnaire Set A and Set B based on reoccurrence and Relative Important Index (RII) as shown in Table IV.

Table IV indicates that there is a correlation between the two results. For instance, effective management has been ranked as the most effective motivation strategy in both questionnaires. Also, the issue of training and development, and safety were pinpointed as significant motivation strategies in both sets of the questionnaires. Finally, motivation strategy such as company’s reputation was excluded from the framework because it has low RII and mean value less than 3. Thus, a motivation framework was established based on the outcome of the entire survey.

6.3 Validation of established motivation framework

To determine the usefulness of the framework, face validation was conducted on the framework by two IM contractors. The face validation was in the form of a focus group discussion. According to validation respondents (two IM contractors), the framework is relevant in the construction context, especially in improving labour productivity of IM construction projects. They were satisfied with the empirical process underwent to establish this framework, and the detailed sub-strategies highlighted in the framework. However, they suggested that the framework should be updated regularly.

<table>
<thead>
<tr>
<th>Strategies for improving labour productivity of IM construction projects</th>
<th>Total No.</th>
<th>Weight</th>
<th>Mean</th>
<th>SD</th>
<th>RII</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective management</td>
<td>5 57 50</td>
<td>305</td>
<td>4.92</td>
<td>0.28</td>
<td>0.98</td>
<td>1</td>
</tr>
<tr>
<td>Viable construction practices</td>
<td>1 10 51</td>
<td>298</td>
<td>4.80</td>
<td>0.44</td>
<td>0.96</td>
<td>2</td>
</tr>
<tr>
<td>Sufficient reward system</td>
<td>3 12 47</td>
<td>292</td>
<td>4.70</td>
<td>0.56</td>
<td>0.94</td>
<td>3</td>
</tr>
<tr>
<td>Continuous training and development of labourers</td>
<td>12 5 45</td>
<td>281</td>
<td>4.53</td>
<td>0.80</td>
<td>0.90</td>
<td>4</td>
</tr>
<tr>
<td>Creating a safe and friendly working condition</td>
<td>10 18 34</td>
<td>272</td>
<td>4.39</td>
<td>0.75</td>
<td>0.87</td>
<td>5</td>
</tr>
<tr>
<td>Creating job security and satisfaction</td>
<td>12 22 28</td>
<td>264</td>
<td>4.25</td>
<td>0.77</td>
<td>0.85</td>
<td>6</td>
</tr>
<tr>
<td>Proper communication and dissemination of information</td>
<td>19 12 31</td>
<td>260</td>
<td>4.19</td>
<td>0.88</td>
<td>0.83</td>
<td>7</td>
</tr>
<tr>
<td>Setting precise goals</td>
<td>8 47 7</td>
<td>247</td>
<td>3.98</td>
<td>0.49</td>
<td>0.79</td>
<td>8</td>
</tr>
<tr>
<td>Use of modern equipment and machines</td>
<td>10 10 30 12</td>
<td>230</td>
<td>3.70</td>
<td>0.97</td>
<td>0.74</td>
<td>9</td>
</tr>
</tbody>
</table>

Table III. Strategies for improving labour productivity of IM construction projects
7. Basis of established motivation framework

The framework works with the principle of quality management and continuous training which was encouraged in the MCICP, as proposed by Harris and McCaffer (2013). Also, the framework adopted the Maslow theory of need and the Vrooms expectancy theory, which have emphasised on the hierarchy of human needs and perception of workers towards their working environment, respectively. The framework is shown in Figure 1.
Figure 1 illustrates the motivation framework established in this study. From Figure 1, quality management is the first step towards the actualisation of IM’s vision. The quality management in this framework entails the use of experienced and competent management, regular training of management crew, adoption of labour productivity improvement models and framework, and also the construction work’s planning, monitoring, and benchmarking processes. The framework continued in that sequence until it reached the last strategy, which is the use of modern equipment and machines. All of the strategies must be implemented sequentially in order for the motivation framework to work efficiently and effectively. This is in line with Nguyen and Hadikusumo (2017) view on the need for efficient human resource development.

7.1 Benefits of established motivation framework

(1) The framework will increase labour productivity in IM, as well as Malaysian construction industry;
(2) the training and development elements in the framework will lead to career progression, which will, in turn, attract local skilled labour to work in IM projects; and
(3) the framework will also be of great benefit to the CIDB, in making policies that will enhance the Construction Industry Transformation Plan.

8. Conclusion

Labour productivity in IM is far below international standard. Therefore, this study proposed a motivation framework for improving labour productivity in IM. The study utilised a quantitative approach to achieve the objectives of this study. The survey discloses the importance of motivation of IM labourers towards higher productivity level. Findings from the study enabled the researcher to identify the major strategies that can be used to enhance labour productivity of IM construction projects. According to the findings, effective management, viable construction practices, sufficient reward system, continuous training, and development of labourers are significant strategies that motivate IM construction labourers. This tallies with most researchers’ (Koch et al., 2010; Issa et al., 2011; Nguyen and Hadikusumo, 2017) opinion on the factors that enhance construction output. The established framework was adapted from the MCICP and it can be used to improve labour productivity of IM construction projects. The training elements in the framework will lead to career progression. Thus, the career prospect of the framework will attract Malaysian youths to work in Malaysia construction industry, especially in the IM region.

However, scheduling a focus group meeting with some of the IM construction professionals for the validation of the established framework was very challenging because of the company policies, limited time, delay in ethics approval by necessary stakeholders, etc. Notwithstanding, the framework was still validated by two IM professionals which is still acceptable according to previous literature. According to the validation respondents, the established framework needs to be extended to other construction projects other than IM construction projects. Also, more research needs to be conducted to address future challenges.

References


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An implementation framework of value management in the Nigerian construction industry

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Abstract

Purpose – The purpose of this paper is to develop a framework for value management (VM) implementation by establishing the effect of critical success factors on current construction practices. This will aid stakeholders to improve productivity of construction practices in the Nigerian construction industry. The study established the requirements that ought to be satisfied for VM to successfully enhance productivity of construction activities.

Design/methodology/approach – Data collection was based on self-administered questionnaires from 344 registered construction professionals in Nigeria. The Statistical Package for Social Sciences version 25 and structural equation modelling were used to analyse the data for both descriptive and inferential analyses. Kaiser-Meyer-Olkin measure of sampling adequacy revealed that the internal consistency of the developed research instrument was appropriate, while the confirmatory factor analysis indicated satisfactory goodness-of-fit indices among acknowledged determinants of the structural model.

Findings – A framework that established the requirements for the successful implementation of VM construction practices in the Nigerian construction industry.

Originality/value – A structural model validated the requirements of applying VM on current construction practices. The established requirements (environment, people, government and information/methodology) can be used by decision makers and stakeholders to improve productivity of the current construction practices in the Nigerian construction environment. A framework was developed and validated by construction experts to confirm its suitability, usefulness and acceptance.

