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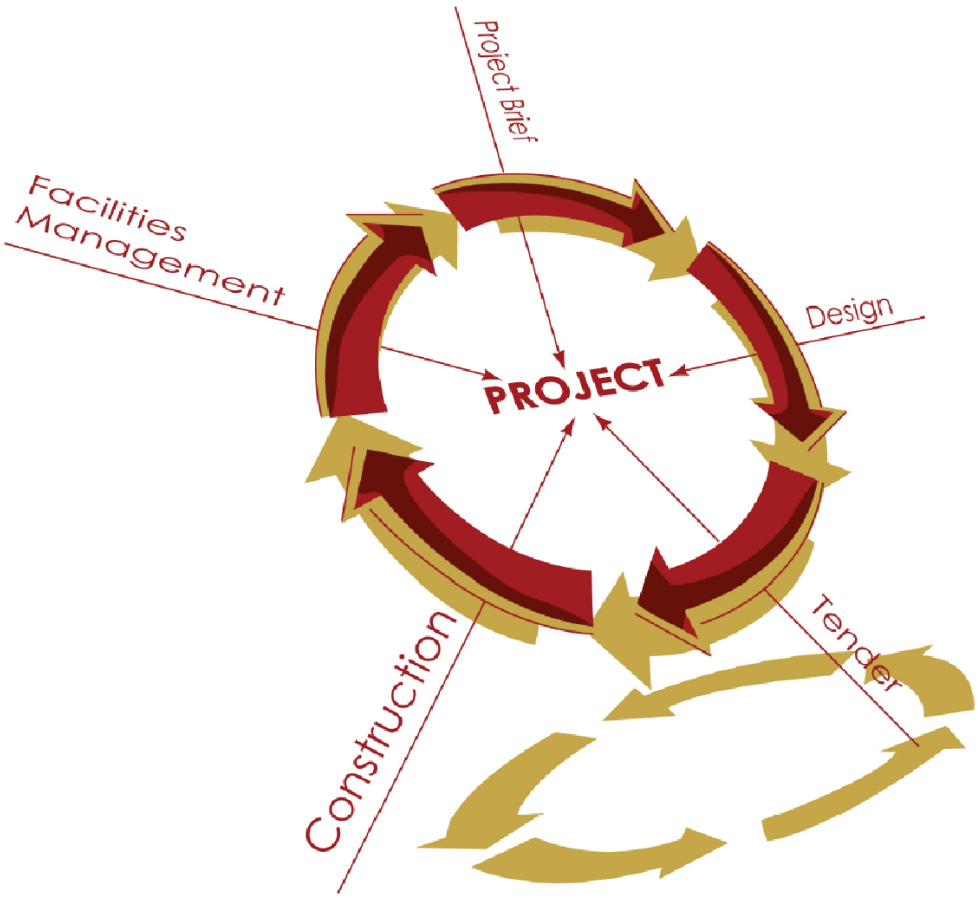
DRIVING THE CONSTRUCTION INDUSTRY TOWARDS PRODUCTIVITY EXCELLENCE



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Introduction

Welcome to this special issue in Malaysian Construction Research Journal (MCRJ), initiated by Construction Industry Development Board (CIDB) and Construction Research Institute of Malaysia (CREAM) with the selected theme: “Driving the Construction Industry towards Productivity Excellence”. Researchers and professionals from universities, R&D centres, businesses, and government sectors were invited to share research findings on any topic related to sustainable construction for this Special Issue. Both original research papers and review papers are welcome. All the submissions have gone through a peer review process before publication.

This special issue elucidates the potential of offsite manufacturing or Industrialised Building System (IBS), a well-known term used in Malaysia, in promoting excellence in productivity. This special issue complements to the lastest research conducted by CIDB and CREAM in developing a Productivity Measuring Tool (PMT) which aims to measure and monitor the productivity of building construction projects in Malaysia. One of the objectives of the development of PMT is to identify the productivity difference between conventional method of construction and modern methods of construction such as IBS.

In this Special Issue, the subtopics include but are not limited to the following:

- Productivity
- Construction productivity
- Productivity measuring tool
- Construction technology
- Offsite manufacturing
- Industrialised building system
- Building information modelling
- Digitalisation
- Mechanisation, industrialisation and automation
- Robotics technologies
- Green construction projects
- Digitalisation
- Mechanisation, industrialisation and automation

We believe that this particular topic will become a compilation of reference works on productivity strategies that will help to drive the construction industry towards productivity excellence.

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Editorial

Welcome from the Editors

Welcome to this special issue in Malaysian Construction Research Journal (MCRJ), hosted by the School of Civil Engineering, Universiti Sains Malaysia. We would like to express our sincere gratitude to our contributing authors, reviewers, organizers and readers.

This special issue in MCRJ contains sevent (7) interesting papers covering the theme of "Driving the Construction Industry towards Productivity Excellence". It is hoped that the readers would greatly benefit from the scientific content and quality of papers published in this issue:

Brief introduction of each article is given as hereunder:

Noor Aisyah Asyikin Mahat et al., analysed issues in green construction productivity performance. Eighteen (18) factors was identified through literature review on the issues. Quantitative method was used in this study to evaluate the ranking of each factors for 400 respondents. Relative Importance Index Technique (RII) was used to rank the importance of the factors. The finding shows that the critical issues are High initial cost of Green Construction Projects (GCP) and lead to the issues of cost performance, unfamiliarity with green construction technology henceforth give effects to schedule delivery, The complexity of GCP delivery system, Issues on availability of material, expertise, and technological requirement and Higher construction standards and additional site precautions which may affect the quality performance of GCP.

Afifuddin Husairi Hussain et al., assessed the organisations decision for digital transformation through Building Information Modelling (BIM) implementation in Malaysia. Qualitative methods using semi-structured face to face interview were employed with 15 Malaysian Housing Developers. Five (5) digital transformation key strategies are outlined which are People, Organizational Synergy, Work Process, Environment and Resources. Recommendation for future research also suggested in this study which is to have design and longitudinal studies to track the organization's adoption progress at two points in time.

Sharifah Akmam Syed Zakaria characterised the productivity aspects in building projects based on the adoption of Industrialised Building System (IBS).The factors is divided into six (6) characterisation which are financial, manpower, machine, materials, time and information. Quantitative method was utilised in this study using survey questionnaire involving distribution to 300 respondents. The findings show that the main factors contributing to the productivity of IBS is Time followed by machines, financial, information, manpower and materials. It is suggested in this study will improve overall project quality and the improvement of construction projects.

Rohana Mahbub developed a broad base perspective on productivity improvement through the use of automation and robotics technologies; focussing on automation of design, planning and costing; the application of off-site automation and robotics technologies through IBS and prefabrication; and the use of task-specific, dedicated machines in specialized on-site construction work. The findings indicated that the perceived productivity improvement in terms of time reduction, cost savings, higher quality products and process efficiency improvement in design, planning and costing is higher compared to other areas under investigation.

Intan Diyana Musa et al., compared the productivity performance of building construction projects between conventional and Industrialised Building System (IBS) using Productivity Measuring Tool (PMT). The comparison is divided into two (2) stages which are overall work satges and construction work stages. Overall work stages involving design, production, logistics, installation and construction stages, while the construction works stages involving installation and construction stages. The building system in this study involves precats concrete, metal framing, reusable formwork, blockwork, timber framing, innovative and conventional. Overall, the findings show that the IBS projects has increased productivity as compared with conventional projects.

Maria Zura Mohd Zain et al., measured the productive and efficient construction public housing projects using Industrialised Building System (IBS). The methodology in this study involving six (6) case studies conducted on the public housing in Klang Valley. It is shown that the IBS projects have higher productivity rate as 12.7 sqft/man-day as compared to the conventional projects. challenges and current issues has been discussed in the Focus Group Discussion (FGD) and identify that the emerging application of technologies, especially Building Information Modelling (BIM) become the main support for effectiveness of IBS projects.

Mohmd Sarireh studied the productivity of construction works for residential buildings and projects in Jordan. Data collection in this study collected from Southern Jordan: Karak and Tafila areas, and from Northern Jordan: East and West of Amman, and Zarqa from project and residential building construction. T-test for independent samples was used to compare the means. It is concluded that there is no significance difference between means of productivity in areas (Karak and Tafila) and in (East and West Amman and Zarqa).it is also indicates that there is no significant difference between means of productivity of Southern and Northern Jordan regions.

ANALYSING ISSUES IN GREEN CONSTRUCTION PRODUCTIVITY PERFORMANCE

Noor Aisyah Asyikin Mahat, Hamimah Adnan and Norazian Mohammad Yusuwan
Centre of Studies for Quantity Surveying, Faculty of Architecture, Planning, and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.

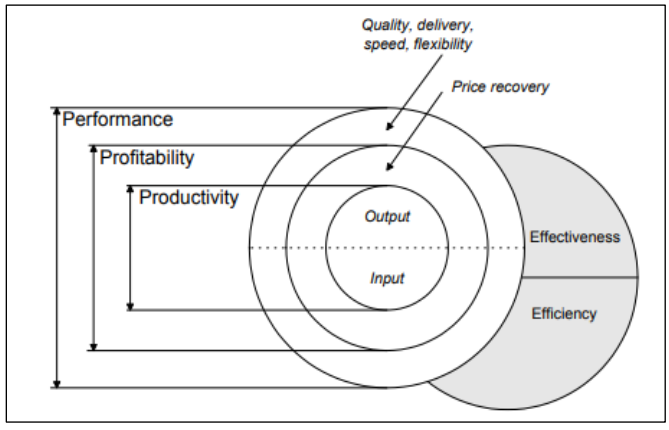
Abstract
Productivity is one of the most widely debated issues in the construction industry due to its essential to the success of most construction projects. Previous researchers have determined different factors that influence construction productivity in conventional construction projects, but yet, there is limited research on productivity particularly in Green Construction Projects (GCP). GCP is more complicated than traditional buildings because its integrate more technology and materials that have a lower impact on the environment. Furthermore, various prerequisites for obtaining a green certificate, as well as the shareholders' lack of acquaintance with the requirements and technologies tend to lead to cost overruns, project delays, and productivity losses. This research addressing the emerging issues influencing GCP that may affect the productivity and the overall performance of the construction projects. Eighteen (18) factors were identified through an extensive literature review. These factors were evaluated by the survey respondents based on their impact and frequency. The respondent was selected based on their affiliation as a green construction practitioner and the list are extracted from the Green Building Index (GBI) website, CIDB Directory of Construction also from the previous completed GCP. Four hundred (400) set of questionnaires were distributed, however, only 128 sets of data were collected and analyzed using statistical techniques such as Relative Importance Index (RII) and Frequency Index (FI) approach. The findings show that the most critical issues were 1) High initial cost of GCP and lead to the issues of cost performance 2) Unfamiliarity with green construction technology henceforth give effects to schedule delivery 3) The complexity of GCP delivery system 4) Issues on availability of material, expertise, and technological requirement 5) Higher construction standards and additional site precautions which may affect the quality performance of GCP. The results of this study can assist construction practitioners to make specific modifications to the project management processes and practices achieving a more productive toward successful delivery of GCP.

Keywords: *Productivity; Construction Productivity; Green Construction Projects.*

INTRODUCTION

The construction industry plays a significant role in economic development, especially for developing nations. It creates new career opportunities and provides solutions to social, environmental, and energy challenges. It has a direct connection with other sectors and, consequently, has a major impact on the Gross Domestic Product (GDP) and economic development.

"Productivity" is often used as a performance indicator in construction projects, also to evaluate the effectiveness of a building project performance. In the construction industry, productivity is a certain set of resources (input), therefore, the amount of goods or services is the output produced by them. Page et al. (2014), stating that "productivity measures how efficiently inputs are used to produce outputs" whereas "performance measures how well something achieves its intended purpose." Performance is a term that includes almost any objective of competition and manufacturing excellence such as cost, flexibility, speed, dependability, and quality. The relationship between productivity and performance terms has been discussed by (Tangen, 2005) in his research by producing the Triple P-Model (Figure 1).



(Source: Tangen, 2005)

Figure 1. The Triple-P Model

The model is based on the terminology descriptions in the previous sections and explains how they are related to each other. Based on the Triple-P model, the relationship between productivity and performance is closely related, thus, it is vital to identify the factors that contribute to the productivity that affects project performance.

Considering the importance of productivity, this research focuses on the topic of productivity in the Malaysia construction industry. Conferring to Construction Industry Transformation Programme (CITP) 2016 – 2020 (CIDB 2016), under strategic thrust number three, it is highlighted that productivity is the primary engine of growth towards Malaysia's high-income target. The construction industry, as a crucial sector for the nation's advancement, will lead with high productivity levels through the effective adoption of new technology and modern techniques, as well as a highly-skilled and well-paid workforce. In addition to the aforementioned national agenda, this research is converging the productivity in green construction projects (GCP). This is to anticipate with the target goal in Green Technology Master Plan (2017 – 2030), whereby the numbers of Green Buildings Projects will be increased by 1750 number by the year 2030, inclusive of green buildings certified by various agencies and organizations such as Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST), Green Building Index, Green RE, etc.

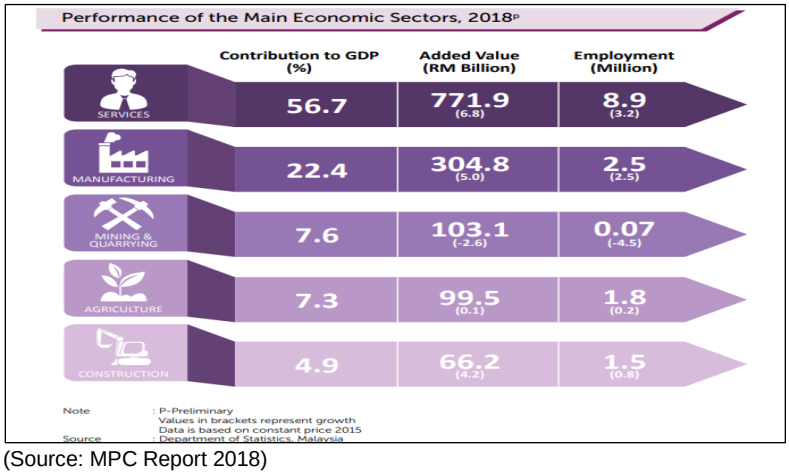
CONSTRUCTION PRODUCTIVITY

The construction industry plays a critical role in national development. Its level of productivity has a substantial impact on the country's economic growth and contributes to Gross Domestic Product (GDP)'s growth as an indicator of sustainable economic and development in the country. Under the Construction Industry Transformation Programme (CITP) 2016 – 2020, the Government of Malaysia has placed productivity as top priority in the agenda. The CITP aims to empower and strengthen the construction industry, and the productivity must be underpinned by the drivers of the workforce, technology, and processes (CITP, 2016).

There are two types of productivity issues: macro and micro. Contracting methods, labor regulations, and labor organization are dealt with at the macro level; administration and execution of a project, mostly at the job site, are dealt with at the micro-level (Dozzi, 1993).

The term 'productivity' is generally defined as the maximization of output while optimizing input (Naoum, 2016; Durdyev et al., 2018). Henceforth, it is known as a measure of the ratio between an output value and an input value used to produce the output. The output consists of products or services and input consists of materials, labor, capital and energy (Durdyev et al., 2018; Jarkas et al., 2013; Yi and Chan, 2014; Dixit et al., 2017; Alaghbari et al., 2019; Dixit et al., 2019).

According to Yi and Chan (2014), the project-based nature of research on construction productivity concerns three levels: (1) Task/activity, (2) project, and (3) industry, with the corresponding factors of production (inputs) required to generate that output. The output and inputs of production thus constitute the basic components of every productivity measure. Specific construction activities, such as concrete laying or structural steel erection, are referred to as tasks. Projects are a collection of tasks that must be completed to develop a new facility or renovation (i.e., additions, alterations, and major replacements) of an existing constructed facility. Studies at the industry level focused on productivity measurement and long-term productivity trends.



(Source: MPC Report 2018)

Figure 2. Performance of Main Economic Sectors (2018)

In Malaysia, the productivity of construction industry measures is based on the productivity performance report done by Malaysia Productivity Corporation (MPC) and represents the total portfolio of projects. According to MPC Report 2018, the construction sector has contributed 4.9% to GDP amounting to RM66.2 billion. While comparing with other main sectors (Figure 2), the construction sector had the lowest productivity level, hence it still demonstrated significant growth. Because of its low productivity level, industries in this sector must be more proactive, and construction productivity needs to improve.

To improve construction productivity, a lot of research relating to construction productivity has been done. According to recent research done by S. Dixit et al. (2018), common studies in construction productivity are focused on seven main areas, which are studies to identify the issues and challenges in construction productivity, measurement techniques for construction productivity, factors affecting construction productivity, use of equipment, and technology in the advancement of construction productivity, developed models, studies at industry level, and framework to improve construction productivity.

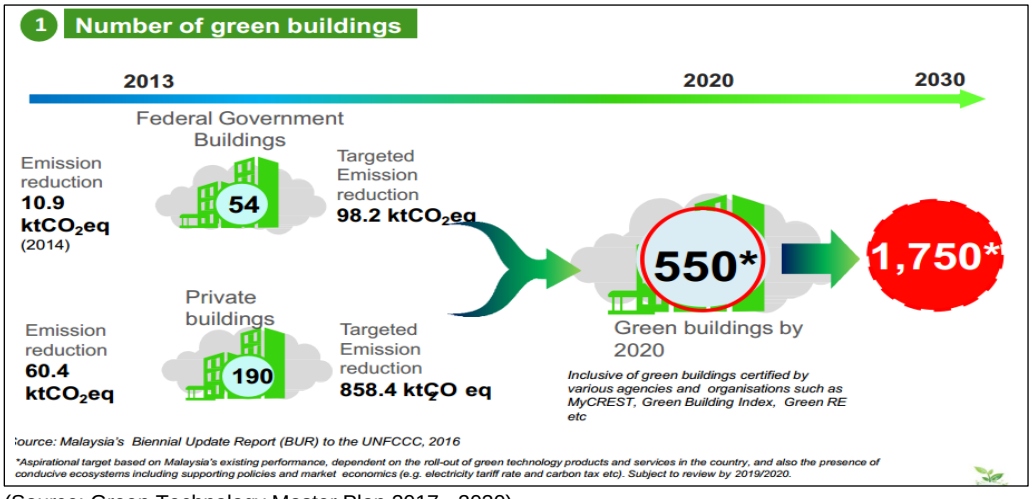
GREEN CONSTRUCTION IN MALAYSIAN CONSTRUCTION INDUSTRY

The construction of green buildings is part of sustainable construction. Sustainable construction is applied throughout the entire life cycle of construction, from pre-construction to disposal of the building. Such construction aimed to reduce the impact of the construction practice on the environment through its planning and managing of a construction project complying with the contract document (Glavinich, 2008). To implement the sustainable development's goals in the Malaysia construction industry, the government introduced the concept of green building. Green building has an important role to play in achieving its aim of sustainable development in protecting the environment and improving the quality of human life. Green building definition encompasses more broadly a building planned, constructed, operating, preserved or reused to preserve occupying wellbeing, enhance employee morale, utilise natural capital wisely, and reduce the effects on the ecosystem (Chandra, 2018). Other researchers define green building refers to the act of developing, constructing, and building structures, and utilizing a procedure that is environmental and resource-efficient in various construction activities (Kamarudin et al., 2011). Therefore, green building is known as sustainable building (Hwang et al., 2012); (Samari et al., 2013) or "high performance" building (Howe, 2010).

Driving toward sustainable development across the country, Malaysia is amid a robust increase in the level of green activities driven by Green Technology Masterplan (2017 – 2030) and several green initiatives (CIDB, 2016). To implement the sustainable development's goals in the Malaysian construction industry, the government has planned to implement sustainable building and infrastructure development in Malaysia, by establishing policies and strategic planning to support the industry moving towards sustainable construction (CIDB, 2009); (EPU, 2014); (CIDB, 2015). Since 2006, Malaysia has progressively advanced the delivery of green building projects. It has high ambitions to increase the delivery of green building projects to meet some ambitious targets in the areas of energy productivity, financial savings on resource consumption and zero-carbon building. CITP 2016 – 2020 is aimed at transforming Malaysia's sustainable infrastructure to be a model for the emerging world, with 100 percent of all large infrastructure and building projects exceeding sustainability requirements and a reduction of four tonnes of carbon dioxide equivalent per year. The adoption of green building design is largely reflected in the number of buildings (new and retrofitted) that have been certified to green building rating tools such as MyCREST, GBI, and GreenRE, among others. Some of the rating tools are integrated to also measure socio, economic, and environmental parameters (Hamid et al., 2014).

As reported in Green Building Index (GBI), as of July 2019, there is 507 numbers of GBI-certified green building projects in Malaysia. As the target goal in Green Technology Master Plan (GTMP) (2017 – 2030) numbers will be increased by 550 number of green buildings by 2020 and the number continue to increase by 1750 by the year 2030, inclusive of green buildings certified by various agencies and organisations such as MyCREST, Green Building Index, Green RE etc. As a massive number of the targeted green building project in the future (see Figure 3), construction productivity can be a basic and determining factor to secure the achievement of this target. However, the slow growth of productivity of the construction industry of Malaysia poses a great question mark to the achievement of this target. The labor productivity, which is a crucial productivity index, of the Malaysia construction industry had been continuing declined from 12.4% in 2016 to – 7.3% in 2019. The growth rate of

commercial buildings is in the range of 3-6% depending on the building typology. The building/construction industry forecast beyond a 5 – 7 year period is difficult to obtain because it is highly dependent on the economic outlook of the country.



(Source: Green Technology Master Plan 2017 - 2030)

Figure 3. Target Number of Green Building

GREEN CONSTRUCTION PRODUCTIVITY

According to M.I Haloul (2016), green development in Malaysia is still new, and researching how these components would contribute towards green development achievement is extremely significant. Henceforth, understanding these variables and uniting all the key components towards green development is critical. Particular attention should be paid to the fact that, given the influence of the mandate in the GTMP, environmental regulations are the driving force for green adoption (Dodge Data & Analytics, 2016). In Malaysia construction industry context, the alignment between the aspects of construction project productivity and sustainability is still very rare and there is almost no attention for the integration of productivity in green construction projects (Mahat et al., 2019). Based on the previous research (2009 – 2018), it is shown that most of the researchers are studies on the Productivity in Construction Industry in Malaysia are limited to the conventional building (Chia et al. (2012);(2014); Ismail et al. (2012); Hamza et al. (2019); Ohueri et al. (2018); Durdyev et al. (2016); Waris et al. (2016); Karim et al. (2012); Abdul Kadir et al. (2005); Rashid et al. (1997)). The limited references make it challenging for the stakeholders to put together holistic strategies for productivity improvement to endeavor sustainable construction development. These matters critically need to be resolved since the government of Malaysia has planned to implement sustainable building and infrastructure development by establishing policies and strategic planning to support the industry moving towards sustainable construction.

Emerging Issues and Problems in Green Construction Productivity

As discussed previously, Malaysia aims to green at least 1750 numbers of green buildings in Malaysia by 2030. Construction productivity can be a significant and determining factor in achieving this target goal. However, the declining productivity in the construction industry poses a great question mark to the achievement of this target. Based on previous studies, issues

and problems in adopting green construction in Malaysia construction industry that relate to the following issues of productivity performance were identified through extensive literature review. From the study, different issues and problems related to GCP performance are found. The finding was categorized according to the issues that affect the GCP performance. This is because the performance of the project has a strong relationship to productivity (Tangen (2005) & Hwang (2017). Table 1 signifies the previous issues found in the literature review that relates to Green Construction Productivity Performance.

Table 1. A Literature Review on Emerging Issues and Problems in Green Construction Project Construction Project

	Issues & Problems in Green Construction Projects Performance Affects Productivity	References
Issues On Schedule Performance		
SP1	The project delivery of Green Building projects is very complex, and negatively affects the schedule performance of Green Building projects	Hwang et al. (2017); Jarkas (2010), Durdyev et al. (2019); Doloi et al. (2012); Dai et al. (2009); Dainty et al. (2005); Bernold and AbouRizk (2010); Ghoddousi and Hosseini (2012) and Abdul Kadir et al. (2005); Hassan et al. (2017)
SP2	The high number of variation orders and changes to design caused by many requirements to achieve a green certificate is another hindrance effect the schedule performance.	Hwang and Ng (2013); Pham et al. (2019); Lam et al. (2010)
SP3	The unfamiliarity with green technologies leading to technical difficulties during a construction process gives effect to schedule delivery.	Hwang et al. (2017); Jarkas (2010); Durdyev et al. (2019); Doloi et al. (2012); Eisenberg et al. (2002); Tagaza and Wilson (2004)
SP4	The special design factors in green construction projects need to be considered early in the design stage, which affects the quality and project delivery method.	Chan et al. (2009); Robichaud and Anantatmula (2011)
SP5	The approvals process for new green technologies and recycled materials can take a long time because designers are expected to need more time for approval.	Hwang et al. (2012); (Tagaza and Wilson, 2004).
SP6	Workers may tend to waive time-consuming for sustainable practices and project managers will need additional time to conduct checks and on-site visits to guarantee that sustainable practices are followed.	Tagaza and Wilson, 2004).
Issues on Cost Performance		
CP1	Green Building projects encompass additional material, expertise, technological and other requirements, and greatly give effects to cost performance.	Hwang et al. (2017); Zhang et al. (2011); Ling (2003)
CP2	Low delivery performance in Green Building projects due to process inefficiencies (waste) and increased costs of Green Building projects	Zhang et al. (2019)
CP3	The high initial cost was indicated as the greatest obstacle to the development of green buildings and give effects to cost performance	Hwang et al. (2017); Jarkas (2010); Durdyev et al. (2019); Doloi et al. (2012); Dai et al. (2009); Tagaza et al. (2004)
CP4	The high number of variation orders and changes to design caused by many requirements to achieve a green certificate is another hindrance that affects the cost performance	Hwang and Ng (2013); Pham et al. (2019); Lam et al. (2010)
CP5	Require a larger financial resource for GB projects and lack of financing schemes (e.g., bank loans, surety bonds)	Li et al. (2011); Lam et al. (2010); Pham et al. (2019); Quangdung et al. (2019)

	Issues & Problems in Green Construction Projects Performance Affects Productivity	References
Issues on Quality Performance		
QP1	The delivery of Green Building projects often requires additional project players, more design iterations, advanced simulation and analysis, higher construction standards, and additional site precautions give effects on quality performance	Hwang et al. (2017); Hanafi et al. (2010); Durdyev et al. (2018); Bernold and AbouRizk (2010); and Abdul Kadir et al. (2005)
QP2	Issues of quality and level of sustainability also pervaded with low performance in Green Building	Li et al. (2011); Lam et al. (2010); Nguyen et al. (2017)
QP3	The special design factors in green construction projects need to be considered early in the design stage, which affects the quality and project delivery method	Hwang and Ng (2013); Hwang and Tan (2012); Pham et al. (2019); Nguyen et al. (2017)
QP4	Low integration and involvement of contractors affect unfamiliarity of design and green technology adoption gives effect to schedule and quality performance	Nguyen et al. (2017); Hwang and Ng (2013)
QP5	Uncertainty in the performance of green materials and equipment affects the quality performance of green building projects	Qian et al. (2013); Hwang and Ng (2013); Pham et al. (2019); Quangdung et al. (2019)
QP6	Imperfect green technological specifications and restrictions of new green productions and technologies	Qian et al. (2013); Robichaud and Anantatmula (2010); Zhang et al. (2019); Hwang and Ng (2013)
QP7	Difficult in controlling and inspecting the quality of materials, equipment, structural components	Nguyen et al. (2017); Hwang and Ng (2013); Pham et al. (2019)

RESEARCH METHODOLOGY

This research carried out an extensive literature review from multiple sources, such as "Green Construction" and "Construction Productivity" websites, reports from public and private institutions, articles and journal papers, to provide a better understanding of the construction productivity as well as green construction development in Malaysia construction industry. After doing a literature assessment of all research work related to construction productivity and project performance, variables/attributes determining construction productivity are identified (see Table 1). Following that, a comprehensive list of the attributes discovered through the literature review was designed, and a survey questionnaire was subsequently developed to capture the emerging issues and problems in Green Construction productivity. The collected data were analysed by the Statistic Package for Social Science (SPSS) version 26 statistical software.

The survey was distributed to the respondents based on their affiliation as a green construction practitioner and the list are extracted from the Green Building Index (GBI) website, CIDB Directory of Construction also from the previous completed GCP. The respondent is namely Project Director, Project Manager, Project Executives, Consultants, Contractors also others (specialist consultants). All the questionnaires were sent out to the respondents manually and through e-mail. The questionnaire's topics on construction productivity, directing on GCP were obtained from reviews of the literature, resulting in the development of a two-sections questionnaire. Section one on the respondent's profile obtained personal information on existing designation, years of experience in Construction Industry and GCP. In Section two, the respondents were asked to rate the criticality issues and problems in GCP toward construction productivity. The respondents were asked to rank the attributes on five points Likert scale on the basis of how much the issues affect the productivity level. The

points on the Likert scale (1 = not critical, 2 = less critical, 3 = critical, 4 = very critical, and 5 = Extremely critical and affect project productivity).

Data Analysis Approaches (Relative Importance Index Technique)

Relative Importance Index Technique (RII) is a statistical method that determines more precisely the relative weight of each variable among total variables. According to (Aibinu & Jagboro, 2002), the RII approach is used to describe the relative importance of the specific causes and effects based on the likelihood of occurrence and effect on the project using the Likert scale of five scales. In addition, the higher value of the index of relative importance (RII) is the critical cause or impact component and is determined by Equation (1).

$$RII\ (\%) = \frac{\sum I}{(A*N)} \times 100 \quad (1)$$

where,

I = weight given to importance by the respondent (1 to 5);
F = weight given to frequency by the respondents (1 to 5);
A = the highest weight (in this case is 5);
N = the total number of respondents.

The value of the RII ranges from zero to one, where a higher value indicates that the attribute is more significant compared to others. In addition, the Frequency Adjusted Importance Index (FAII) was also computed to rank the productivity-influencing factors, considering the frequency of occurrence based on the respondents' views. In order to calculate FAII, the relative importance index (RII) and the frequency index (FI) are estimated at the beginning using the following equations (2).

$$FI\ (\%) = \frac{\sum F}{A(N)} \times 100 \quad (2)$$

FAII provides better ranking results since it reflects the effects of importance and frequency altogether. This way, the effect of each factor on GCP productivity is estimated more realistically. Using Equations (1) and (2), the frequency adjusted importance index will be calculated according to Equation (3).

$$FAII(\%) = (RII(\%) \times FI\%) /100 \quad (3)$$

For this research, a total of 400 sets of questionnaires were sent out and 128 (19.5%) questionnaires were received. Present built-environment survey response, rates range from 7% to 40%, in general (Moyo & Crafford, 2010), therefore the received survey response (32%) is accepted.

RESULT ANALYSIS & FINDINGS

Quantitative approach was used for analysing research data via SPSS version 26. Cronbach's Alpha Coefficient (α) was used to calculate the questionnaire's accuracy. Tavakol

& Dennick (2011) indicated that the acceptable values of Cronbach's alpha would range from 0.70 to 0.95. Consequently, the coefficient (α) was 0.986 signifying that the questionnaire was highly reliable.