Keywords Current, Structural equation modelling, Critical success factor, Productivity, Practices, Value management

Paper type Research paper

1. Introduction

Value management (VM) is a multi-disciplinary, team-oriented, structured, analytical and systematic analysis function that specifically seeks best value through the design and construction process to meet client’s perceived needs (Jaapar et al., 2009). This advocates a process which begins at the planning stage and after the project has been completed. Therefore, throughout the life of construction projects, the need for enhanced and productive construction practices is paramount. VM can stimulate sustainable design and development and can remove unnecessary costs thereby allowing the integration of sustainability into projects while maintain the budget (Shen and Yu, 2012). The appeal to improve construction industry productivity energies government strategies and aims to reduce construction costs, since governments are major clients for construction projects (Kenley, 2014). Hence, it is vital for construction professionals to reduce project costs, completion time and optimise project value via the VM approach.

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According to Kissi et al. (2015), the Royal Institution of Chartered Surveyors termed VM as one of the ten drivers in seeking to improve productivity and value for money. This is supported by Tanko et al. (2017) who advanced that VM unequivocally aims at optimising value without sacrificing quality and performance. The fact that no two projects are the same, unnecessary costs are unavoidable. Thus, the need to identify unnecessary costs and eliminate them. In a similar submission, the Federal Government of Nigeria has realised the need to improve service delivery by stipulating that procurement of public assets and services must go through the application of value-added standards and practices (Kolo and Ibrahim, 2010). Consequently, the use of value-added management systems and new innovations is indispensable.

Globally, VM seems to be an accepted approach for achieving value for money (Kolo and Ibrahim, 2010) and enhanced productivity. This has recorded a lot of successes in both developed and developing countries. Ellis et al. (2005) confirmed that when VM is properly implemented at the initial phase of a project, it could reduce cost by 10–25 per cent on the proposed capital cost of construction projects. Experience of time past has also indicated that the technique has led to cost savings of 5–10 per cent for a good number of construction-related projects (Norton and McElligott, 1995; Zhang et al., 2009). The Prime Minister of Malaysia also submitted that the Malaysia’s economy can be more competitive only if VM is applied at the early stages of a project (Abdul-Razak, 2011). Nonetheless, Oke and Ogunsemi (2011) stated that VM has not formally been embraced in the Nigerian construction industry and recommended the need for Nigeria clients to adopt the technique.

The purpose of this paper is to develop a framework for VM implementation by examining the relationship between critical success factors (SFs) and the current practice (CP) of VM applications in the Nigerian construction industry. This study was carried out in Abuja, Kaduna and Jos cities of Nigeria. Abuja, being close to Jos and Kaduna cities, has a significant level of construction output, and is the federal capital of Nigeria located at the centre of the country, and the headquarters of Economic Community of West African States.

2. Critical SF of VM
Rockart (1979) defined CSFs as “areas in which results if they are satisfactory, will ensure successful competitive performance for the organisation”. Thus, Chan et al. (2001) and Yu et al. (2006) have used this approach as a means to improve the performance of the management process. Moreover, CSFs can be viewed as those critical areas of managerial planning and action that must be practised in order to achieve effectiveness (Saraph et al., 1989). Hence, CSFs are regarded as those actions and practices that ought to be addressed in order to ensure effective application of VM among stakeholders in the construction industry.

The review of the literature suggested various CSFs that can be identified as being fundamental to the successful implementation of VM, which are likewise essential to attaining improved productivity of construction projects. In order to ensure the success of VM, CSFs must be identified to assist construction practitioners to recognise the barriers of VM and carry out necessary steps to realise its benefits and potentials. Ramly et al. (2015) and Shen and Liu (2003) found out that the multi-disciplinary mix of a VM team is a critical success indicator in a VM workshop, while Male et al. (1998) see the skills of a VM facilitator as a CSF of VM. A study by Chen et al. (2010) also revealed the personality of the facilitator as a major SF in a VM study. In this vein, Palmer et al. (1996) observed that the competence and qualifications of the facilitator is an important SF of VM. Therefore, the proficiency of value managers or facilitators is fundamental to improving the productivity of construction projects by attaining the ultimate goal of value optimisation. In addition, the presence of decision makers in a VM workshop (Male et al., 1998) and client’s active support and participation (Ramly et al., 2015) is prominent CSFs of VM. Other CSFs identified by some
scholars include: clearly defined objectives of VM studies (Shen and Liu, 2003); function analysis (Male et al., 1998); collaboration among VM participants (Shen and Liu, 2003; Maurer, 1996); input of original design team (Palmer et al., 1996); and end user’s participation (Ramly et al., 2015).

3. Current construction practices
The current construction practices are usually carried out by a multi-disciplinary group of construction professionals, the client (owner), the end user and other relevant stakeholders. Generally, the process of carrying out these practices in a VM approach is separated into pre-workshop, workshop and post-workshop stages. The pre-workshop stage is dedicated to gathering of relevant background details of proposed projects. Ramly et al. (2015) put forward that at the pre-workshop stage, roles and responsibilities are assigned to stakeholders. Next, the workshop stage has six phases which include: information; function analysis; creativity; evaluation; development; and presentation phases (Hwang et al., 2014; SAVE International, 2007; Kelly et al., 2004).

At the information phase, recognising client’s needs with regard to function and cost (Chen and Liao, 2010), and sharing of project information related to scope, timing, location and functions are imperative. Other activities carried out at this phase include carrying out site visitation, defining and understanding the objectives and functions of the project and involving clients at the initial stage of the project. At the function analysis phase, functions are generated and classified into basic and secondary functions (SAVE, 2007), and high cost areas are also identified. Next, at the creativity phase, ideas are being brainstormed and assessed to meet the desired functions of projects (Kelly et al., 2004). In Ramly et al. (2015) study, the authors submitted that at the evaluation phase, brainstorming should go through further screening to realistically determine how they could be applied to meet the desired function, and should be classified into: realistically possible to be implemented; remotely possible; and impossible to be implemented. Subsequently, at the development phase, the short-listed ideas are developed into a feasible solution and presented as an action plan at the presentation phase. Therefore, since the CSFs of VM could have an impact on the current construction practices, it is thus hypothesised that:

H1. There is a significant relationship between the critical SFs of VM and current construction practices.

4. VM framework
VM frameworks by and large, support team synergy and outline successive phases to be followed within an organised process. The Society of American Value Engineers (SAVE) International (2006) describes the actions that are typically carried out during each phase of the job plan. Chavan (2013) and Chougule et al. (2014) defined the job plan as a framework which guides the processes of analysing a project. The job plan used by VM team during the workshop has six distinct phases which examines a project with respect to its functions. These include: information; function analysis; creativity; evaluation; development; and presentation phases (Jaapar et al., 2012; SAVE International, 2006). The US VM process has three stages: pre-workshop; workshop (job plan); and the post-workshop. These have been discussed in Section 3 of this paper. Nonetheless, Chen and Liao (2010) submitted that an important part of the VM process is the use of a carefully outlined and meticulously tested job plan. Therefore, VM frameworks are systematically conducted carried out by means of a structured job plan.