Section 1: Respondent Profile

The respondents' profiles were based on job designation, years of experience in the construction industry, total experience in the Green Construction Projects and type of Green Construction Project involves. These profiles are important to study how the different groups of respondents perceive issues and challenges in GCP productivity.

Table 2. Profile of the Survey Respondents

Respondent Profiles	Categorization	Number of Respondents	Percentage
Type of designation	Project Director	7	5.47%
	Project Manager	23	17.97%
	Project Executives	15	11.72%
	Architect	12	9.38%
	Engineer	18	14.06%
	Quantity Surveyor	27	21.09%
	Contractor	22	17.19%
	Others	4	3.13%
Years of Experience in Construction Industry	1 - 5	32	25.00%
	6 - 10	56	43.75%
	> 10	40	31.25%
Years of Experience in Green Construction Projects	1 - 5	18	14.06%
	5 - 10	40	31.25%
	> 10	15	11.72%

Table 2 shows the profile of the survey respondents. The respondent are namely Project Director, Project Manager, Project Executives, consultants, contractors also others (specialist supplier) . According to the total years of work experience in construction, respondents were classified in the following four groups: less than 5 years, 6 to 10 years, 11 to 15 years, and more than 15 years 6. These groups' (less than 5 years, 6 to 10 years, and more than 10 years) percentage levels are presented by 25%, 43.75%, 23%, and 31.25%, respectively. In addition, nearly 57.03% percent of respondents have experience in GCP.

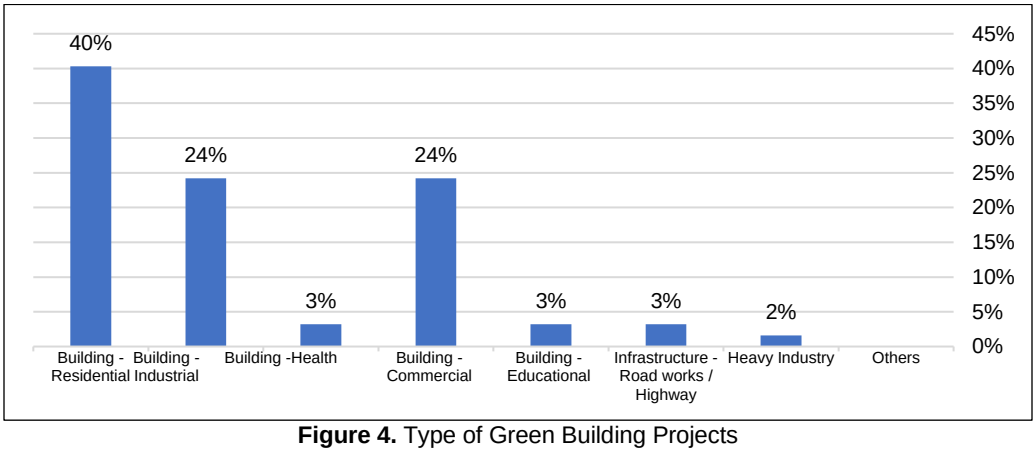


Figure 4. Type of Green Building Projects

Figure 4 shows the type of GCP that are commonly involved by the company. The most GCP involve by the respondent are Building Residential (40%), followed by Commercial & Industrial Building (24%). Others GCP are Educational and Health building (3%). However, it has been noted that civil engineering works has been cited less than 5% in implementing Green Construction Project. This includes the infrastructure works (3%) and heavy industry (2%).

Section 2: Emerging Issues in Green Construction Project Performance Effect Productivity

Respondents were asked to evaluate the importance of eighteen (18) factors in order to assess issues in GCP performance that give effects to productivity. The frequency was rated in order to identify how often the factor is considered in construction projects. This study used the collected data to compute RII, FI, and FAII values for each productivity factor. Based on that, the influencing factors were ranked in ascending order, wherein a higher RII or FAII value indicates a higher importance level and vice versa. Table 3 shows the RII, FI, and FAII values. The productivity factors were ranked using the FAII values based on all the completed responses.

Table 3. Relative Importance Index (RII), Frequency Index (FI), and Frequency Adjusted Importance Index (FAII) Values and The Rank of Factors Based on Completed Responses

Emerging Issues	Code	RII (%)	FI (%)	FAII (%)	Rank
The project delivery of Green Building projects is very complex, and negatively affects the schedule performance of Green Building projects	SP1	93.3	76.09	70.99	3
The high number of variation orders and changes to design caused by many requirements to achieve a green certificate is another hindrance effect the schedule performance	SP2	83.8	58.59	49.10	7
The unfamiliarity with green technologies leading to technical difficulties during a construction process gives effect to schedule delivery	SP3	93.8	85.94	80.61	2
The special design factors in green construction projects need to be considered early in the design stage, which affects the quality and project delivery method	SP4	81.1	53.13	43.08	8
The approvals process for new green technologies and recycled materials can take a long time because designers are expected to need more time for approval	SP5	48.1	45.00	21.64	14
Workers may tend to waive time-consuming for sustainable practices and project managers will need additional time to conduct checks and on-site visits to guarantee that sustainable practices are followed	SP6	57.2	37.50	21.45	15
Green Building projects encompass additional material, expertise, technological and other requirements, and greatly give effects to cost performance	CP1	93.3	71.09	66.33	4
Low delivery performance in Green Building projects due to process inefficiencies (waste) and increased costs of Green Building projects	CP2	55.5	47.19	26.19	12
The high initial cost was indicated as the greatest obstacle to the development of green buildings and give effects to cost performance	CP3	93.8	86.72	81.34	1
The high number of variation orders and changes to design caused by many requirements to achieve a green certificate is another hindrance that affects the cost performance	CP4	84.2	62.50	52.63	6

Emerging Issues	Code	RII (%)	FI (%)	FAII (%)	Rank
Require a larger financial resource for GB projects and lack of financing schemes (e.g., bank loans, surety bonds)	CP5	82.0	51.56	42.28	9
The delivery of Green Building projects often requires additional project players, more design iterations, advanced simulation and analysis, higher construction standards, and additional site precautions give effects on quality performance	QP1	91.7	60.78	55.74	5
Issues of quality and level of sustainability also pervaded with low performance in Green Building	QP2	64.7	38.91	25.17	13
The special design factors in green construction projects need to be considered early in the design stage, which affects the quality and project delivery method	QP3	80.5	47.19	37.99	10
Low integration and involvement of contractors affect unfamiliarity of design and green technology adoption give effect to schedule and quality performance	QP4	59.8	23.59	14.11	18
Uncertainty in the performance of green materials and equipment affects the quality performance of green building projects	QP5	65.9	48.75	32.13	11
Imperfect green technological specifications and restrictions of new green productions and technologies	QP6	55.0	31.25	17.19	16
Difficult in controlling and inspecting quality of materials, equipment, structural components	QP7	58.9	28.1	16.57	17

The following tables (Tables 4) present the five most important factors as rated by respondents according to emerging issues in Green Construction Project Performance. The respondents reported that main issues and problems in GCP would result in high initial project costs, as relatively due to unfamiliarity of new technologies and systems are required to comply with expected performances of buildings constructed. This issue not only give effect to project cost, but also to schedule performance. The result support the finding from Tagaza et al. (2004) also Zhang et al. (2011), whereby higher cost is due to design complexity and this will effects the capital costs for green projects, whereby the cost is 1 to 25% higher.

Finding from the survey also found that the unfamiliarity of green technologies with a tight project schedule gives affects to project team members to understand green requirements. The adoption of green technologies requires complicated techniques and construction processes. The design can be more complicated than a conventional building due to the evaluation of alternative materials and systems (Hwang, 2010). If complexities are not addressed well then it may affect the project schedule delivery. The empirical research from Hwang (2010) shows that 32% of the green building construction projects in Singapore were completed behind schedule and suffered from additional construction periods.

The issue that is also received a major concern from the respondent is the cost performance in GCP. Green projects are costly due to the presence of complexities in building design and the modeling of green practices to integrate into the projects. This result support the research finding from Hwang (2010). According to Hwang (2010), the use of green technologies and green materials is the main cause of the increased cost of these projects. The cost of materials in green projects is about 4% higher as compared to conventional projects. Other than material cost, the professional's cost in GCP is expected to have something extra. The additional responsibility, have green knowledge and expertise will increase the consultation cost of the green professionals (Nazirah, 2016).

The delivery of GCP also often requires additional project players, more design iterations, advanced simulation and analysis, higher construction standards, and additional site precautions give effects on quality performance. This is to assure the green technology features installed function according to the expected performance. This challenge may be solved by adopting a good quality management system and great interaction among project members.

Table 4. Top 5 RAII ranked in Emerging Issues in Green Construction that affect projects performance

Code	Emerging Issues	FAII (%)	Rank
CP3	The high initial cost was indicated as the greatest obstacle to the development of green buildings and give effects to cost performance	81.34	1
SP3	The unfamiliarity with green technologies leading to technical difficulties during a construction process gives effect to schedule delivery	80.61	2
SP1	The project delivery of Green Building projects is very complex, and negatively affects the schedule performance of Green Building projects	70.99	3
CP4	Green Building projects encompass additional material, expertise, technological and other requirements, and greatly give effects to cost performance	66.33	4
QP1	The delivery of Green Building projects often requires additional project players, more design iterations, advanced simulation and analysis, higher construction standards, and additional site precautions give effects on quality performance	55.74	5

CONCLUSION

The role of construction in the economy and its development indicates the need for continuous improvement of productivity performance in the industry. Although there is a great quantity of literature on construction productivity and green project development, but the discussion on productivity in green construction projects is still little. Therefore, this research is carried out to bridging the gaps upon this essential topic. This research identifies and assesses the critical issues and problems in Green Construction Projects' performance that can give effect to project productivity. Eighteen (18) factors were identified through the literature review. These factors were evaluated by the survey respondents based on their impact and frequency. Statistical techniques such as the Relative Importance Index (RII) and Frequency Index (FI) were used to measure and quantify the importance of the success factors. A frequency-adjusted importance index (FAII) was also introduced with this research. Table 3 and Table 4 signify the result of the research. The results of this study can assist construction practitioners to make specific adjustments to traditional project management processes and practices achieving a more productive delivery of GCP. For practitioners attempting to enter the green construction industry, the findings of this study can also help them possess a prior practical knowledge of such issues and reduce productivity-related risks. Consequently, this study will add to the body of knowledge particularly in the successful delivery of GCP.

REFERRENCES

Abdul Ghani, N. A., and Ismail, S. (2017). Public Project Delay Monitoring by Implementation Coordination Unit. J. Manage. Econ. Ind.

Abdul Kadir, M.R., Lee, W.P., Jaafar, M.S., Sapuan, S.M. and Ali, A.A.A. (2005). Factors Affecting Construction Labour Productivity for Malaysian Residential Projects. Structural Survey, Vol. 23 No. 1, pp. 42-54

Abidin, N. Z. (2010). Investigating the awareness and application of sustainable construction concept by Malaysian developers. Habitat International, 34,421- 426

Arditi D, Mochtar K. (2000). Trends in Productivity Improvement in the US Construction Industry. Constr Manage Econ. 2000; 18(1): 15–27p

Barbosa, F., Woetzel, J., Mischke, J., Ribeirinho, M. J., Sridhar, M., Parsons, M., Bertram, N., and Brown, S. (2017). Reinventing construction through a productivity revolution. McKinsey Global Institute, (https://goo.gl/1Nqqf8) (Feb. 06, 2017), (Access 2017)

Chan, A. P. C., Darko, A., Ameyaw, E. E., and Owusu-Manu, D.-G. (2017). Barriers affecting the adoption of green building technologies. Journal of Management in Engineering, 33(3), 04016057

Chan, E. H. W., Qian, Q. K., and Lam, P. T. I. (2009). The market for green building in developed Asian cities—The perspectives of building designers. Energy Policy, 37(8), 3061–307

Chandra S.S (2018). Green Construction: Analysis on Green and Sustainable Building Techniques. Department of Civil Engineering, Amity University Chhattisgarh, India Submission: January 21, 2018; Published: April 17, 2018

Chia, F C (2012). Construction and economic development: The case of Malaysia. The International Journal of Construction Management, 12(1), 23-35. Organ., 1(2), 17–23

Construction Industry Development Board of Malaysia (CIDB) (2007). Construction Industry Master Plan Malaysia 2006 –2015. Construction Industry Development Board, Kuala Lumpur.

Construction Industry Development Board of Malaysia (CIDB), (2016). Construction Industry Master Plan 2016-2020 (CIMP). Construction Industry Development Board (CIDB) Malaysia, Kuala Lumpur.

Crawford, P. and Vogl, B. (2006). Measuring productivity in the construction industry. Building Research & Information, 34(3), 208-219.Jarkas and Bitar 2014

Darko, A., Zhang, C. and Chan, A.P. (2017b). Drivers for green building: a review of empirical studies. Habitat International, Vol. 60, pp. 34-49

Durdyev, S., Ismail, S. (2016). On-site construction productivity in Malaysian infrastructure projects. Structural Survey, 34(4-5), pp. 446–462. https://doi.org/10.1108/SS-12-2015-0058

Eisenberg, D., Done, R., Ishida, L., (2002). Breaking down the barriers: Challenges and solutions to code approval of green building" Research report by the Development Centre for Appropriate Technology

Glavinich, T.E. (2008). Contractor's guide to green building construction. New Jersey: John Wiley & Sons

Hamid, Zuhairi & Zura Mohd Zain, Maria & Foo, Chee hung & Syarizal Mohd Noor, Mohd & Roslan, Ahmad Farhan & Mat Kilau, Nurulhuda & Ali, Mukhtar. (2014). Towards a national green building rating system for Malaysia. Malaysia Construction Research Journal. 14. 1-16.

Hasan, M.S (2017). Examining the Effects of Challenges Faced in Green Construction on Project Outcomes: A Chinese Perspective. International Journal of Engineering and Technology vol. 9, no. 4, pp. 315-321, 2017.

Hwang, B. G., Zhu, L., & Ming, J. T. T. (2017). Factors affecting productivity in green building construction projects: The case of Singapore. Journal of Management in Engineering, 33(3), 04016052.

Hwang, B. G., & Ng, W. J. (2012). Project management knowledge and skills for green construction: overcoming challenges. International Journal of Project Management, 31(2), 272-284.

Hwang, B. G., and Tan, J. S. (2012). Green building project management: Obstacles and solutions for sustainable development." Sustainable Dev., 20(5), 335–349.

Hwang, B., & Tan, J. C. (2012). Sustainable project management for green construction: Challenges. impact and solutions. World Construction Conference 2012 – Global Challenges in Construction Industry. Colombo, Sri Lanka.

Jarkas, A. M., and Bitar, C. G. (2014). Factors affecting construction labor productivity in Kuwait."J. Constr. Eng. Manage., 10.1061/(ASCE)CO .1943-7862.0000501, 811–820.

Jingxiao Z, Ayokunle Olubunmi Olanipekunc (2019), A successful delivery process of green buildings: The project owners' view, motivation and commitment, Renewable Energy Volume 138, August 2019, Pages 651-658.

Kamarudin, A. B., Mohd Fazli, M. S., Md Nor Hayati, T., Ismi, R., & Norhana, M. (July, 2011). Green technology compliance in Malaysia for sustainable business. Journal of Global Management, 2(1)

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., and Harris, F. C. (1997). "Factors influencing craftsmen's productivity in Indonesia." Int. J. Project Manage., 15(1), 21–30.

Lam, P. T. I., Chan, E. H. W., Poon, C. S., Chau, C. K., & Chun, K. P. (2010). Factors affecting the implementation of green specifications in construction. Journal of Environmental Management, 91(3), 654–661.

Li, Y.Y., Chen, P.H., Chew, D.A.S., Teo, C.C. and Ding, R.G. (2011), "Critical project management factors of AEC firms for delivering green building projects in Singapore", Journal of Construction Engineering and Management, Vol. 137, pp. 1153-1163

Mahat N.A.A, Hamimah Adanan and Norazian Mohammad Yusuwan (2019). Productivity Improvement Strategies in Green Construction Project: Formulation of a Theoretical Framework. IOP Conf. Ser.: Earth Environ. Sci. 385 012067

Malaysia Productivity Corporation (MPC); Malaysia Productivity Report 2016-2018, available online: http://www.mpc.gov.my/category/productivity-report

Mollaoglu-Korkmaz, S., Swarup, L., and Riley, D. (2013). Delivering sustainable, high-performance buildings: Influence of project delivery methods on integration and project outcomes. J. Manage. Eng., 10.1061/(ASCE)ME.1943-5479.0000114, 71–78

Nguyen, H.-T. and Gray, M. (2016). A review on green building in Vietnam. Procedia Engineering, Vol. 142, pp. 313-320.

Page, I. and D. Norman (2014). Measuring construction industry productivity and performance. Porirua City, New Zealand, BRANZ - Building Research Association of New Zealand.

Pham, H., Kim, S.Y. and Luu, T.V. (2020). Managerial perceptions on barriers to sustainable construction in developing countries: Vietnam case. Environment, Development and Sustainability, Vol. 22, pp. 2979-3003.

Pulaski, M. H., and Horman, M. J. (2005). Continuous value enhancement process. J. Constr. Eng. Manage., 10.1061/(ASCE)0733-9364(2005) 131:12(1274), 1274–1282

Robichaud, L. B., & Anantatmula, V. S. (2011). Greening project management practices for sustainable construction. Journal of Management in Engineering, 27(1), 48–57.

Samari, M., Godrati, N., Esmaeilifar, R., Olfat, P., & Mohd Shafiei, M. W. (15 January, 2013). The investigation of the barriers in developing green building in Malaysia. Modern Applied Science, 7(2). doi:10.5539/mas.v7n2p1

Shi, Q., Zuo, J., Huang, R., Huang, J., & Pullen, S. (2013). Identifying the critical factors for green construction–an empirical study in China. Habitat international, 40, 1-8

Tagaza, E., Wilson, J.L., (2004). "Green Buildings: Drivers and Barriers E Lessons Learned from Five Melbourne Developments". Report Prepared for Building Commission by University of Melbourne and Business Outlook and Evaluation.

Tangen, S. (2005), Demystifying Performance and Productivity. International Journal of Productivity and Performance Management, Vol.54. No. 1.

Zhang, X.L., Shen, L.Y., Wu, Y.Z., (2011). Green strategy for gaining competitive advantage in housing development: a China study. Journal of Cleaner Production ,19 (1), 157– 167.

ASSESSING THE ORGANIZATIONS DECISION FOR DIGITAL TRANSFORMATION THROUGH BIM IMPLEMENTATION IN MALAYSIA

Afifuddin Husairi Hussain[1], Mohd Rafie Abdul Alam[2], Sabariah Eni[3], Adi Irfan Che Ani[2] and Ahmad Farhan Roslan[4]
[1]Pusat Pengajian Citra Universiti, Universiti Kebangsaan Malaysia.
[2]Department of Architecture, Universiti Kebangsaan Malaysia.
[3]Department of Real Estate, Universiti Tun Hussein Onn Malaysia.
[4]Centre for Advanced Construction Technology and Innovation, Construction Research Institute of Malaysia (CREAM).

Abstract
Digital transformation is paving its way in global construction industry, where BIM stated to be among the catalyst for future construction advancement. This paper aim to assess organizations decisions for digital transformation through BIM implementation. A qualitative technique with semi-structured face-to-face interviews were employed with 15 Malaysian Housing Developers. Our findings suggested that that the digital transformation journey through BIM implementation in Malaysia is already in place and practised. This result shows that digital transformation success in all construction project involves a mind-set change towards cultural, organizational and operational transformation, and requires an innovative integration of emerging technologies, processes and competencies across construction life cycle. Furthermore, to promote the digital transformation process in Malaysian Construction Industry, we propose a Digital Transformation Process in Construction Project Ecosystem Framework and the Digital Transformation Key Strategies. The overall finding provides feasible support and reference for the governments, policy makers and construction organizations to benchmark and formulate a sustainable direction of digital transformation adoption according to the local industry setting.

Keywords: *Building Information Modelling; Digital Transformation; Construction 4.0; Malaysian Construction Industry.*

INTRODUCTION

Emerging from the digital concept, BIM is a process to digitalize construction information and is being used simultaneously throughout the construction life cycle. It gradually changes how building, infrastructure, urban and other built assets are designed, built, operated and maintained, leading to the global construction industry. Indeed, BIM has been developed and implemented by many governments around the world. Many early-adopting countries have benefited from BIM adoption (Hashim et al., 2020; Hussain et al., 2019; Kassem, Succar, and Dawood, 2013). The insatiable demand for BIM in these countries demonstrates that BIM will be a game-changer in further revolutionizing the global construction industry landscape.

Nevertheless, the digital transformations can ease matters for some while making life harder for others. Most developed countries such as the United States, United Kingdom, Hong Kong and Singapore have already positioned themselves for digital transformation by mandating BIM; whilst, most developing countries remains slow (Makabate et al., 2021; Wang and Lu, 2021). In other words, the success of BIM adoption is greatly dependent on a respective country's industrial maturity. As compared to the developed countries, many studies from late entrant countries always refer their BIM adoption is at low or at infant level (see Olawumi & Chan, 2019; Saka & Chan, 2020; Vidalakis, Abanda, & Oti, 2020), and

disregard the embrace pace of the BIM adoption. Most organizations in developing countries testified excessively rely on the conventional construction process (Babatunde et al., 2020b, 2020a; Olawumi and Chan, 2019), indicating that they are not enthusiastic about embracing with digital transformation. Likewise, little research on BIM research in those countries has gone beyond the enquiry on how organizations in early adopting countries embrace (adopt) and implement (execute) digital transformation. Due to the lack of awareness (Gamil and Rahman, 2019; Olapade and Ekemode, 2018) and resistance to change (Blay, Tuuli, and France-Mensah, 2019; Liao and Teo, 2019), these issues significantly triggered the widening digital divide between developed and developing countries. As such, industry and academia require a more profound understanding of the underlying organizational decision for digital transformation through BIM, especially in developing countries settings.

To study this phenomenon, by using the Malaysian construction industry as the context and organization as the unit of study, this paper aim to assess organizations decisions for digital transformation through BIM implementation.

THE STATE OF BIM ADOPTION IN LATE ENTRANT COUNTRIES: A REVIEW

Since the last two decades, the global Architecture, Engineering and Construction (AEC) industry has transformed from a relatively labour-intensive process to a digital-based process through BIM implementation. The spread of adoption is never even. Many early adopter countries have been endeavouring to mandate BIM as part of construction policy and legislation. Furthermore, many countries are beginning to institutionalize and adopt the BIM process to improve construction productivity.

While it continues to gain momentum globally, BIM increasingly attracted attention from researchers. In reviewing the worldwide development of BIM, Saka and Chan (2019) revealed a varying level of BIM growth across the six continents globally; South America and Africa are lagging in the BIM research and Asia growing, whilst Europe and North America are ahead. Although still at the BIM infant maturity stage, Jung and Lee (2015) and Olawumi et al. (2018) highlighted that most developed countries had implemented BIM to some reasonable degree across the project development phases. Sanchís-Pedregosa, Vizcarra-Aparicio, & Leal-Rodríguez (2020); Shibani, Awwad, Ghostin, & Farji (2020) and Zima, Plebankiewicz, & Wieczorek (2020) further stated the need for more studies in developing countries to make the outputs available and explore new research clusters whilst adopting a socio-technical perspective.

In the context of Africa, the development of BIM shows a noteworthy trend. Various research and studies have been carried out to identify the lack of BIM adoption in African-based countries. In early 2000, Alufohai (2012) examined BIM adoption in the Nigerian construction industry suggested that the adoption level among private and public sector clients have been prolonged. In assessing BIM knowledge, Marcus et al. (2015) suggested a low level of BIM due to the low utilization among the stakeholders. This may confirm Akerele and Etiene (2016) findings, who had earlier implied that the low level of BIM adoption in Nigeria is due to low awareness. This finding supports the findings by Ogwueleka and Ikediashi (2017) that state that the lack of interest by the Government, lack of formal BIM skill, and the lack of support from consultants are among the bottlenecks for BIM adoption in Africa countries. This is somewhat similar to the findings espoused by Saka and Chan (2020) and

Babatunde et al. (2020), which state that most of the demand for BIM projects in Nigeria is initiated by private organizations despite the lack of support by the Government.

As compared to African countries, Asian countries are witnessing rapid growth with significant uptake for BIM adoption. Although most developing countries in Asia highlighted the low level of adoption, the benefits of using BIM were still acknowledged.

Contributing over 15 billion New Zealand Dollars for Gross Development Product (GDP) and employing more than 184 thousand people, initially Amor et al. (2007) and Miller et al. (2013) reports show that BIM adoption in New Zealand is still in its early stages with low uptake levels and insufficient gain attention from researchers indicated by a very few BIM-related publications. To drive the force towards BIM adoption, BIM Acceleration Committee and the National BIM Education Working Group was established (BAC, 2018). Recently, coming to similar conclusions, in examining critical perspectives on BIM adoption in New Zealand, Doan et al. (2020) advocate that most construction practitioners in New Zealand are not well-aware of BIM, especially the contractors, QSs, supply chain companies and the SMEs.

In other Asian countries, the study by Akdag and Maqsood (2020) roadmaps for BIM adoption and implementation has revealed that although there is a lack of awareness. However, as an example, the demand for BIM adoption exploded at exponential growth and has transformed the landscape of the Pakistani construction industry. In Bahrain, Ahmed and Suliman (2020) have been suggested that the slow adoption is due to a lack of published studies on BIM. In another case, it identifies to a lack of BIM adoption in Iraq, Shibani et al. (2020) revealing that the level of BIM awareness in the AEC Iraqi construction industry is still low and needs more efforts from the Government to motivate the adoption process. A study by Juan, Lai and Shih (2016) involving a survey with 224 Taiwanese architectural firms on how accepting and readiness of the firms were to implement BIM revealed that one-third of the firms had already adopted BIM-based tools on strongly influenced by governmental policies. Tran et al. (2014) investigated the status of BIM adoption in the Vietnam construction industry. They suggested that BIM implementation in Vietnam is in its infancy and faces a range of challenges, including high investment costs and the lack of requirements from authorities and skilled personnel and BIM training. These issues have been addressed in the Vietnam BIM roadmap for 2015 to 2020.

As among emerging economies, the Construction Industry in Malaysia has traditionally been acknowledged as a powerful growth engine. It represents some 7% of GDP or RM110 billion per annum of expenditure; some 40% of this being in the public sector, with the Government being the industry's biggest customer. The Government has paid much attention to investing in the construction industry in boosting economic development. The vibrant construction industry is vital to the Eleventh Malaysia Plan (RMK11) and the Economic Transformation Programme (ETP), as both of these plans call for a robust and dynamic economy.

The Construction Industry Development Board (CIDB) Malaysia has taken a step towards construction transformation through Construction Industry Transformation Programme (CITP) 2016 to 2020. The CITP lay the critical strategic goals and milestones for an era of unprecedented progress and growth in the Malaysian Construction Industry. It was a five-year

transformation plan to transform the Malaysian construction industry into a highly productive, sustainable, and world-class nation towards becoming a high-income nation by 2020 (CIDB, 2015). The modernized construction industry will create significant physical infrastructure developments, a steady flow of high-income employment at all levels of society and secure sustainable economic growth.

A National BIM adoption survey by the Construction Industry Development Board revealed that only 17 per cent of the industry players embrace BIM adoption in Malaysia (CIDB, 2016). Although the adoption rate is encouraging, it was far from the Government's desired rate, which was a minimum of 40 per cent implementation rate stage 2 (especially for public projects valued at RM 100 million). Despite strenuous efforts through various policies and initiatives, it has not yet triggered a positive diffusion and reached its full potential (Roslan et al., 2019; Hussain, Razali and Eni, 2018; Musa et al., 2018).

RESEARCH METHOD

An invitation to participate in this research was sent out to all 925 housing developers' who were registered with the Real Estate and Housing Developers' Association Malaysia (REDHA) through an online survey. After two months, 113 organizations were completed and returned, resulting in a response rate of 12 per cent. Nineteen organizations (2 per cent) marks that they have experience with BIM projects, and only 15 organizations are willing to share their opinions and experiences according to their current BIM practice. Based on the information from the online survey, and due to the low number of participants, convenience sampling was chosen, where15 organization participants were interviewed (see Table 1).

The interview questions were written in both English and Bahasa Malaysia. The interviews were digitally recorded, transformed and transcribed into text. The interview transcript was then manually grouped, coded, and themed according to emergent themes as soon as the interviews finished.

DEMOGRAPHIC ANALYSIS

The collected participants' demographics in this study varied widely on individuals and organization's characteristics. Table 1 summarizes the descriptive demographic information for 15 participants regarding their `background, expertise, experience, and knowledge of BIM.

Table 1. Demographic Analysis

Participants	Age	Highest tertiary education	Working experience in the industry	Current Position Held in the Organisation	Rate of understanding of BIM	Experience involving with BIM project	Years of organizational establishment	Level of BIM implementation
R1	30 – 40 years	Degree	5 to 10 years	Senior Project Manager	Some knowledge	Yes	10 to 15 years	Have Been Implementing BIM
R2	40 – 50 years	Professional Qualifications	15 – 16 years	General Manager	Fair knowledge	Yes	15 to 20 years	Have Been Implementing BIM
R3	More than 60 years	Master	More than 20 years	Director	Some knowledge	Yes	15 to 20 years	Have Been Implementing BIM
R4	40 – 50 years	Degree	16 – 20 years	Senior Engineer	Some knowledge	Yes	> 20 years	Have Been Implementing BIM
R5	30 – 40 years	Degree	10 to 15 years	General Manager	Some knowledge	Yes	> 20 years	Have Been Implementing BIM
R6	40 – 50 years	Degree	More than 20 years	Senior Architect	Some knowledge	Yes	15 to 20 years	Have Been Implementing BIM
R7	More than 60 years	Degree	15 – 16 years	Director	Some knowledge	Yes	15 to 20 years	Have Been Implementing BIM
R8	50 – 60 years	Professional Qualifications	More than 20 years	Director	Fair knowledge	Yes	Less than 5 years	Have Been Implementing BIM
R9	More than 60 years	Professional Qualifications	More than 20 years	Director	Competent	Yes	> 20 years	Have Been Implementing BIM
R10	50 – 60 years	Degree	16 – 20 years	General Manager	Fair knowledge	Yes	15 to 20 years	Have Been Implementing BIM
R11	40 – 50 years	Master	10 to 15 years	Senior Project Manager	Competent	Yes	15 to 20 years	Have Been Implementing BIM
R12	Less than 30 years	Degree	Less than 5 years	Senior Engineer	Some knowledge	Yes	> 20 years	Have Been Implementing BIM
R13	50 – 60 years	Professional Qualifications	16 – 20 years	Senior General Manager	Competent	Yes	10 to 15 years	Have Been Implementing BIM
R14	30 – 40 years	Degree	5 to 10 years	Senior Engineer	Competent	Yes	> 20 years	Have Been Implementing BIM
R15	50 – 60 years	Professional Qualifications	10 to 15 years	General Manager	Fair knowledge	Yes	15 to 20 years	Have Been Implementing BIM

ANALYSIS OF THE CLIENT EXPERIENCE ON BIM TRANSFORMATION JOURNEY

Why does BIM Transformation Matter for Your Organization?

Reflecting the clients' needs, BIM transformation can overcome conventional 2D design issues that arose during the construction life cycle.