Also, the UK generic VM process has eight stages with the VM workshop phase having five stages of the whole process (Male and Kelly, 1998). The eight stages are pre-workshop,
information, creativity, evaluation, development, action planning, workshop report and implementation. These stages described the whole VM process beginning with information gathering and synthesis, brainstorming and sorting of ideas, selection of ideas for development, preparation of action plan, preparation and circulation of workshop report, implementation of action plan and feedback workshop. The UK workshop phase (information, creativity, evaluation, development, action planning) is similar to that of the US job plan. Kelly et al. (2004) noted that, likewise the US job plan, complexity/size of the project and other sensitivities may affect the timeframe of the UK VM job plan. Hunter and Kelly (2007) confirmed that it is a norm to have a one-day workshop in the UK, while in the USA it ranges from three to five days. Also, the project team is typically responsible for carrying out VM studies in the UK, while an independent team does this in the USA. Even though both countries uphold multi-disciplinary teamwork during a VM study, only the USA has presentation phase in her VM job plan. Thus, Hunter and Kelly (2007) acknowledged that the major dissimilarity between UK and US practice is how the workshop time is utilised. Consequently, five to seven days duration of a VM study, a multi-disciplinary team-mix of an independent team and a six-phase VM job plan are recommended for the Nigerian construction industry. These recommendations are necessary because an independent team would take a longer duration to objectively appraise tasks without being influenced by internal persons or the original project team.

5. Methodological approach
The study adopted a stratified random probability sampling approach. The research instrument was divided into demographic and constructs measure. The demographics were mainly nominal and ordinal responses, while a five-point Likert scale from “5—always” to “1—never” was used for the other section. This was necessary in order to receive certain tendency from the respondents. Data were collected through self-administered questionnaires. However, prior to the administration of the questionnaire, a validation survey was carried out using small convenience group of experienced construction professionals to validate the study instrument. The style and language of questions, ambiguous and double-barrelled statements, anticipated responses, comments and feedback were captured to improve the questionnaire.

In total, 465 questionnaires were administered to architects, quantity surveyors, builders, civil engineers and services engineers across the selected locations in Nigeria. The professionals were chosen from contracting, project management, consulting engineering, quantity surveying, consulting architects and client organisations. In total, 73.98 per cent (344) of the questionnaires were appropriately answered and returned. The collected questionnaires were carefully coded and entered into the Statistical Package for Social Sciences (SPSS V.25) and saved in the SPSS data editor. The normality test was first conducted using skewness and kurtosis to confirm the normality of the data collected, while Tabish and Jha (2012) pointed out that in order to establish the stability and comprehension of respondents, instrument reliability should be used to adequately measure the variables of a study. Therefore, reliability test was also conducted using the Cronbach’s $\alpha$ coefficient to confirm the reliability of the data collected.

Furthermore, exploratory factor analysis using the SPSS version 25 software was used to establish the structure of the measurement models. The Kaiser-Meyer-Olkin (KMO) and Barlett’s test of sphericity were used to establish the instrument validity by assessing the sample adequacy and multivariate normality of the study variables. In addition, structural equation modelling (SEM), using confirmatory factor analysis (CFA) in AMOS software further validates the measurement models by indicating satisfactory goodness-of-fit (GFI) indices among acknowledged determinants of the study.
6. Results and discussion

6.1 Demographics of respondents

Most of the respondents worked for a good number of years in the construction industry. From Figure 1(a), it can be deduced that the respondents had the necessary experience to carry out this research survey because 83 per cent of the respondents had at least six years working experience, while only 17 per cent had less than five years’ experience in the construction industry.

Figure 1(b) indicates the specialisations of the respondents in the Nigerian construction industry. It is apparent that 31 per cent of the total respondents are quantity surveyors, 26 per cent architects, 20 per cent builders, 17 per cent civil engineers, while 6 per cent are services engineers.

The role played by the different organisations in the Nigerian construction industry is shown in Figure 2(a). Respondents from the quantity surveying firms constitute 31 per cent, 23 per cent from consulting/designing engineering firms, 16 per cent from contracting firms, while 13, 11 and 6 per cent were from consulting architects, project management and client organisations, respectively. These indicate that the respondents are from the core domain of study under investigation. This gives credibility to the data used for this research.

Figure 2(b) shows the degree of familiarity on VM among construction professionals in the Nigerian construction industry. The response reveals that 52 per cent (178) of the respondents were familiar with VM, 31 per cent (105) were moderately familiar, while 8 per cent (29) and 9 per cent (32) were totally familiar and not familiar with VM, respectively. It is imperative to note that about 91 per cent of the respondents are either totally familiar, familiar, or moderately familiar with VM. In addition, it is necessary to
also establish the exact degree of familiarity on VM among the respondents. Thus, using the mean score index (Equation (1)), the mean score is 2.59 (64.75 per cent). Hence, 65 per cent of the respondents are familiar with the technique:

\[
MS = \frac{\sum n_i \cdot p_i}{N} (0 \leq index \leq 4)
\]

where \(n_i\) is the number of respondents that chose \(p_i\); \(p_i\) the 1–4 on a Likert scale; and \(N\) the total number of questionnaire returned.

6.2 Current construction practices and critical SFs of VM

Studies on VM have concentrated on factors affecting the successful application of VM. However, no study did considered nor evaluated the activities and methods that constitute the practice of VM. Therefore, in this research, the CP of VM is the major construction activities of VM that are carried out by the respective construction professionals. These include: Carrying out site visitation (CP1); obtaining relevant background information on proposed projects (CP2); defining the timeframe and scope of projects (CP3); defining and understanding the objectives and functions of proposed projects (CP4); involving clients at the initial stage of projects (CP5); involving and assigning responsibilities to construction professionals at the initial stage of projects (CP6); defining the procurement approach of proposed projects (CP7); committing client organisations in the project cycle (CP8); clarifying project background information and constraints (CP9); sharing project information among professionals and stakeholders (CP10); making client to unequivocally express the scope and expectation of proposed projects (CP11); presentation of perceived project constraints by stakeholders (CP12); identifying high cost areas by undertaking relative cost ranking (CP13); generating and classifying functions/elements into basic and secondary elements with their associated costs (CP14); brainstorming ideas to meet the desired functions/elements and associated costs (CP15); assessing brainstormed ideas to meet the desired functions/elements (CP16); classify the ideas into realistically possible to be implemented (CP17); classify the ideas into remotely possible to be implemented (CP18); classify the ideas from the brainstormed section into realistically impossible to be implemented (CP19); developing an action plan on short-listed ideas (CP20); and holding an action plan review meeting (CP21). These activities are executed from the pre-workshop to post-workshop stages and were identified from literature and preliminary survey.

SFs are basically measures on which the success or failure of a system is judged. Various researchers (Jha and Iyer, 2007; Nawi et al., 2011; Hwang and Lim, 2013) investigated CSFs of construction projects for different objectives with varied outcomes. Others researchers are concerned with determining the CSFs that are most impactful on different construction project objectives. However, SFs vary from one country to another. Therefore, relying on judgement of experienced construction professionals in Nigeria, factors critical to the effective performance of VM were identified. This study recognises and prioritises the SFs for the successful implementation VM in Nigeria, and uses the knowledge garnered from relevant literature and preliminary pilot survey to arrive at the SFs.