> "*Previously, for a long time, we were working with two-dimensional (2D) design software. We frequently faced issues on poor design coordination and unstructured information exchange processes that increase discrepancies in clashes and inaccurate material lists. This led to significant and costly problems in the design and construction phase. By implementing BIM, we manage to improve design efficiencies, promotes effective collaboration and significantly eliminating costly and time-consuming activities*" (Participant 13).

This opinion may be agreeable by all of the participants. However, the acceptance and BIM adoption process are different between the participant's organizations. They have different motives and understanding levels on BIM transformation needed for their organizations.

> "*As a funder and Client for the construction project, in many cases, the final product is not as we had wished. We are constantly looking for new technology to overcome these construction problems. From our experiences, exploring BIM open a new dimension for close monitoring a project's progress. We are satisfied with the deliverables from BIM investment*" (Participant 9).

> "*The outcomes from BIM transformation were exemplary. From BIM Model, we can generate material take off reports easily, which is not possible using a 2D-based design. We were able to order the exact quantities of materials based on the reliable material take-off report. Nearly 40 per cent of cost saving was achieved, with a minimal margin of errors material order*" (Participant 2).

> "*The objects and components in the BIM Model are presented simultaneously in 2D designs and 3D models. We were able to check any potential clashes of the components between multiple disciplines. Any modification and changes to the design can be easily done*" (Participant 14).

All participants agreed that accurate information is essential for a BIM project delivery. Due to the advancement of technology, BIM also has its transformation to customize cross-application information workflows. Participant 13 strongly suggest that in comparison to the existing 2D design methods-based process, BIM transformation provides innovative solutions to improve how the project information is created and shared among the stakeholders to produce lifecycle orientation project design.

"*It is common for us to have five projects running simultaneously, and we must diligently monitor each project. Before the BIM implementation, the design team spent years on design without visualizing the project in its entirety. During the construction stage, we monitor the progress of the projects based on the paper-based information presented by our Project Manager and Consultants. This is inefficient and not effective. When BIM was introduced, we centralized amounts of fragmented and uncoordinated documents into one comprehensive BIM model. From the federated BIM model, we manage to monitor real-time design status. And most important, it is user friendly*" (Participant 13).

Furthermore, BIM involves navigating a data-rich design process and practice to assess the capability and gain acceptance through compelling experiences. The information in BIM connects people, data and analytics.

"*I believe that the magic for BIM implementation is on the alphabet 'I' - information. We need to bear up to 40% additional unnecessary costs in every project due to our consultant and contractor's poor collaboration and dissimilation of information. Although we are not satisfied with the final product, we must pay our consultants to produce the design, and we must pay our contractors for their work done. On top of that, we also should bear additional costs because of their mistakes, not to mention the loss of time due to project extension. I believe that the 'I' in is a valuable point to mitigates our current issues. The actual value is how the Client and consultant analyze and use this information to optimize project outcome*" (Participant 11).

"*Previously, we used to intensify lines, shape and files in 2D design methods-based process to translate the design intent into the physical building. The most complex activity is the transition from CAD to BIM, which involves a steep learning curve and costly*" (Participant 3).

Other issues highlighted by the participants are the accuracy of information. The participants aware of BIM implementation believe that accurate and accessible information empowers the project stakeholders to make better-informed decisions and respond quickly to project needs. This is in line with the reliability and relevancy of the information to minimize time and cost factors (stated by Participant 9) and simultaneously increase productivity by reducing the request for information (RFI) during the construction process. This is strongly agreed by Participant 2, whereby the time and essence of project delivery can be minimized using the BIM approach.

"*As Client, we have worked according to a very aggressive timeline. Normally we are stuck between the design and construction stages. We hired consultants to produce the design. During construction, contractors discover discrepancies that may involve loss of time and additional cost and opens for potential disputes*" (Participant 2).

The more conventional (in transition stages for BIM implementation) participants had a mere thought on BIM, especially for project detailing, in pace with the advanced technology provided in BIM. Most of the participants strongly feel that communicating among the stakeholders plays a vital role in project success. Effective communication at the design stage was a catalyst for optimized project costs while contributing to higher productivity and

increasing efficiency among the project teams. Since all data are documented and communicated early and even before the project reach the site, this will benefit the client organizations. As a result, input data, the profit and revenue derived from the project will become respiratory databases for the execution of the next project. Hence, Participant 5 gives more pungent remarks that BIM implementation will improve the competitiveness of the construction business.

> "*By leveraging BIM, we encourage mindset change working process by promoting an effective way of working. BIM offers new avenues for us to make our business stronger and boosts organization's revenue and margin from the project*" (Participant 5).

In summary, the conventional construction process highlighted issues that lead to inefficient client organization decisions. All issues discussed above focused on what triggers the organizations' interest in adopting BIM and optimizing them as part of the construction transformation process. Since BIM was introduced in Malaysia and slowly gained traction in the market, this transformation means a more effective process to improve coordination, efficient information management, quality assurance, and cost optimization for a construction project. These can be translated into business and economic benefits that client organizations should embrace.

How does the Transformation Process (BIM) in the Construction Project Look Like?

Most of the participants initially feel obliged to exercise full implementation of BIM in their project. This is due primarily to BIM transformation requiring huge investment where some of the participants felt burdened by it. Participant 3 highlighted that organizations have a choice to choose on what kind of BIM tools to be adopted and at what stage to adopt in their project. As for Participant 3's experience, his organization explores the basic features for BIM merely to experiment, understand the process, and look for output derived from BIM application.

> "*At the initial stage, we recognize BIM involves a complex process and uses that need to explore, and it is too risky if our organization adopts all the uses at one time. Thus, we customize the transformation process based on how BIM can effectively be streamlined into the organizations and projects current practices. To reduce uncertainty and assess its workability, we only explore the use of basic features of BIM for a limited period practically. It is to ensure the project team has enough time to practice and familiarized with BIM-based process*" (Participant 3).

Looking at the current scenario, most of the participants imply that the effective BIM transformation in the organization is based on project needs. As transpires by Participant 3, their organization only focusing essential BIM tools according to the project requirement when initially exploring BIM benefits. As a result, their pragmatic decision to explore a BIM basic solution enables them to focus on the right key area: up-skill their workforce and execute the BIM process for their future projects. Unlike the fundamental tools, Participant 5 and Participant 9 moved a step ahead by applying the BIM process during the initiation pilot project; to evaluate the effectiveness of BIM. Hence it was well embraced and effectively increased productivity.

"*We start the journey of BIM by initiating the pilot project and acquire BIM consultant to assist us for transformation journey*" (Participant 5).

"*The outcomes for the pilot project reveal that we can improve the productivity and efficiency of the project by providing greater project insight on the impact of design on the cost and time earlier. Inevitably, BIM provides the solution to accelerate time for the design process and improve the productivity of design coordination by reducing risk, error and waste for the project*" (Participant 9).

BIM involves navigating data-rich design processes and practices to enhance coordination and improve construction outcomes. Most of the participants are well informed that BIM provides an innovative approach for clients to effectively get better design insight, address potential problems and resolve critical issues at the beginning of the design process; before moving to the construction stage. It encourages the project team to resolve potential conflicts before it arises.

"*We already embraced BIM implementation for the last three years. BIM has become a platform for us to establish a single source of truth for data to unlock conventional collaboration during design and construction stage*" (Participant 1).

"*As compared to the 2D workflows, BIM facilitates us to address the constructability issues from the initial concept design. It promotes the 'build twice and constructs once' working methodology. BIM enables us to control over outcomes for the project*" (Participant 4).

The ability to visualize and simulate how future occupants will experience a building and accurately predict a building's performance before it is built is crucial for the Client to justify the feasibility of a project. This is one of the main factors that influence the decision taken by client organizations for BIM implementations. It is proven in the study where BIM is perceived as a platform to provide innovative solutions for the Client to visualize the behavioural pattern of the targeted occupants and process requirements into the physical and functional aspects of a building. This further improves understanding of the spatial relationship of building components to produce lifecycle orientation project design.

"*Having a complete BIM model, we were able to understand how the design looks and evaluate design options in the 3D environment. We could also explore design options and get iterations more quickly using virtual reality (VR) and real-time walkthroughs. All the complete design-to-construction information continuously can be access and exchanged in real-time without any paper-based activities. The rendered and fly-through BIM models provide impressive views of the project, that very useful as marketing model to sell the commercial space*" (Participant 9).

Another benefit highlighted by the participants is the accuracy and accessibility of information to empower the Client to make better-informed decisions and respond quickly to project needs. These provide opportunities to avoid time wastage through design revision, costly changes and rework or delays in project schedules. This will simultaneously increase productivity by reducing RFI during the construction process. This supports the recent claim

made by Edirisinghe & Woo (2020) and Seyis (2020) concerning the benefit of BIM as a decision-making tool. In response to that, Participant 12 stated that,

> "*By modelling all the elements and components, we managed to solve more than 500 clashes and inconsistencies between model and site by reducing almost 30% construction cost and time. Potential clashes that may significantly affect time and cost are discovered early, and project cost can be controlled*" (Participant 12).

By implementing BIM, each party has access to a unified communication platform. It improves agility for the project team to react and manage the broad spectrum of construction data anywhere and anytime in a Common Data Environment (CDE). BIM can connect the project teams in real-time and promotes collaborative working culture between multiple disciplines to minimize costly mistakes, as pointed out by Participants 2, 9 and 8.

> "*It was a great deal when we have the BIM model that synchronized to the cloud platform. This allows the project teams to stay connected with the latest work from anywhere, anytime and on any device in real-time. It enables our team to collaborate and communicate effectively*" (Participant 2).

> "*By implementing BIM, we can gather all the data from the cloud and manage the 'live data' from design and construction remotely. This also promotes effective multi-directional communication. Based on our experience, embracing BIM is not just a bandwagon for our organization to jump on, but rather seen as an opportunity for us to unlock our long-dreamt goals to optimize the project delivery process*" (Participant 9).

> "*The project team starts to appreciate BIM processes when the project can be easily modified, reviewed, simulated, and extraction of the information from the 3D model is faster, as compared to 2D drawing. We start to improve digital content for a BIM model and explore another advanced interface of BIM, such as generative and immersive digital. To build a better building, BIM enhances the design-construction process to become more efficient by bringing information of a BIM model to the job site. In a nutshell, by adopting BIM, we manage to optimize predictability, productivity and profitability of a project by streamlining collaboration, coordination and communication process*" (Participant 8).

The BIM process revolves around data gathering and involves managing considerable sensitive and confidential information, fundamental to communicate such information to the project team. Since BIM promotes and encourages seamless collaboration, the Client needs to maintain the integrity of the construction data. In response to this, Participants 7 shared that:

> "*As we run our business as property developers, the main issue in managing the design and construction process is the ability to access the project information anytime, anywhere and from any device. By implementing BIM, it enables real-time communication with the design and project team. All the commercial information is safely stored and encrypted in a central server. It promotes transparency in managing confidential construction information*" (Participant 7).

The considerable potential of BIM is not just during the design and construction stage but also throughout the lifecycle. As a respected organization, producing a good product is when the building has minimum liabilities and defects even when the projects have been handed over to the clients. With BIM implementation, the Client can readily produce the requirement on operation and maintenance as part of Employer Information Requirement (EIR). Thus, BIM provides an opportunity to the clients to maximize the return from investment for the entire asset lifecycle. Participants 10 and 12 shared that:

> "*In our construction process, there are loopholes between design and construction activity with operation and maintenance activity. Currently, we are not only selling a completed building. Nevertheless, we sell a completed building unit with service to our clients. We have a range of hotels, service apartments, SOHOs, condominiums, offices, shops and suites towers. Therefore, we need to consider the maintenance and operation as early as the concept design stage. By implementing BIM, we can acquire a comprehensive as-built model that consists of intelligent information and data for the building's entire life. As the building operation and maintenance changes over its lifetime, the operation and maintenance team can enrich the information and data in BIM model accordingly*" (Participant 10).

> "*By integrating the physical and virtual environment, we can visualize and monitor our projects and assets based on our business requirements. The model-based asset information is essential to provide data analytics to justify the current decision-making and planning and can be referenced for future work*" (Participant 12).

The above discussion revealed that the deliverable from the BIM transformation journey involves improving the coordination process, an early formulation of operational requirements, quality assurance, and cost optimization that can be translated into the value of the construction project.

DISCUSSION

Based on the above analysis, we can conclude that most organizations are well embraced with the digital transformation journey through BIM in their projects. The transformation process is not a one-time and straightforward decision but involves a dynamic decision in which organizations continuously learn, improve or give up over time. This is proven by the acceptance and readiness for digital transformation in a project based on the current practices, followed by optimization of the processes via identified BIM uses. These results agree with Musa et al. (2020) that although BIM implementation is considered low in the Malaysian construction industry, the industry players agree on the benefits from BIM implementation. This indicates that digital transformation in Malaysia is profitable way ahead in reaching its maturity, transforming how the construction project runs its operation.

Findings from this study reveals that the digital transformation in construction projects is not just about technology; it is rooted in a fundamental shift in integrating the project management process with innovative technologies. It is highly acknowledged that most investigated projects have constantly improved their construction projects by becoming more agile and flexible to adapt to changes after embracing digital transformation. Even though during the initial implementation, there were some projects reported having difficulties (such

as budget constraints, culture change and talent struggle), in the end, the participants seem to be satisfied with what digital transformation can offer and able to translate into many opportunities and possibilities, unlocking new area of project management and enhance their business models.

This study also reported that the digital transformation in construction projects involves a mind-set change where cultural, organizational and operational review is required through smart integration of emerging technologies, processes, and competencies across all the construction projects in a staged way. This requires a continuous challenge to the status quo, re-skilling and encouraging innovation in the construction project ecosystem. In this way, the findings suggest that the digital transformation process in a construction project can be conceptualized into four (4) stages (Table 2):

Table 2. The Digital Transformation Process in Construction Project Ecosystem Framework

1 Upskilling	• Identifying key roles and competencies area. • Acquiring current knowledge on innovation, software, application and workflow to support project operation. • Continuous learning.
2 Efficiency	• Identifying the right tools and processes to solve the construction project issues. • Applying innovation, software, application and workflow. • Measure the effectiveness in form time, cost and project performance.
3 Optimization	• Benchmarking to achieve best practice. • Formulating automation process to support repeatable tasks • Establishing systematic monitoring and reporting process. • Assessment of achievement for continual improvement.
4 Harmonization	• Synergise construction processes together with underlying digital technology. • Using analytics data for better decision-making. • Enable scalability factors to improve project productivity.

This study indicated that digital transformation enables the organization to reduce unnecessary costs and time by nearly 30 to 40 percent due to poor collaboration and dissimilation of information between the consultant and contractor. As noted in the findings, nearly 40 per cent of cost optimization was achieved through early clash detection and accurate quantity extraction. In this way, the findings suggest that digital transformation can be a powerful means to improve productivity yield by promoting cost-effectiveness and timesaving, enabling the organizations to be more responsive, flexible, and competitive in the market.

All the findings from the above discussion show that if BIM is executed correctly at the project level, many benefits can be gained. The current study results also revealed that the perceptions of trialability and observability are essential factors influencing digital transformation adoption. As being mentioned by Participants 3, 5 and 9, they initially observe how BIM tools could fit into their work-related tasks before deciding to adopt them. As noted in the findings, the common attributes to develop knowledge and to adopt the BIM transformation process for the project can be conceptualized into three approaches:

- *Awareness-based knowledge*: Represents the knowledge on the fundamental of BIM and the overall digital transformation process. This type of knowledge can motivate the organization to question and explore the benefits gained from BIM adoption and, eventually, lead to a decision to adopt digital transformation;

- *Operational-based knowledge*: Represents the knowledge on the technical principles describing how and why need to integrate digital transformation into the current practices, including the contribution to operational and financial efficiency. This knowledge always becomes the primary input to justify the effectiveness of digital transformation adoption into the organization-wide workflow; and
- *Know-how knowledge*: Represents the principle knowledge of how to adopt digital transformation effectively to maximize the benefit of adoption. The experiential approach justifies the effectiveness and appropriateness of the digital transformation adoption based on organization and project requirements. Towards successful digital transformation, an organization should have enough level of know-how knowledge before the digital transformation adoption.

The successful digital transformation strategy can be conceptualized into "POWER": People readiness (P), Organizational synergy (O), Work processes (W), Environment (E), and Resources (R). This enables the business and construction process to move closer together (Table 3).

Table 3. The Digital Transformation Key Strategies

(P) People Readiness	• Develop individual knowledge competency. • Form-up execution team with subject matter expert included. • Developing human capital through training and mentoring programme. • Continuous on-job learning and training.
(O) Organizational Synergy	• Establish organizational digital transformation mission and goals. • Institutionalize digital transformation process into the business process. • Strong management support for digital transformation. • Establish digital transformation desired levels of implementation maturity. • Initiating a clear end-state vision for the digital transformation.
(W) Work Process	• Establish a workflow as the guideline to execute the desired mission and goals. • Identify pilot project based on organization core competency. • Further develop the workflow based on the experiential value. • Acknowledge the workflow as the best practice solution.
(E) Environment	• Acquiring technology infrastructure (software, hardware, and server). • Adequate resources to facilitate digital transformation implementation. • Conducive work environment that supports digital transformation implementation.
(R) Resources	• Continuous financial commitment to support digital transformation activity. • Establishing technical support to assist digital transformation implementation.

This study reveals the success of the BIM transformation journey differs from each organization depending on its objectives and requirements. BIM transformation requires a mindset change involving working culture, paradigm and behaviour, which is difficult to change and unlikely to be enforced but possible to be nurtured within time. Thus, the BIM process should be aligned with the business strategy that requires time, commitment, and resources to sustain the transformation journey. The acceptance or assimilation of BIM practice within the organization will determine the pace of BIM adoption in the industry.

Since most of the BIM adoption study in Malaysia is referred to as 'infant stage', the findings show otherwise. This reveals that the digital transformation journey of construction projects in Malaysia is on the right track, with a different maturity pace. This further suggests that adopting Industrial Revolution (IR 4.0) will continue the future contribution of BIM in Malaysia.

CONCLUSION, LIMITATION AND RECOMMENDATION FOR FUTURE STUDIES

The initial motivation for this paper stems from the lack of research in understanding how the organizations embrace (adopt) and implement (execute) digital transformation in construction projects, especially in Malaysia. It is essential to fill in the gap on digital transformation business case in late entrant's country; well implemented, reaching its maturity level and at par with the adoption by early adopter countries. Based on the research findings, this study concludes that the digital transformation in Malaysian construction industry is practised and encouraging. However, the overall successful implementation is perhaps underreported. Nevertheless, this study gives an initial impression that Malaysia (and other developing countries) is currently getting ready for the next digital agenda in the construction industry - Industry 4.0.

However, this study has some glaring limitations: first, this study is qualitatively confined to only 15 'innovators' involved pioneer players in BIM implementation. The findings could not be generalized on digital transformation journey acceptance among all the construction industry players in Malaysia. Secondly, this study only investigates why and how the organization embraced the digital transformation journey as their business strategy, lacking the policy view. Thirdly, the study is not appropriately tested and validated; the rationale for digital transformation may differ based on the nature of the projects.

There are some potential areas for further investigation that can be elicited from this study. A potential future research trajectory would be to design and conduct longitudinal studies to track the organization's adoption progress at two points in time, i.e., when it first adopts and post the digital transformation process. At this juncture, additional research must be performed to understand better the factors that drive continuance and rejection to justify the transformation maturity level based on the project management case. It would be valuable to know the enabler and barrier to institutionalize digital transformation in a typical project setting. It is also worthwhile for future studies to explore policy guidelines and roadmap development to support the digital transformation process. This will become a significant predictor to justify the future direction of the construction industry in Malaysia.

It is hoped that the findings of this study will provide some valuable insights for those who seek to understand the success of digital transformation, especially from late entrant countries such as Malaysia.

REFERENCES

Ahmad, Zubair, Muhammad Jamaluddin Thaheem, and Ahsen Maqsoom. 2018. “Building Information Modeling as a Risk Transformer: An Evolutionary Insight into the Project Uncertainty.” Automation in Construction 92(August): 103–19. https://doi.org/10.1016/j.autcon.2018.03.032.

Ahmed, S. H. A., & Suliman, S. M. A. (2020). A Structure Equation Model of Indicators Driving BIM Adoption in the Bahraini Construction Industry. Construction Innovation, 20(1), 61–78. https://doi.org/10.1108/CI-06-2019-0048.

Akdag, S. G., & Maqsood, U. (2020). A Roadmap for BIM Adoption and Implementation in Developing Countries: The Pakistan Case. Archnet-IJAR: International Journal of Architectural Research, 14(1), 112–132. https://doi.org/10.1108/ARCH-04-2019-0081.

Akerele, A. and Etiene, M. (2016), Assessment of the Level of Awareness and Limitations on The Use of Building Information Modelling in Lagos State, International Journal of Scientific and Research Publications, Vol. 6 No. 2, pp. 229-234.

Amor, R., Jiang, Y. and Chen, X. (2007), BIM in 2007 – Are We There Yet? 24th W78 Conference' Bringing ITC Knowledge to Work', 27-29 June 2007, Slovenia, Maribor, pp. 26-29.

Awwad, K. A., Shibani, A., & Ghostin, M. (2020). Exploring the Critical Success Factors Influencing BIM Level 2 Implementation in the UK Construction Industry: The Case of SMEs. International Journal of Construction Management, 0(0), 1–8. https://doi.org/10.1080/15623599.2020.1744213.

Babatunde, S., Udeaja, C. and Adekunle, A. (2020b), Barriers to BIM Implementation and Ways Forward to Improve Its Adoption in The Nigerian AEC firms, International Journal of Building Pathology and Adaptation, Vol. ahead-of-print No. ahead-of-print, doi: 10.1108/IJBPA-05- 2019-0047.

Babatunde, Solomon Olusola, Damilola Ekundayo, Adedayo Opeyemi Adekunle, and Wasiu Bello. 2020a. "Comparative Analysis of Drivers to BIM Adoption among AEC Firms in Developing Countries: A Case of Nigeria." Journal of Engineering, Design and Technology.

BAC (2018b), BIM Tertiary Education, BIM Acceleration Committee, available at: https://www. biminnz.co.nz/about-us-1/ (accessed 1 July 2021).

Blay, Karen B, Martin Morgan Tuuli, and Jojo France-Mensah. 2019. "Managing Change in BIM-Level 2 Projects: Benefits, Challenges, and Opportunities." Built Environment Project and Asset Management 9(5): 581–96.

CIDB (2015). Construction Industry Transformation Programme 2016-2020. https://doi.org/10.1007/s13398-014-0173-7.2.

CIDB (2016). Malaysia BIM Adoption Report 2016. CIDB Technical Report Publication 1217.

Doan, D. T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T., & Tookey, J. (2020). Examining Critical Perspectives on Building Information Modelling (BIM) Adoption in New Zealand. Smart and Sustainable Built Environment. https://doi.org/10.1108/SASBE-04-2020-0043

Edirisinghe, Ruwini, and Jin Woo. 2020. "BIM-Based Performance Monitoring for Smart Building Management." Facilities.

Gamil, Yaser, and Ismail Abd Rahman Rahman. 2019. "Awareness and Challenges of Building Information Modelling (BIM) Implementation in the Yemen Construction Industry." Journal of Engineering, Design and Technology 17(5): 1077–84.

Hashim, B., Safie, N., & Husairi, H. S. A. (2020). Building Information Modelling (BIM) and the Internet-of-Things (IoT): A Systematic Mapping Study.

Hussain, A. H., Husain, M. K. A., Roslan, A. F., Fadzil, F., & Ani, A. I. C. (2019). The Fourth Industrial Revolution and Organisations' Propensity towards Building Information Modelling (BIM) Adoption. Malaysian Construction Research Journal (MCRJ), 79.

Hussain, A. H., Razali, M. N., & Eni, S., 2018. Stakeholders' Expectations on Building Information Modelling (BIM) Concept in Malaysia. Property Management, 36(4), 400–422. https://doi.org/10.1108/PM-02-2017-0013.

Hussain, A.H., Husain, M.K.A. and Ani, A.I.C., 2015. Unlocking the Potential Value of BIM Implementation in Malaysia: A Pilot Study. European Journal of Advances in Engineering and Technology, 2(12), pp.11-20.

Hussain, A.H., MKA Husain, AF Roslan, F Fadzil, AIC Ani., 2019. The Fourth Industrial Revolution and Organisations' Propensity towards Building Information Modelling (BIM) Adoption. Malaysian Construction Research Journal 27(1): 79–92.

Juan, Y., Lai, W., & Shih, S. (2016). Building Information Modelling Acceptance and Readiness Assessment in Taiwanese Architectural Firms. Journal of Civil Engineering and Management, 23(3), 356–367. https://doi.org/10.3846/13923730.2015.1128480.

Jung, W. and Lee, G. (2015), The Status of BIM Adoption on Six Continents, International Journal of Civil, Structural, Construction and Architectural Engineering, Vol. 9 No. 5, pp. 406-410.

Kassem, M, B Succar, and N Dawood. 2013. "A Proposed Approach to Comparing the BIM Maturity of Countries." Proceedings of the CIB W78 2013: 30th International Conference (Succar): 9–12. http://novaprd-lb.newcastle.edu.au/vital/access/manager/Repository/uon:15200.

Kassem, M. and Succar, B., 2017. Macro BIM Adoption: Comparative market analysis. Automation in construction, 81, pp.286-299.

Liao, Longhui, and Evelyn Ai Lin Teo. 2019. "Managing Critical Drivers for Building Information Modelling Implementation in the Singapore Construction Industry: An Organizational Change Perspective." International Journal of Construction Management 19(3): 240–56. https://doi.org/10.1080/15623599.2017.1423165.

Miller, G., Sharma, S., Donald, C. and Amor, R. (2013), "Developing a building information modelling educational framework for the tertiary sector in New Zealand", 10th IFIP WG 5.1 International Conference (PLM 2013), 6-10 July 2013, Nantes, France, pp. 606-618.

Makabate, C. T., Musonda, I., Okoro, C. S., & Chileshe, N. (2021). Scientometric analysis of BIM adoption by SMEs in the architecture, construction and engineering sector. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-02-2020-0139

Musa, S., Marshall-Ponting, A., Shahron, S.A. and Nifa, F.A.A., 2019. Building information modeling (BIM) benefits and challenges: Malaysian construction organization experience. Journal of Computational and Theoretical Nanoscience.

Ogwueleka, A.C. and Ikediashi, D.I. (2017), The future of BIM technologies in Africa: prospects and challenges, Integrated Building Information Modeling, pp. 307-314.

Olapade, Daramola Thompson, and Benjamin Gbolahan Ekemode. 2018. "Awareness and Utilisation of Building Information Modelling (BIM) for Facility Management (FM) in a Developing Economy." Journal of Facilities Management 16(4): 387–95.

Olawumi, T. O., & Chan, D. W. M. (2019). Development of a benchmarking model for BIM implementation in developing countries. Benchmarking, 26(4), 1210–1232. https://doi.org/10.1108/BIJ-05-2018-0138.

Olawumi, T.O. and Chan, D.W.M. (2018), "Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: a delphi survey of international experts", Sustainable Cities and Society, Vol. 40, pp. 16-27.

Olawumi, Timothy O., and Daniel W.M. Chan. 2019. "Development of a Benchmarking Model for BIM Implementation in Developing Countries." Benchmarking 26(4): 1210–32.

Roslan, A. F., Hamid, Z. A., Zain, M. Z. M., Kilau, N. M., Dzulkalnine, N., & Hussain, A. H. (2019). Building Information Modelling (BIM) Stage 2 Implementation Strategy for the Construction Industry in Malaysia. Malaysian Construction Research Journal (MCRJ), 153.

Saka, A. B., & Chan, D. W. M. (2020). Profound barriers to building information modelling (BIM) adoption in construction small and medium-sized enterprises (SMEs): An interpretive structural modelling approach. Construction Innovation, 20(2), 261–284. https://doi.org/10.1108/CI-09-2019-0087.

Saka, A.B. and Chan, D.W.M. (2019a), A Scientometric Review and Meta-Synthesis of Building Information Modelling (BIM) Research in Africa, Buildings 2019, Vol. 9, p. 85, doi: 10.3390/ buildings9040085.

Saka, Abdullahi B., and Daniel W.M. Chan. 2020. "Profound Barriers to Building Information Modelling (BIM) Adoption in Construction Small and Medium-Sized Enterprises (SMEs): An Interpretive Structural Modelling Approach." Construction Innovation 20(2): 261–84.

Sanchís-Pedregosa, C., Vizcarra-Aparicio, J. M., & Leal-Rodríguez, A. L. (2020). BIM: A technology acceptance model in Peru. Journal of Information Technology in Construction, 25(February), 99–108. https://doi.org/10.36680/j.itcon.2020.006.

Sanchís-Pedregosa, Carlos, Juan Manuel Vizcarra-Aparicio, and Antonio L. Leal-Rodríguez. 2020. "Bim: A Technology Acceptance Model in Peru." Journal of Information Technology in Construction 25(February): 99–108.

Seyis, S. (2020). Mixed method review for integrating building information modelling and lifecycle assessments. Building and Environment, 173(October 2019), 106703. https://doi.org/10.1016/j.buildenv.2020.106703.

Seyis, Senem. 2020. "Mixed Method Review for Integrating Building Information Modeling and Life-Cycle Assessments." Building and Environment 173(October 2019): 106703. https://doi.org/10.1016/j.buildenv.2020.106703.

Shibani, A., Awwad, K. A., Ghostin, M., & Farji, O. (2020). Adopting Building Information Modelling in Small and Medium Enterprises of Iraq's Construction Industry. In Proceedings of the International Conference on Industrial Engineering and Operations Management (pp. 457–470).

Shibani, Abdussalam, Khaled Abu Awwad, Michel Ghostin, and Omar Farji. 2020. "Adopting Building Information Modelling in Small and Medium Enterprises of Iraq's Construction Industry." In Proceedings of the International Conference on Industrial Engineering and Operations Management, 457–70.

Succar, B. & M. Kassem (2015). Macro-BIM Adoption: Conceptual Structures. Autom. Constr. 57(May), 64–79.

Tran, H. M., Nguyen, V. H., Ta, N. B., & Le, T. H. A. (2014). BIM Implementation Worldwide and the Status of BIM Adoption In Vietnam Construction Industry. Vietnam Construction Economics Megazine, (2).

Vidalakis, C., Abanda, F. H., & Oti, A. H. (2020). BIM Adoption and Implementation: Focusing on SMEs. Construction Innovation, 20(1), 128–147. https://doi.org/10.1108/CI-09-2018-0076.

Vidalakis, Christos, Fonbeyin Henry Abanda, and Akponanabofa Henry Oti. 2020. "BIM Adoption and Implementation: Focusing on SMEs." Construction Innovation 20(1): 128–47.

Wang, J., & Lu, W. (2021). A deployment framework for BIM localization. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-09-2020-0747

Zima, K., Plebankiewicz, E., & Wieczorek, D. (2020). A SWOT Analysis of the Use of BIM technology in the Polish Construction Industry. Buildings, 10(1). https://doi.org/10.3390/buildings10010016.

Zima, Krzysztof, Edyta Plebankiewicz, and Damian Wieczorek. 2020. “A SWOT Analysis of the Use of BIM Technology in the Polish Construction Industry.” Buildings 10(1).

CHARACTERIZATION OF PRODUCTIVITY ASPECTS IN BUILDING PROJECTS BASED ON THE ADOPTION OF INDUSTRIALIZED BUILDING SYSTEM (IBS)

Sharifah Akmam Syed Zakaria
School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia.