The SFs are: cooperation and excellent working relationship of stakeholders and agencies (SF1); decision-making authority granted to each participant by their respective organisation (SF2); VM session intervention into project development cycle (SF3); clear and defined objective of VM session (SF4); establishing and clarifying clients value system (SF5); multi-disciplinary VM team (SF6); competence of VM facilitator (SF7); commitment of all stakeholders to VM session (SF8); ability to conduct VM session (SF9); effective
communication among participants (SF10); knowledge and experience of participants on VM (SF11); professional knowledge and experience of participant’s respective disciplines (SF12); client’s ability to communicate requirements and needs to the design team (SF13); input from the relevant governmental departments and local authorities (SF14); government commitment to implement VM (SF15); presence of decision makers (SF16); active participation and support of clients (SF17); VM study plan for implementation (SF18); proactive, creative and structured approach (SF19); adequate timing of VM session (SF20); background information collected (SF21); VM feedback mechanism (SF22); analysis of project elements and functions (SF23); input of original design team (SF24); and VM awareness among clients (SF25).

6.3 Factor analysis
The KMO and Barlett’s test of sphericity were used to establish the instrument validity by assessing the sample adequacy and multivariate normality of the study variables. According to Alsolami et al. (2016), while KMO test is a measure of sampling adequacy that compares the magnitudes of the partial correlation coefficients of measuring variables, Barlett’s test of sphericity tests if the correlation matrix is an identity matrix. This study revealed KMO values of 0.94 and 0.62 for the current construction practices and SFs, respectively. The KMO values of both variables are above the accepted minimum of 0.6 and their Barlett’s tests of sphericity are significant ($p < 0.05$).

Furthermore, the extraction of the components of current construction practice and SFs was based on the total variance explained which indicated eigenvalues of 1 and above. Thus, the three components of the current construction practice attributes explain a total variance of 82.77 per cent, while the four components of the SFs explain a total variance of 57.70 per cent.

According to Baba et al. (2017), variables with cross-loadings on at least two factors of $> 0.4$ and items with a factor loading of less than 0.4 are usually removed. Nonetheless, the exploratory loadings for all the variables in this research were above the values of 0.40. However, variable SF11 which earlier met the reliability prerequisite could not meet the loading requirement for rotated component matrix. The varimax rotation method was used with Kaiser normalisation.

Based on the outcome of factor analysis, the phases of the CP are categorised into three: information (CPA), information/function analysis (CPB) and creativity/evaluation/development/presentation (CPC). While the SFs are classified into four groups: environment (SFL); people (SFP); government (SFM); and information/methodology (SFI).

6.4 Reliability of instrument
Tabish and Jha (2012) established that in order to establish the stability and comprehension of respondents, instrument reliability should be used to adequately measure the variables of a study. Therefore, Cronbach’s $\alpha$ values were used to examine the internal consistency of similarly interrelated multiple scale items. The results of reliability and validity test (through the Cronbach’s $\alpha$) of the SFs are: environment (SFL) = 0.81; people (SFP) = 0.82; government (SFM) = 0.78; and information/methodology (SFI) = 0.85. While that of the current construction practices are: information (CPA) = 0.96; information/function analysis (CPB) = 0.97; and creativity/evaluation/development/presentation (CPC) = 0.97.

These imply that the results are highly significant because the values obtained are higher than the recommended minimum value of 0.60 (Enegbuma et al., 2015).

The tenacity of establishing the effect of CSFs on the CP of VM is to develop a model of CSFs and current construction practices that will help stakeholders to enhance the value of construction practices in the Nigerian construction industry. The first-order measurement model which demonstrates the strength of relationship among the constructs
of this research in Figure 3 reveals that environment (SFL), people (SFP), government (SFM) and information/methodology (SFI) are all correlated factors that constitute a scale for CSFs for information (CPA), information/function analysis (CPB), and creativity/evaluation/development/presentation (CPC) phases of the current construction practices.

Figure 3.
First-order measurement model

Notes: Fit values: $\chi^2 = 897.007, \text{df} = 602, \text{GFI} = 0.878, \text{NFI} = 0.971, \text{CFI} = 0.974, \text{RMSEA} = 0.038, \text{CMIN} = 1.490, p\text{-value} = 0.000$
This CSF scale was assessed through CFA. In refining the model, the rationality and consistency of the data with theoretical underpinnings in construction management was considered. The base limits of indices utilised as a part of measuring the GFI of the measurement model are stipulated by Awang et al. (2015), Enegbuma et al. (2015) and Hair et al. (2008) as $p < 0.05$, comparative fit index (CFI) $\geq 0.90$, GFI $\geq 0.90$, $\chi^2$/df ($\chi^2$/df) $< 5$ and root mean square error of approximation (RMSEA) $\leq 0.05–0.80$.

The statistics shown in Figure 3 discovered a $p$-value of 0.000, CFI value of 0.974, GFI, 0.878, $\chi^2$/df value of 1.49 and RMSEA value of 0.038. This indicated that the fit statistics are adequate and within the acceptable thresholds to establish the convergence validity of the measurement model for the critical SFs of VM and current construction practices. The GFI indices in Figure 3 have also confirmed the positively hypothesised covariance between the two major constructs.

SEM was used at the second stage of the model to test the relationships between the first-order constructs and the second-order constructs of the CSFs and that of current construction practices. The test of the second-order model shown in Figure 4 implies that the results of the structural model are also found to have met acceptable thresholds on all of the statistical parameters in literature for a model fit. A $p$-value of 0.000, CFI value of 0.973, GFI, 0.875, $\chi^2$/df value of 1.49 and RMSEA value of 0.038 were revealed. The tested effects of the critical SFs of VM and current construction practices in the Nigerian construction industry have been verified by the analysis of results.

Therefore, the requirements for VM implementation principally constitute the variables that were validated by the measurement and structural models of this study.
This is presented in Figure 5 as the framework for VM implementation in the Nigerian construction industry.

The framework was further positively validated by experienced construction professionals by answering the following questions:

1. Is the framework understandable?
2. Does the framework reflect the ideologies of VM?
3. Are the components (scope and requirements) of the framework consistent with the implementation needs of VM in the construction industry?
4. Are the elements of the framework well set up?
5. Can the framework serve as a guide for VM implementation to construction professionals and other stakeholders?
6. Does the framework show the process involves in carrying out a VM study?

A total of 15 participants were involved in the validation survey with a complete response rate of 86.67 per cent. In total, 69 per cent (9) of the experts had MSc/MBA degree, 15 per cent (2) had PhD, 16 per cent (2) had HND/BSC, while none had a diploma. That is to
say 100 per cent of the experts had at least a degree. In total, 31 per cent (4) of the total construction experts are quantity surveyors, 23 per cent (3) are civil engineers, 16 per cent (2) architects, 15 per cent (2) builders, and 15 per cent (2) are services engineers. Regarding the expert’s years of experience, 54 per cent (7) of the experts had 11–15 years of experience, 38 per cent (5) had more than 20 years of experience, while 8 per cent had 6–10 years of work experience. In order to determine the degree of suitability and acceptance of the framework, experts were asked of their opinions about the framework. Results from the survey revealed that, among the 13 experts, only one of the participants considered the framework incomprehensible and not well set up. In total, 92.31 per cent (12) of the participants understood the framework and accepted its set up. Therefore, the experts that participated in the survey accepted the framework and confirmed that the framework is appropriate. In addition, all the participants (100 per cent) of the survey acknowledged that the framework reflected the ideologies of VM. Similarly, 100 per cent (13) of the experts recognised that the components of the framework are consistent with the implementation needs of VM in the Nigerian construction industry. However, 92.31 per cent (12) of the experts indicated that the framework has, respectively, shown the process involved in a VM study, and can serve as a guide for VM implementation to construction professionals and stakeholders. Consequently, from the aforementioned, it can be inferred that the experts are in high agreement that the framework is appropriate and acceptable.

It is important to note that most empirical research on VM in developed and developing countries did not explore the activities and methods that constitute the practice of VM but only concentrated on factors that affected the successful application of VM. Thus, this study incorporated and evaluated the key activities of VM practice and drivers that would enhance the construction industry’s efficiency and productivity. The study contributes to the body of knowledge as it also explores the requirements that ought to be met for the successful implementation of VM in order to reduce unnecessary project costs, shorten project completion time, optimise project functions and to improve overall construction management skills.

7. Conclusion
Although the Government of Nigeria makes enormous allocations towards the construction of projects, it is still uncertain on what constitutes the SFs of some of the current construction practices. VM creates innovative and systematic ideas, reduces unnecessary costs, optimises quality and develops teamwork as a means to improve productivity. This study developed a framework for VM implementation in the Nigerian construction industry to enhance productivity of construction activities.

From the measurement and structural models, the requirements for a successful application of VM on construction practices are environment, people, government and information/Methodology. VM needs “people” since it is a proactive and creative approach. This factor consists of clients, government agencies, construction professionals, contractors and other stakeholders. The aforementioned should be focussed and must have good disposition to commitment, capability, open-mindedness, tolerance, efficiency and creativity. The “people” factor would be essential to adequately facilitate the VM methodology with the requisite knowledge and experience.

“Government” is the biggest client and investor as a large amount of capital formation goes into investments in real estate and infrastructure development. Therefore, the support and active participation of government would be vital for VM implementation on current construction practices. In addition, the ability to implement VM guidelines and roadmaps by “government” is imperative and most welcome.

The “environment” consists of the conditions and surrounding in which people operate to allow effective communication and working relationship amid the stakeholders.
Collaboration and cooperation amongst the VM team members will enhance creative and innovative solutions to prevailing problems. Therefore, the attitude of VM participants and the ability to identify, define and establish the functions and objectives of construction projects through team-oriented, structured and problem-solving approach falls under “environment” factor and would absolutely optimise the value of construction practices.

Last but not least, “Information/Methodology” is a requirement for a successful application of VM on current construction practices. Researchers are of the opinion that each stakeholder at the preparatory stage of a VM workshop should prepare background information on how the project is related to them. Information are usually deliberated through a structured, proactive and team-oriented methodology. Therefore, information must spell out the procurement approach, project timeframe, project cost and quality, project programme and environmental issues. While methodology is a process or procedure that must be executed in order to realise a project.

The aforementioned requirements are therefore recommended for decision makers and stakeholders to improve productivity of current construction practices by construction professionals in the Nigerian construction environment. Since about 35 per cent of the respondents are not familiar with VM, the following are recommended to the Nigerian government to create awareness and training for experienced industry professionals:

1. A long-term plan should accommodate dissemination of VM awareness among construction professionals and other stakeholders so as to maximise its full potential benefits.

2. The establishment of training and certification system to certify the competence of VM facilitators in order to always have satisfactory outcome of VM workshops.

3. Professional bodies should incorporate VM as part of their professional development and training criteria.

4. VM should be introduced as courses in tertiary education in order to help future and intending graduates to enhance the awareness of VM.

5. Regular VM workshops should be introduced in the construction industry as a capacity building initiative in order to make clear to construction professionals and other stakeholders on the significance of VM practice.

6. Government should introduce department of VM practice and also develop a policy of rewards and remuneration to encourage VM practitioners to share experiences and knowledge among other stakeholders in the industry.

The outcome of this study would provide opportunity for the construction industry to gain competitive advantages over other industry competitors, optimise the value and productivity of construction projects by maintaining better quality products, facilitate decision-making process, and provide the ability to obtain new knowledge and professional experiences. This study mainly considered architects, quantity surveyors, builders, civil engineers and services engineers in the construction industry. Other construction professionals were not considered, thus, the term “construction professionals” cannot be generalised. The findings of this research are pinned to the construction industry and may not be generalised to other sectors of the Nigerian economy. In addition, this study was also restricted to three major cities of northern Nigeria due to insecurity in some parts of the country. Therefore, an empirical research should be carried out in other locations, and consider other construction professionals and stakeholders in order to improve the overall performance of the construction industry.
References


Further reading


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An exploratory study on the impact of mobile ICT on productivity in construction projects

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Abstract

Purpose – The issue of low productivity has remained a very stern and chronic problem in construction projects. Previous studies have found poor communication as one of the leading causes of low-construction productivity. Recent advances in the field of information and communication technologies (ICT) have the potential to enhance communication and access to information in construction projects. However, the implications of the use of mobile ICT on construction productivity have not been investigated in sufficient depth, especially from the perspectives of its users, i.e. construction management (CM) professionals. The paper aims to discuss these issues.

Design/methodology/approach – A focus group session involving ten experienced CM professionals from different organisations of the South Australian construction industry was moderated by a group of four researchers to gather data on mobile ICT usage and its implications for construction productivity.

Findings – Lack of training and guidelines on effective applications of these technologies to construction projects is a major bottleneck. Results indicate that despite noticeable advances in mobile ICT, differences in usage style and user attitude have limited their overall impact on productivity.

Research limitations/implications – This paper is based on data gathered from CM professionals working in the South Australian construction industry.

Practical implications – The study highlights the importance of strategising the use of mobile ICT to achieve the desired productivity rates through policy, training, work-life balance, and deeper and wider understanding of these technologies.

Originality/value – The study examines the perceptions of CM professionals on the usefulness of mobile ICT in construction projects and its implications for construction productivity.

Keywords Information technology, Productivity, Construction industry, Communications, Communications technology, Mobile communications

Paper type Research paper

Introduction

The construction industry contributes significantly to both the economy and employment in various countries (Naoum, 2016). In Australia, the construction industry directly employs over one million people (around 8.9 per cent of the total workforce) and contributes 7.7 per cent to the gross domestic product (GDP) (Office of the Chief Economist, 2015). However, the construction industry’s productivity is low compared to service and other industries such as manufacturing. In a recent study on improving Australia’s global competitiveness, the consultancy firm McKinsey-Australia (2014) recommended a more focussed approach for the construction industry to improve GDP per-hour worked in Australia. The Productivity

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Commission (2015) has also noted that productivity rates in many sectors, including the construction sector, are not sufficient to sustain ongoing growth in Australia. Many construction projects suffer from time delays and cost overruns due to productivity issues. Employment of unskilled workers and slow adoption of information and communication technologies (ICT) are found to be the major reasons for such low productivity (Jarkas, 2010). Due to involvement of multiple parties in a construction project, proper communication between them is critical to its success (Cheng et al., 2001). Although recent advances in ICT in the form of mobile technologies have changed the way communication and information sharing take place in many industries (Bresnahan and Yin, 2017), there are certain characteristics that differentiate the construction industry from others. A very high ratio of turnover to profit or low-profit margins of construction organisations limit their capacity for any substantial investment on ICT. Moreover, the industry is heterogeneous, highly fragmented, geographically dispersed, labour intensive, highly regulated, and relationships in construction projects are temporary or short-term (Dainty et al., 2006).