Abstract
The adoption of Industrialized Building System (IBS) in the construction industry throughout the world has various positive impacts in improving the overall industry performance. IBS is an innovative building technology that involves a reduction of site labor, lower wastage, less site materials, cleaner environment, better quality, neater and safer construction sites, faster project completion as well as cost efficient in total construction. These features can contribute towards the productivity improvement and development of the construction industry. This research aims to determine the characterization of IBS technology adoption from the perspective of productivity namely financial, manpower, machine, materials, time and information, in terms of how these factors can contribute towards the productivity and quality of building projects. Specifically, this paper presents research evidence using a quantitative method through questionnaire surveys for ranking the influence of productivity factors on IBS technology adoption, with attention to the hierarchy of each productivity aspect and outcome measures reported. It is concluded that the three significant productivity-related factors in building projects are time, machines and financial.

Keywords: *Productivity; building; projects; Industrialized Building Systems (IBS).*

INTRODUCTION

The Ministry of Works Malaysia, through the Construction Industry Development Board (CIDB), has developed the Construction Industry Transformation Programme (CITP) to empower and strengthen the construction industry as adopted in the thrusts of the Eleventh Malaysia Plan (RMK11) (CITP, 2015). One of the four strategic thrusts which aims to transform the construction industry is on the aspiration of raising the overall productivity level of the industry. Productivity is the primary engine of growth towards Malaysia's high-income target. Improving construction productivity can go some way toward eliminating time and cost overruns (Durdyev and Ismail, 2016; Haslinda et al., 2018; Ullah et al., 2017). Today, the construction industry has one of the lowest productivity levels in the economy that requires some collaborative practices (Ofori, 2015). Unfortunately, the level of IBS usage in the local construction industry is considerably low despite it has been proven to be a modern construction method with various advantages (Rashidi and Ibrahim, 2017). Practically, in Malaysia, the adoption of IBS technology in building projects is not accelerating as expected because of these two factors namely; the low labour cost in Malaysia (Zakaria et al., 2018) and most of building projects prefer the use of traditional construction approaches (Ali et al., 2018).

The acceptance of IBS system for the specific focus or purpose of increasing productivity levels in building projects is still uncertain (Fateh et al., 2017; Musa et al., 2015), which emerges as the research problem of this study and require further studies in this area. The consideration of IBS to accelerate building projects can lead to a faster system of construction process in order to fulfill the required specifications and performance of those projects in

terms of time, cost and quality (Baharuddin et al., 2015). Therefore, the construction industry should utilize the adoption of IBS technology to overcome the difficulties and limitations of conventional or traditional construction methods which involve high wastage, low quality of the products and project delays. These difficulties may be also caused by various environment factors such as climate factors such as rains and windy which cause the delay of construction work, besides the availability of abundant cheap foreign labour in the construction industry.

In building projects, under uncertain economic conditions, the aspects of risk are well considered. This risk also relates to the aspect of quality and productivity of the building projects. Generally, the risk of failure outweighs IBS benefits as IBS technology adoption is considered as a fast-track system compared to the conventional construction methods. Rahim et al. (2016) discover that building-technology advancements have been improving in terms of their practical applications because the construction industry requires rapid, labour-efficient, cost-effective and quality solutions and that building projects struggle to keep up with such developments. As time becomes a crucial problem in a project implementation, IBS can be an effective solution to this problem (Musa et al., 2015). Therefore, it is important to determine the acceptance of IBS for timing purposes from the companies, contractors, consultants, house owners, workers and the end users. Consequently, the aspects of productivity and quality pertaining IBS should be well considered in the adoption of IBS technology in building projects.

The aim of this study is to determine the characterization of IBS implementation from the perspective of productivity namely financial, manpower, machine, materials, time and information, in terms of how these factors can contribute towards the productivity and quality of building projects. The research seeks to explore the significance of utilizing IBS in the building projects that may give many benefits in terms of productivity development since the productivity of construction projects has to be of an emerging trend in developing countries (Banihashemi et al., 2017). This study adopts a perspective that attempts to explore the relevancy of productivity in the adoption of IBS technology as perceived by the stakeholders of the construction industry. Specifically, this study intends to answer the research question 'What productivity-related factors associated with building projects are influencing the adoption of IBS technology?'.

LITERATURE REVIEW

Adoption of Industrialized Building System (IBS) Technology in Construction Industry

The initiatives of Industrialised Building System (IBS) adoption are expected to tackle issues in the construction industry holistically, including the economic, regulatory, operational, technological, human capital and innovation aspects in order to achieve the transformative outcomes. There are four strategic thrusts that have been identified to focus the Malaysian Construction Industry Transformation Plan 2016-2020 (CITP, 2015) initiatives in order to be all-encompassing of the critical issues which are quality, safety and professionalism, environmental sustainability, productivity and internationalisation. IBS is a construction method that is developed to manage various drawbacks associated with conventional construction methods. Generally, IBS is a construction system that is built using prefabricated components. The manufacturing of the components is systematically done using

machine, formworks and other forms of mechanical equipment. The components (precast) are manufactured off-site and once completed will be delivered to construction sites for assembly and erection.

The introduction of IBS as a new construction method has allowed the construction industry to achieve remarkable productivity gains and is considered as an optimistic choice which suits sustainability factors (Ramli et al., 2016). Industrialized Building System (IBS) is the term to represent the prefabrication and construction industrialization concept in Malaysia. The term was developed to reflect the paradigm shift from the typical conventional construction methods to a prefabricated system. IBS has been introduced as a construction method with better productivity, quality and safety (Holla et al., 2016; Pozin et al., 2016). As Malaysia is going towards achieving sustainable development, IBS is one of the transformation strategies to achieve this aspiration. IBS technology adoption is also related to the aspects of sustainable consumption and production concept. The Eleventh Malaysia Plan (RMK-11, 2016-2020) stated that Malaysia has a major interest in stepping up its pledge to the development and improvement of labour productivity. Therefore, IBS technology is a preferred technology that comes with productivity aspects from the perspectives of project resources such as manpower, machine, financial, materials, information and time.

According to Dixit et al. (2017), because of its central consequentiality to competitiveness and world prosperity, the topic of productivity has been a matter of interest since the commencement of industrialization. Productivity is perhaps one of the most important and influential basic variables governing economic production activities, including the construction industry (Finkel, 2017). According to Pheng and Meng (2018), high productivity can be a significant source of competitive advantage in the construction industry. Due to the size of the construction industry, productivity trends in this industry have notable effects on national productivity and on the economy as a whole (Dabla-Norris et al., 2017). In fact, the construction industry is related to labour productivity with the consideration on how vital it is to success or how it can be measured, analysed or improved (Tsehayae and Fayek, 2016).

Efforts to produce better performance and increasing productivity in construction requires an understanding of the various indicators of productivity as a path to understanding the performance of the project (Nasir et al., 2012). Besides that, efforts to improve productivity in the construction industry can essentially be done by reducing project cost overrun and also project completion delay (Alinaitwe et al., 2013). The relatively low productivity level reflects the industry's need to adopt modern technologies, materials, and practices, and reduce its belief on low-skilled construction workers. Rising cost of labor will enhance the cost of housing. According to Construction Industry Development Board (CIDB) Malaysia, 69% (552,000) out of total 800,000 of registered workers as at June 2007 is foreign workers (CIDB, 2016). Moreover, Jarkas (2012) and Yun et al. (2012) also argue that while the introduction of IBS technology is never straightforward, productivity measures are even more complex because they face resistance from a broad range of stakeholders. IBS involves various consideration of, not only technological and environmental factors but also the dynamics of social change in relation to productivity (Zabihi et al., 2013).

The conventional construction methods have been considered to be less productive and dangerous due to the process of constructing buildings (Kamali and Hewage, 2017). It is important for the Malaysian construction industry to develop and be ready for digital economy

whereby increase of quality and productivity are compulsory and the reduction of cost and construction period must be taken into account. Thus, in response to productivity matters from conventional construction methods, the construction industry too is increasingly adopting building solutions as a part of strategic decisions to create intelligent buildings (Jia et al., 2019), and IBS is one of the solutions. With less labour involved with the adoption of IBS technology in building projects, overall construction time can be reduced by taking the advantages of automation. This enables building constructors to save the overhead costs of building projects besides focusing on the increase in productivity aspects.

Productivity Factors and the Adoption of Industrialized Building System (IBS) Technology

The level of productivity in construction shows a decreasing rate compared to other sectors (Antunes and Gonzalez, 2015). Efforts to achieve a higher level of project performance and a rapid increase in the productivity level of construction projects require an understanding on the various indicators of productivity aspects (Pheng and Meng, 2018). Understanding critical factors affecting the productivity of building projects from both positive and negative perspectives can be used to generate strategies in reducing project inefficiencies and to improve the effectiveness of project performance (Forsythe, 2018). Therefore, IBS is a construction method that can be used as a strategy of productivity improvement whereby the construction industry is driven towards the adoption of integrated and automation technology to produce and utilize prefabricated and mass production of building components. This will help to enhance the efficiency of the construction process, allowing a higher productivity, quality, time and cost saving (Chen et al., 2018).

Manpower (Labour)

Generally, the aspect of manpower in building projects pertaining productivity levels is related to labour efficiency and output. In relation to the constriction industry's position to the Malaysian economy, building projects are developed in an increasingly competitive world, with many challenges in the aspect of labour productivity. Therefore, the identification and evaluation of factors affecting the level of labour productivity in construction projects have become a critical issue facing project managers for a long time in order to increase the performance of construction industry (Hiyassat et al., 2016). IBS technology adoption involves the replacement or assistance of human capabilities and for tasks performed in dangerous environments and tasks that are beyond human capabilities. IBS is becoming more important and significant in the specific skill areas of building projects like the integration, coordination and assembly of construction activities (Ahmad et al., 2019). Consequently, the adoption of IBS technology pertaining the productivity improvements of building projects is about the contribution of semi and high skilled workers besides the replacement of human operators in tasks that involve hard physical or monotonous work (Chen et al., 2020). As stated by Luo et al. (2015), as IBS reduces the number the workers on site, this may reduce the potential risk of incidents occurring. Akmam and Amtered (2020) discover the idea of introducing IBS is vital as a solution to reducing the heavy reliance on migrant workers in the country, many of whom are illegal and with little or no skills. According to CIDB (2016), the Malaysian government aimed to achieve 100 percent usage of IBS and to reduce to 15 percent or approximately 50,000 of foreign workers in the construction industry by 2020. With adequate training of skilled labour to install IBS components, this factor is expected to

improve the productivity level of building projects (Ali et al., 2018). Musa et al. (2016) also discover that the conventional building method which is more labour intensive which should be substituted with IBS technology adoption, due to labour productivity issues.

Financial

From the perspective of financial aspects, the achievement of project productivity and performance in terms of its success or failure and cost issues are important in the adoption of IBS technology adoption (Hong et al., 2018). Generally, the initial building cost is also a commonly employed decision criterion for decisions about productivity assessment in IBS technology adoption. IBS technology adoption offers an opportunity to improve a variety of project performance indicators including project productivity, particularly on cost effectiveness (Pan and Pan, 2019). Since IBS or precast concrete components are bulky and involve heavy materials, the transportation cost of these components should be well considered in a building project. The transportation cost of these components is directly proportional to the number of truckloads used in the delivery process and the unit cost of delivery (Li et al., 2018a). The number of truckloads is mainly affected by the weight and size of the precast concrete components to be conveyed and the capacity of the trucks utilized for distribution, whereas the unit cost of delivery is directly influenced by the distance between the manufacturer's plant and the construction site. Therefore, the project productivity of IBS components transportation is another important factor that contribute towards a project success (Hwang et al., 2018; Wuni and Shen, 2020). Hence, it is justifiable to pay closer attention to productivity improvements if there is a good potential for savings from less double handling and use of cranes for hoisting operations (Wang and Hu, 2017). Many professionals believe that by adopting a life cycle costing approach, the first cost of prefabrication can be largely offset by other factors such as potential reduction in construction time, on-site activities and labour requirements, waste and resources (Kong et al., 2018). It is commonly acknowledged that the adoption of precast concrete systems in building projects can save costs thus contributing towards productivity improvements (Chen et al., 2016). In addition, Tam et al. (2015) discover that in IBS technology adoption, if standardized design layouts are used at the early stage of a project similar as the previous projects, better project performance in terms of cost reduction can be achieved. By adopting IBS technology or prefabrication and the mass production of building components, a building project can reduce construction cost effectively, thus increasing the level of project productivity (Xue et al., 2018).

Machineries

An industrialized building system allows flexibility in architectural design through automation in order to minimize the monotony of repetitive facades (Azam Haron et al., 2015). According to Navaratnam et al. (2019), an industrialized building system provides flexibility in the design of precast elements with unique prefabrication construction methods and automation using various machineries. In building projects, the use of automation systems using various machineries and equipment for improving productivity is adopted as a part of project performance criteria (Manikandan et al., 2018). Contractors believe that quality of precast components would be relatively higher due to the use of steel moulds and the controlled factory conditions in the casting yard (Wang et al., 2019). As such, quality is not expected to vary much between various pre-casters, hence this is contributing towards the productivity of building projects (Holla et al., 2016). Most importantly, the continuous,

uninterrupted manufacturing and erection of precast structural components using massive machineries lend prefabrication perfectly to track construction schedules (Chen et al., 2016). In building projects that adopt IBS technology, the use of automation is extremely important to ensure that project outcomes could also lead to project productivity (Pan and Pan, 2019). Specifically, with the use of machines in precast productions, design predicated on codes and standard with environmental friendly requisites can be achieved (Trung et al., 2019). This will lead to not only the quality requirements of a building project, but project productivity can be improved in terms of better communication in the design and construction stages of less delay in erection and construction tasks (Cho et al., 2017). Moreover, Li et al. (2018b) discover that prefabrication has an effective control mechanism as it mechanizes the construction process by using heavy plants and turning construction into an assembling industry rather than site production.

Materials

In order to cope with design specification and quality, materials are one of the important factors that contribute to the performance of building construction (Allen and Iano, 2019). During the planning and designing stages of building projects, the concern is with new materials and innovation to improve project productivity (Naoum, 2016). Precast for instance, is an innovative method to reduce the waste minimization and it is an effective and productive way for the better solution of wastage minimization during the construction phase (Esa et al., 2017). Similarly, prefabrication has been identified as a solution to reduce waste arising during design and construction phases (Won and Cheng, 2017). According to Holla et al. (2016), IBS involves construction methods which can reduce waste materials and give positive effect towards projects' productivity. In addition, saving construction materials on site will result not only in savings of natural resources but also saving energy resources, fossil fuels, nuclear and hydroelectric facilities, that are used in the mining, manufacturing, transportation and installation of construction materials (Cao et al., 2015; Chel and Kaushik, 2018). An industrialized building system component produces higher quality of components attainable through careful selection of materials, use of advanced technology and strict quality assurance control (Faghirinejadfard et al., 2016; Fleischman and Seeber, 2016). In relation to IBS technology adoption, the reduction of natural sources for new building construction involves both design concepts and building technology besides the selection of building materials (Malmqvist et al., 2018; Wu et al., 2019). Specifically, IBS enables on-site prefabricated or precast building components manufactured at factories offers minimal wastage, fewer site materials, cleaner and neater environment, controlled quality and lower total construction cost (Rahim and Qureshi, 2018).