Despite the above limitations, mobile ICT such as smartphones and tablets, mobile applications, wireless network, and cloud storage can offer an effective way to overcome the problems of collaboration in construction projects. However, unlike other industries, its use within the construction industry has not been explored in sufficient depth. Since these technologies can close the existing gaps in communication and collaboration (Anumba et al., 2012; Mathiassen and Sørensen, 2008), it is argued that leveraging these technologies to their full extent could pave a new direction in improving construction productivity. Consequently, this study aims to examine the use of mobile ICT in construction projects and its implications on construction productivity. The results are expected to shed some light on the above relationship, users’ expectations, and barriers of mobile ICT in construction projects.

**Literature review**

As quoted by Lester (2014, p. 359), “Information, together with communication, are the very lifeblood of project management”. From conception to completion of a construction project, as a means of record and communication, a large number of documents are generated and exchanged (Downey, 2006). However, the manual approaches to dealing with information often result in wasted time and increased cost in construction projects (Cervone, 2014; Mohamed and Stewart, 2003).

Based on a review of 42 articles on factors affecting construction productivity, poor communication was cited by 22 different studies (Hasan et al., 2017). Various communication issues such as misunderstanding between worker and superintendents, lack of clarity of instructions and technical specifications, low level of coordination among construction parties, delay in responding to requests for information, and slow decision making have continued to impede productivity in both developed and developing countries (Dai et al., 2009; El-Gohary and Aziz, 2013; Jarkas and Bitar, 2012). Hughes and Thorpe (2014) using a case study of Australian construction projects showed that poor communication has a moderate to strong effect on productivity.

The literature generally demonstrates that good communication and timely availability of information are prerequisites for achieving higher productivity rates in a construction project. However, Yang et al. (2007) argued that traditional ICT cannot meet the desired levels of communication and information transfer in construction projects due to their functional limitations. On the other hand, mobile ICT has the potential to significantly improve field work, on-site information management, and productivity in projects because its users can access computing and communication functionalities seamlessly, regardless of space and time (Anumba and Wang, 2012; Son et al., 2012). Mobile devices allow users to perform tasks more efficiently with greater accuracy and less management inefficiencies and thus enhance communication and collaboration (Ellis and Collins, 2015; Sattineni and Schmidt, 2015).
Mobile applications augment the capabilities of mobile devices by performing a range of different tasks (Seewald, 2014). The professional use of social media is also gaining popularity across various industries for information exchange and collaboration (Azhar and Abeln, 2014; Burke-Garcia and Scally, 2014).

Currently, with the remarkable advancements in both hardware and software, the use of mobile ICT has increased enormously in the construction industry (Sattineni and Schmidt, 2015). A questionnaire survey conducted by Atalah and Seymour (2013) in the Ohio construction industry in the USA found 72.1 per cent of respondents showed a high level of interest in tablet PCs, smartphones, and wireless hotspots. Feldman and Feldman (2013) reported that half to two-thirds of contractors and subcontractors in USA were using smartphones daily while about one in five tablets. In Saudi Arabia, Sidawi and Alsudairi (2014) found that the use of mobile ICT helps construction professionals to manage remote construction projects efficiently. Sattineni and Schmidt (2015) found that mobile devices are constantly used amongst superintendents and project managers on construction sites in the US construction industry.

From the review of the extant literature, it seems that the previous researchers have primarily focussed on the extent or type of mobile ICT being used in construction projects predominantly using quantitative research methods involving surveys. The interaction of users with these technologies and their impact on productivity has not been properly investigated. Therefore, more studies inquiring the perceptions of construction management (CM) professionals on mobile ICT could help the industry to develop strategies to overcome barriers of its adoption. Moreover, by studying the implications of the use of mobile ICT on construction productivity, new approaches to improve its effectiveness could be identified.

Research method
The choice of a particular research method is driven by research questions (Creswell, 2014). Due to the exploratory nature of this study, a qualitative research method was selected. A qualitative research approach is recommended in situations where the topic is new and key variables are unknown (Creswell, 2014; Fellows and Liu, 2015). Since this study focusses on mobile ICT from a user perspective, an in-depth investigation of its use and the relationship to productivity was undertaken through a focus group interview. Focus group interviewing is particularly suited for obtaining differing perspectives about the same topic from the people who are involved in the subject under investigation. It helps in increasing the depth of the enquiry and reveals less accessible aspects of the subject resulting from the discussion (Doody et al., 2013). The main advantage of focus groups over one-to-one interviews is the insight and data produced by the interaction between participants (Lindlof and Taylor, 2002). Collis and Hussey (2009) suggested that if the topic is of interest and relevance to the focus group participants, the members will generate relevant discussion.

In regard to the number of participants, Murray (2010) concluded that a group of five to ten participants is the most effective for exploration of a topic. Consequently, a focus group session was conducted with ten experienced CM professionals working in the South Australian construction industry. A purposive sampling technique was used to select the participants (DePoy and Gitlin, 2016). The mean age of the participants was 44 years (SD = 12.87) whereas, the mean experience was 17 years (SD = 7.73) which is considerably high and helped in achieving a rounded view about the topic under consideration. The main strength of the group was that eight out of the ten participants held a senior position in their respective companies. Hence, the participants were well experienced and capable of judging the implications of mobile ICT use on productivity. Moreover, the participants were from different sectors and had worked in different projects spanning across South Australia. Therefore, their views represented a cross-section of CM professionals working in the South Australian construction industry. Due to their long association with the industry, the participants were known to each other. Murray (2010) suggested that it is appropriate to
select participants known to each other if the topic is not sensitive to members, as this allows for the discussion to take place in a natural setting. The profile of the participants is shown in Table I.

The discussion of the focus group was recorded (with the permission of the participants), transcribed, and analysed, using code-based content analysis. Words, phrases, and sentences were used for coding the transcript. The 90 minutes session focussed on three major aspects of mobile ICT and productivity: the type and extent of mobile ICT in the South Australian construction industry; the implications of mobile ICT on construction productivity; and the limitations of mobile ICT when it is used in construction projects. The session was moderated by four researchers from two leading universities in South Australia who had a range of expertise and experience conducting research in the area of CM. The moderators assumed a neutral position towards the group members.

Findings and discussion
Any formal analysis of focus group, interview, or panel discussion should include a summary of the most important themes, the most noteworthy quotes, and any unexpected findings (Breen, 2006). The analysis led to four themes: user preference of devices and applications; implications for productivity; reflections on organisational practices and training; and health and safety considerations for users. Anonymous quotes from participants have been used here. Due to space limitations, all quotes relevant to

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an observation cannot be included. Rather, one or two as example (representative) quotes have been used. In brackets the code of the participant is shown; i.e. the code (PM2-CB) refers to a project manager 2 (PM2) from a commercial building (CB) background. Table I shows the codes of all participants.

User preference of devices and applications

Smartphones and tablets have become an integral part of day-to-day process across every business sector, and the construction sector is no different (Kidger, 2014). While CM professionals are using different kinds of mobile devices ranging from smartphones and tablets to convertible laptops in construction projects, the participants favoured the use of tablets on construction sites. It is usually more convenient to review and modify electronic documents on a tablet due to the larger display (Ballan and El-Diraby, 2011; Latham, 2014). On the other hand, the small screen size of smartphones does not fulfil the keyboard computing needs of many applications (Ellis and Collins, 2015). Consequently, the form factor of the mobile device plays an important role in deciding its suitability for a particular job. This was also confirmed by the focus group participants. The following quotes are examples that best reflect their preferences:

I rarely send an email from my smartphone if it is not concise. I (usually) send emails from my tablet (EX3-CB).

I need data connectivity from mobile and then I write emails using my laptop even when I am on the site. However, I read or receive emails on my tablet rather than on my smartphone. It is because the tablet has a bigger display and it is closer to what I always prefer i.e. a hard copy (EX1-RB).

The functionality gap between smartphone, tablet, and the laptop, necessitates the use of a combination of these devices to serve different purposes (Ellis and Collins, 2015). However, the content, hierarchy, and timing or urgency of the communication also dictate the selection of ICT use on construction sites. In addition, size and importance of a document affect the choice of the device. These convictions are reflected in the transcripts, for example:

If you are using smartphones for emails while working simultaneously in the field, there is a danger that you would send the information that you do not want to send. In the construction space, it is important that the information you are giving is correct because it can be traced back. If there is a legal aspect, do not do it on your smartphone (EX2-CB).

On site, I am using a tablet but when in the office, I use the laptop. I use my smartphone primarily to contact people. Call – Text – Email to get their attention (EX4-IP).

While the younger generation is considered to be the main users of mobile devices compared to their older counterparts, the panel argued that it is not necessarily true. Some workers are more comfortable with these technologies than others and it does not have any correlation to age. The usage also depends on other factors such as educational background, type of job, and interest in technology. Atalah and Seymour (2013) also found that technology interest and use is becoming less dependent upon age. The following quote is an example of this general observation:

We use a cloud-based project management application. If there is an instant report, one manager does straight on his/her (smart) phone and other one goes back to the office and takes a printout, fills it out, and then fills it in again on the computer. Even they are of same age, they have different backgrounds and attitudes towards technology and therefore, different ways of doing the same thing (PM2-CB).

Although it is argued that getting rid of paper can only direct the CM professionals to use these devices more efficiently, participants opined that the industry is still not ready for paperless work environment. Although Australia is considered as an advanced user of ICT and higher levels of electronic document exchange is expected, paper-based processes are
prevail at all levels in many areas of the Australian construction industry (Gajendran and Perera, 2017). This has a major limitation on mobile ICT usage on construction projects. The following example quotes illustrated these dynamics:

I cannot survive without paper drawings and a sketch book where I can draw up the details and explain how I am going to build a particular element (PM1-RB).

We are in the middle of a transition (from paper to digital). We still like to see printouts and paper (PM3-IB).

Participants confirmed that delicate nature of devices poses handling problems for the construction organisations and the users alike. Ahuja (2011) also concluded that the harsh nature and location of construction sites affect the adoption of mobile ICT in projects. While few durable and rugged devices are available in the market, they are quite expensive. The following quote is an example of this general observation:

The delicate nature of devices is a concern for site people even when it is our policy that they must have a hard cover on it (EX4-IP).

When it comes to mobile applications, it was found that a wide range of applications both in-built and custom made are used by CM professionals for various purposes. For example, weather updates help in organising and planning tasks such as concrete pours. Similarly, features like built-in cameras are used to take pictures and make videos of construction defects and work progress. The development of easy-to-use mobile application has benefitted the CM professionals in performing and completing their day-to-day work activities (Nourbakhsh et al., 2012). Yuronich (2011) also found that using built-in cameras, photos and videos from the construction site can be shared with other project team members for an informed discussion. Mobile devices can also manage different types of data and provide accessibility from any device with a cloud-based solution and internet access (Feldman and Feldman, 2013). Based on the focus group discussion, the five most commonly used mobile ICT applications are: defect management, cloud-based project management, 4D software, AutoCAD (computer-aided design) software, and built-in applications (global positioning system, weather forecast, etc.). This corresponds to Gajendran and Perera’s (2017) research which also found that construction firms in Australia use “internet” and “CAD” at high levels of usage with “cloud computing” and “building information modelling (BIM)” at lower levels of usage. It can be inferred from the current discussion that cloud services adoption is increasing in the Australian construction sector.

**Implications for productivity**

Participants agreed that mobile ICT has certainly increased the speed of information transfer and access which have resulted in faster decision making and better flow of information. Using cloud-based applications, data can be fed into mobile devices that can be later used instantaneously in the field to assess planning or design issues. As a result, accurate and timely delivery of information could prevent undesirable outcomes (Matusik and Mickel, 2011). The following quotes are examples that best reflect their experiences:

I had an inspection on my site. I got an inspection report even before I reached the office. The architect was just typing down the report as he was walking around (on site). Less downtime between inspection and receiving the report increases your speed of construction (PM1-RB).

It is also true that for a Supervisor, the information is readily available to make an informed decision rather than a judgement call (SS-IP).

The participants also opined that the use of these technologies has improved construction quality due to better reporting and less rework. By allowing seamless and effective
transmission of information, it also eliminates the kinds of errors and delays that are inherent in manual approaches (Son et al., 2012). It was highlighted that the use of mobile ICT has resulted in better contract management in construction projects. The following example illustrates this:

I have seen some contracts in which if things get delayed, you get 24 hours to give notice for that. So, you can take a photo (using your smartphone), and include other information and send it to the Superintendent highlighting potential delays or cost adjustments (EX2-CB).

Although mobile ICT has potential to improve productivity in construction projects, the actual change in productivity rates is largely dependent on the ways in which these technologies are adopted (Fulford and Standing, 2014). Participants argued that the continuous flow of information at an incredible pace can be problematic sometimes. The following quotes are examples of their feelings:

Within one hour, the architect can completely change the document on the cloud. The real challenge is that how do you get that information to the guy at the front line and it influences the productivity rates in your project (PM2-CB).

A negative thing of mobile ICT is the architect’s tendency to change drawings at the drop of a hat. Massive information flow is happening and it is not always a positive thing (PM1-RB).

Participants suggested that more frequent usage of these technologies could be counter-productive. Previous studies have also found that the reduced cost of communication can increase the number of interactions and time required to process them exponentially, thus resulting in more unproductive work (Bertschek and Niebel, 2016; Mankins, 2016). Moreover, temptation to check emails can cause a lot of distraction on sites. Some example quotes are given below:

Sometimes you find that irrelevant emails and unnecessary information just drag you along and make you less productive (PM4-IP).

Non-uniformity in sending and responding to information sometimes bring many people into the decision-making process even when they are not needed to be involved and this may cause a real productivity problem (PM1-RB).

Reflections on organisational practices and training

When asked about the organisational policy on mobile ICT, it was found that majority of organisations provide smartphones and tablets to CM professionals. The focus group findings confirmed that cost is not a barrier for introducing mobile ICT in construction projects, especially in developed countries such as Australia. Previous findings also indicate an increase in investment and use of ICT by construction firms (Rezgui and Miles, 2010). However, participants disclosed that data security is still a big concern for construction organisations. While most of the large construction companies have a dedicated IT department to monitor and regulate mobile ICT use, small and medium sized enterprises usually do not have a detailed policy framework. Consequently, CM professionals can use these devices for both personal and professional purposes which may lead to loss or misuse of confidential data and other security implications. Previous researchers have also identified some major risks, such as malware infection, copyright violation, reduced privacy and confidentiality, legal issues, user resistance, and misuse associated with the implementation of these communication tools in an organisational context (Turban et al., 2011; Väyrynen et al., 2013). According to the focus group participants, many organisations in South Australia are now using their own (internal) servers to reduce these potential threats by exercising more control on information flow.

It was also evident from the discussion that the implications of using social media by firms for organisational processes are not yet well-understood. It seems that social media
applications are only used on construction sites to facilitate information searches to locate suppliers or find other local information. However, the potential of enterprise social networks in information dissemination and sharing, communication, collaboration, knowledge management, and training cannot be simply overlooked (Epstein et al., 2014; Noorden, 2014). Furthermore, improper training or lack of awareness regarding mobile ICT usage can also create interpersonal issues and conflicts among the project team members. Also, the aspect of worker inclusivity was also raised in the focus group discussion. Few responses are given below to represent the views of the participants:

Unlike an email, sometimes the use of language is not very courteous in text messages. It can create problems while working with people from different cultures due to cultural sensitivities (EX3-CB).

Mobile ICT can empower people more than the process, so it can be more of an inclusivity tool so that nothing is missed out (EX4-IP).

Participants confirmed that training CM professionals to make the best use of mobile ICT and as a result, improve productivity has remained a challenge for many organisations. Considering the familiarity and user-friendliness of mobile ICT, the training needs are often ignored (Erdogan et al., 2009). Moreover, participants argued that it is getting more difficult to keep track of new technologies due to constant innovations in this area. The following example illustrates this need:

I would like to see more practical training for industry professionals as many people do not know a lot of stuff that could be done using these technologies. It is mainly about lack of product awareness (EX2-CB).

Health and safety considerations for users
Participants emphasised the safety challenges related with the use of mobile ICT on construction sites. The following quote illustrates this:

Safety is a real challenge when you are too immersed in these technologies. There have been a heap of slips and trips due to these mobile devices on my site (PM2-CB).

In addition to safety, participants raised serious concerns over the negative impacts of mobile ICT on the health and well-being of CM professionals. Although mobile ICT offers flexibility to work from anywhere, it has reduced personal autonomy of the users and their ability to disconnect from work (Mazmanian et al., 2013). These findings were confirmed by focus group participants. The following quotes best reflect their feelings:

Checking your phone and emails all the time even when you are watching a TV programme with your kids has become a norm these days. Sometimes you pull the laptop out and start working out on a query and then you are there for another two hours even on a holiday (SE-CB).

Most of us have email accounts on our smartphones. If I do not answer an email/call instantly, I have to answer many when I get back to work (PM4-IP).

Having a phone somehow puts a compulsion to remain accessible because if the phone rings, you have to answer. You can never really break from this information flow (PM1-RB).

Consequently, users experience a huge pressure to make themselves accessible and responsive even during non-work hours (Matusik and Mickel, 2011). Moreover, the increased use of mobile ICT and more demands on employees’ time and attention could create conflicts in their personal lives.

Implications of the study
This study provides certain measures that the construction companies could implement to improve construction professionals’ use of mobile ICT and its implications on productivity.
These measures include but are not limited to recognising the suitability of various devices in different context, understanding both positive and negative implications of these technologies on productivity, developing innovative solutions to address health, safety, and security risks, and focussing on training.

While smartphones provide maximum mobility, it was found that their small screen size and data input restrictions are still a major limitation for construction applications. Consequently, the use of tablets and convertible laptops is expected to gain more popularity in the construction space. It is recommended that the organisations should invest in different mobile devices to address the specific needs of CM professionals rather than adopting one device for all purposes. This study also revealed that the extent of usage of mobile ICT is not age-dependent as widely perceived. It is usually governed by both job requirement and personal attributes such as educational background and interest in technology. Consequently, organisations can motivate old or mature age CM professionals, who were not exposed to this kind of technology earlier, with the help of training and incentives.

Due to lack of training, CM professionals have continued to use mobile ICT in their own style without much strategic consideration on productivity. Since these technologies have both positive and negative effects on productivity, it is recommended that the training programs intended for CM professionals should substantially be revised to include information on mobile ICT and their applications in construction projects. It was also found that within the construction industry context, social media applications are not efficiently utilised. Nonetheless, the findings revealed that positive effects of mobile ICT on construction productivity due to better flow of information across the supply chain, timely access to data, improved quality, less rework, and effective contract management are enormous. However, the negative impacts of these technologies on CM professionals’ health, personal relationships, and work-life balance should not be overlooked and thereby, need due consideration.

Finally, it seems that most of the participants’ construction organisations had no policy framework or detailed guidelines to regulate the use of mobile ICT on sites. The lack of awareness on mitigating safety and security risks was quite evident. It needs to be recognised that the personal use of the internet that may take place whilst at work is not only counter-productive, but may also present significant safety challenges on construction sites. These findings could inform future revisions of the industry guidelines or code of practices that promote safe work on construction sites. For example, some guidelines to educate the users of mobile ICT could potentially reduce the incidents of slips, trips, collisions or other movement disturbances that usually happen when CM professionals are too immersed into these technologies.

Conclusions

Given current trends to increase the use of mobile ICT on construction sites, research into the implications of these technologies on productivity is highly warranted. While the previous studies have mainly adopted quantitative methods to investigate the diffusion of mobile ICT in the construction industry, the aim of this study was to examine the use of mobile ICT and perceptions of CM professionals on its impact on productivity. Using a focus group discussion, this research explored the uses and preference of mobile ICT along with its perceived impact on productivity and shortcomings. Furthermore, the implications of this study for practice were drawn from the findings. The study also uncovered some issues that require further investigation and thereby, may form important areas of further research in this domain. For instance, more studies to strategise the use of mobile ICT are needed to identify the health, safety, and training challenges from both user and organisational perspectives.

It can be concluded that the true potential of mobile ICT on construction productivity is yet to be realised in construction projects. The construction organisations need to embrace these technologies as opportunities by strategising their use in construction projects with
the help of proper policy and guidelines, employee training, and deeper and wider understanding of their functionalities. Since these technologies have both positive and negative implications on productivity, practitioners and future researchers need to devise innovative measures to address various issues highlighted in this research.

The findings of this study must be considered within the context of its limitations. As a focus group study, the inherent limitations of this methodology, such as the interdependence of participants’ responses, facilitator bias through in-session behaviours and communication strategies, and the limited ability to examine the validity of the study, also apply to this research (Pierry and Nickerson, 1996). In addition, the data for this qualitative study was gathered only from CM professionals working in the South Australian construction industry and therefore, cannot be necessarily generalised to other contexts. However, despite these limitations, the findings enrich our current understanding of how CM professionals use mobile ICT and its perceived impact on construction productivity. The high quality of participants involved in this study, as discussed under methodology, provides valuable insights which otherwise cannot be obtained through any other research design. These insights can inform future qualitative and quantitative research in this area.

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Impact of mobile ICT on productivity


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