Time

The performance of building projects contains the elements of time pressure, specification compliance, quality assurance and productivity achievements (Rumane, 2016). Where project operations and its workload resulted in limited time availability, IBS technology adoption is a building solution to ensure the achievements of project performance (Wu et al., 2019). The innovation of IBS as construction method and its promising features such as quality improvement, cost and time saving besides safety features have inevitably made IBS an exceptional option construction project (Razkenari et al., 2020). This is due to the fact that IBS involves off-site production and it can reduce the duration of construction time and

eliminate re-works that require extra time for the completion of building projects (Arashpour et al., 2016). Moreover, there are growing needs to cope with faster, on time, building-project completion while improving productivity levels, has reinforced the importance of IBS technology adoption in building projects (de Soto et al., 2018). According to Molavi and Barral (2016), an industrialized building system allows for faster construction time because the casting of the precast element at factory and foundation work at a site can occur simultaneously. In in project developments, IBS technology is adopted to keep up with the time of growing industrial building projects (Gao et al., 2018). In terms of project productivity, IBS adoption is aimed at speeding up the delivery time and quality in building projects as advances in building technologies have substantially impacted on project performance (Musa et al., 2016). According to Li et al. (2018b), although the increased use of IBS technology in a project often shortens construction time, speed is an important consideration based on the predictable schedule of project completion. The benefits of IBS technology adoption are not limited to cost and quality aspects, with significant cost and time savings, as these also contribute towards the productivity of building projects (Holla et al., 2016).

Information

Project information is needed as the foundation and reference of timely and wise decision-making in building projects. In this case, project members should be able to integrate the various elements of the project and information sharing which requires their highly coordinated efforts. In building projects, as uncertainty is always present, the adoption of IBS technology based on the relevant information to a certain extent contributed towards the desired output of productivity perspectives (Abanda et al., 2018). In addition, the performance of building projects in terms of its productivity is also contributed by the adoption of IBS technology based on its building information (Noor et al., 2018). The adoption of IBS technology should lead to higher quality decisions and productivity performance, as IBS adoption is based on more complete information, anticipating and improving unexpected negative project outcomes before they occur during project implementation (Halil et al., 2016). IBS project performances in terms of its productivity reflects the best practices and provide builders with information that will help them make informed decisions about modular coordination (Lee and Kim, 2017). Similarly, IBS adoption in building projects includes project information about the correct building solution (Hajdukiewicz et al., 2019). Thus, IBS adoption in building projects can give valuable information on the real nature of project specifications in terms of design and standardization. Based on the precise design information of IBS technology adoption in building project development which are required prior to the beginning of the building project contributed to the improvement of its productivity (Ramaji et al., 2017).

RESEARCH METHODOLOGY

The focus of this study is to analyse the characterization of IBS technology adoption from the perspective of productivity namely financial, manpower, machine, materials, time and information, in terms of how these factors can contribute towards the productivity of building projects. The differences in views and experience that emerge among the construction stakeholders affected their perceptions on IBS technology adoption related to the productivity of building projects. Thus, this study aims to answer this research question: ‘What

productivity-related factors associated with building projects are influencing the adoption of IBS technology?'. The perception of the construction stakeholders as respondents who are involved in building projects that adopted IBS technology were verified in order to attain the objectives of this study namely: (1) To analyse the characteristics of IBS in terms of its productivity in building projects and (2) To determine the factors that contribute towards the productivity of IBS in building projects.

A questionnaire survey was performed to obtain data for this study. The close-ended questionnaire was established and backed up with a review of related past research literatures on productivity-related factors associated with building projects that are influencing the adoption of IBS technology. The questionnaire contained forty-eight (48) items on six (6) productivity factors related to IBS technology adoption in building projects namely manpower, financial, machines, materials, time and information. Each productivity factor was categorised into two (2) productivity groups namely process and output. The responses of productivity factors on IBS technology adoption in building projects were recorded using five-point Likert scale. The Cronbach alpha value for these items was 0.9513.

A sample of construction companies was first selected based on information obtained from the Malaysian Builders Directory (2017/2018). Potential companies were selected as the survey respondents according to their professional positions as civil engineers, design architects, developers, quantity surveyors, consultants, contractors, project managers, manufactures and project owners/clients. The registered list of contractors, consultants were obtained from CIDB directory (www.cidb.gov.my).

RESULTS AND DISCUSSIONS

A set of 300 close-ended questionnaires were distributed by postal and e-mail, company visits, Google forms and Survey Monkey. The survey was performed in 2018 – 2019 for six (6) months. From the feedback, a final set of 80 questionnaires were selected and analysed. The participants were verified in terms of their experience in IBS building projects and backgrounds, i.e., work experience, academic qualifications and managerial position (Table 1).

Table 1. Research Respondents Profiles

Background:	Profile:	Number (Percentage):
Designation	Architect	4 (5%)
	Civil Engineer	46 (58%)
	Quantity Surveyor	4 (5%)
	Others	26 (33%)
Academic qualifications	Master's Degree	2 (3%)
	Bachelor's Degree	45 (56 %)
	Diploma	22 (28 %)
	Others	11 (14%)
Working experience in the construction industry	More than 15 years	44 (55 %)
	11 to 15 years	6 (8 %)
	5 to 10 years	19 (24 %)
	Less than 5 years	14 (8%)

Table 2. Ranking of Productivity Group Factors and Characteristics

Productivity Factors and (Average RII)	Factor Group (Relative Importance Index, RII):	Characteristics of Productivity Factors:	Rank
Time (Average RII = 3.81)	Process (RII = 3.66)	"Process - …Reduction in mistakes and rework time. …Unexpected site conditions can be handled, within timeframe.…Less delayed project, higher efficiency. …Ability to apply cost factors to time commitment."	1
	Outcome (RII = 3.96)	"Outcome - …Faster completion rate / project duration. …Less total working time.…Time estimation that can be performed effectively.…Possibility to control the duration of project completion. "	
Machine (Average RII = 3.67)	Process (RII = 3.53)	"Process - …Method of construction / installation that is environmentally friendly.…Design based on codes and standard with environmental requirements using machines, …Use of machines for IBS production in a controlled environment. …Design changes that can be handled efficiently."	2
	Outcome (RII = 3.82)	"Outcome - …IBS component that are manufactured using highly automated machines.…Better quality of workmanship with energy efficiency.…Control of the construction site that is sufficient and easy.…Faster production of IBS components using machineries."	
Financial (Average RII = 3.62	Process (RII = 3.58)	"Process - …Low maintenance costs of precast components. …More transportation cost for logistics.…Cost estimation can be made more accurate. …Work efficiency with costs reduction."	3
	Outcome (RII = 3.66)	"Outcome -…Great investment for greater project value.…Shorter project length that dramatically reduce cost.…Construction waste that can be recycled as an income…Cost-effectiveness / value for resource or energy savings."	
Information (Average RII = 3.60)	Process (RII = 3.50)	"Process - …Lack of references or data on IBS successful projects in the industry.…Availability of information on IBS assists project design. …IBS information that is important to check the impact if there is a change in conditions.…IBS manufacturer's production information that is useful in conducting a comparative analysis."	4
	Outcome (RII = 3.60)	"Outcome - …IBS manufacturers that can provide reliable productivity information.…Accurate IBS information that is required when developing a conceptual estimate or schedule.…Speed that is critical information to determine the cycle times of a project. …IBS standardisation that provides information to make decisions regarding future actions."	
Manpower (Average RII = 3.57)	Process (RII = 3.50)	Process - Tasks that are beyond human capabilities…, replacement of human operators in tasks that involve hard physical or monotonous work…, Replacement of /assistance on humans for tasks performed in dangerous environments…, labour efficiency that is comparatively high.	5
	Outcome (RII = 3.65)	"Outcome - Contribution of semi- and high- skilled workers, less dependency on foreign workers, better work quality…, higher accuracy than that is provided by unskilled workers."	
Materials (Average RII = 3.37)	Process (RII = 3.29)	"Process - …High thermal mass (ability of material to store heat) of IBS components.…Low water cement ratios in IBS components.…No wet threads or off-site fabrication.…Lesser raw material consumption and possess higher concrete strength."	6
	Outcome (RII = 3.46)	"Outcome - …Easier control on the mix, placement and curing of IBS components.…More advanced material that is more environmentally acceptable.…Reduction of demand for natural resources / materials.…Energy, water and building material savings."	

The data analysis was conducted where the scores recorded against each item of IBS productivity factors by all respondents were computed. The recorded data from the questionnaire were analysed using frequency analysis and the average index analysis. Statistical analysis in this quantitative method was done with the use of IBM SPSS statistics, software for predictive analysis, version 21.0. The mean was recognized to determine the importance of each productivity group of every productivity factor as indicated by the relative importance index (RII) using the formula: Index Average = (Σ ai X xi)/ Σ xi, where ai = constant, weighing factor and xi = variables representing participants' frequency of response. Relative Importance Index (RII) technique was applied to estimate the relative necessity of various productivity factors related to IBS building projects. The five-point scale ranged from 1 (not relevant) to 5 (very relevant) was adopted using the concept of a Likert's scale and then transformed to relative importance index (RII) for each productivity factor. Table 2 presents the average index of productivity factors influencing the adoption of IBS technology in building projects as perceived by the construction stakeholders.

The data presented in Table 2 are according to the average index value of productivity factors related to the adoption of IBS technology on building projects. The factors are arranged or sorted according to their descending order of RII values and are duly ranked. The highest RII designates the most critical and important productivity factor with rank 1 and the next indicates the second most critical factor with rank 2, and so forth, as presented in Figure 1 below:

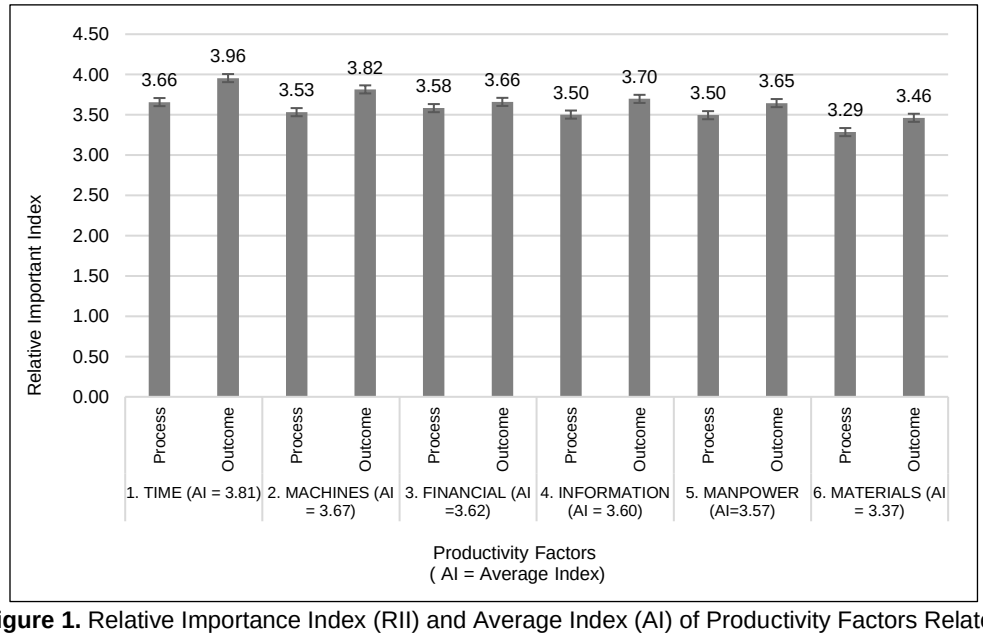


Figure 1. Relative Importance Index (RII) and Average Index (AI) of Productivity Factors Related to IBS Building Projects

Figure 1 shows the rankings of average index for all six productivity factors that influence the decision of IBS technology adoption in building projects. Each productivity factor was measured based on the respondents' perceptions related to their experience and knowledge on the adoption of IBS technology adoption. The results show that out of six productivity factors, the aspects of time were perceived as the most relevant factors of IBS technology adoption in regard to productivity. These results also reflect that time issues as the most

influential factors of IBS towards the higher level of projects' productivity with the highest average index or relative importance index, RII of 3.81. Time is also the most importance aspects of measuring the productivity which has been proven by the input and output of time give the highest productivity (AI = 3.96) compared to other productivity process and outcome groups. Generally, the time factor is important in the development and construction of building projects since the focus on time aspect in IBS technology adoption can influence the duration of building projects. This reflects that the completion of building project construction based on the actual schedule, the project can be completed according to the projected duration with a faster completion rate starting from the conceptual stage, feasibility stage, design stage, construction stage until the completion and operation of a building project. As a result, it may help to overcome the problem of project delays and ensure faster completion rate to achieve a high productivity level in building construction. Thus, the efficiency of adopting IBS technology in Malaysia can be increased as the element of time factor plays an important role in the construction industry. Respondents also perceived that time factor in the adoption of IBS leads to the reduction of total working hours which can increase the level of project productivity due to more efficient and effective time management as discovered by Arashpour et al. (2016) and Chen et al. (2018). Furthermore, with the adoption of IBS technology, unexpected time related to site conditions can be managed in terms of handling the influence of weather changes or uncertainties. For example, the use of conventional construction method during heavy raining seasons, concreting works cannot be performed since concrete's attribute is weak, particularly in obtaining the correct water to cement ratio. Therefore, with the adoption of IBS technology, the possibility of facing unexpected weather changes can be reduced and the duration of construction completion can be handled within the required timeframe of building projects. Similar to Musa et al. (2016) and Li et al. (2018a) findings, with IBS adoption in building projects, it is possible to reduce mistakes and reworks time during the construction stages as IBS panels or compartments are prefabricated in the factory or off-site. Thus, the time estimation of project completions can be performed more accurately.

The second productivity factor related to IBS technology adoption as perceived by the respondents is machine factor, with an average index of 3.67 and the second highest of productivity outcome (AI = 3.82). The functions of machines related to the productivity factors of IBS technology adoption include the manufacturing or production of building materials particularly building structures since IBS technology has to compute on the appropriate loading factor, live load, dead load and etc. The credibility of visualization during installation needs to be considered because IBS components include a high level of precision and are manufactured using highly automated machines. The method of IBS construction or installation is based on specific building codes and standards and is perceived as relevant towards productivity development as IBS technology uses highly mechanized machineries or automation for the production of IBS components in a controlled environment as discovered by Manikandan et al. (2018). In addition, by determining the element of standardization in building projects it can offer a better quality of workmanship with energy efficiency and faster production of IBS components using machinery, similar to the findings of Trung et al. (2019). The specification and requirements of IBS standards need to be emphasized to facilitate the efficient installation process of building components with the control and monitoring tasks of the construction site. Meeting the requirement of project specifications and standards through IBS technology adoption will contribute towards productivity improvements in building projects.

Accordingly, the respondents perceived that financial aspects are the third important factor in the adoption of IBS technology to increase the productivity of building projects with relative importance index, RII of 3.62. Financial factor related to the productivity of IBS building projects was considered as an important aspect in terms of cost estimation which can be made more accurate based on the standardization nature of IBS technology. Although the adoption of IBS technology in building projects requires huge initial, this investment was perceived as generating a greater return in terms of project value and its productivity. Based in the results of productivity outcomes (AI = 3.66), it shows that financial factor was considered by the respondents as important because despite a high initial capital or cost in IBS projects, the savings of labour costs can be achieved. Besides that, in relation to the financial factor of IBS projects, the respondents also considered the aspect of transportation cost, particularly on logistic costs as an important productivity factor. This result is supported by the findings of Hwang et al. (2018) and Li et al. (2018b) who discovered that the logistics matters are certainly important and crucial to supply IBS components to the construction sites. Moreover, Wuni and Shen (2020) also highlighted the benefits of the prefabricated methods that are distinctive compared to the conventional construction method as the construction waste and moulds can be recycled and reuse, respectively. Generally, construction waste which can be recycled can be a source of income to a company that can also contribute towards the project's productivity and quality of the environment.

Consequently, the respondents also perceived that the fourth productivity factor related to IBS technology adoption is in formation factor, with an average index of 3.60. In this case, the respondents considered in the adoption of IBS technology in building projects, the accuracy of project-related information is important in terms of project specification and requirements to improve the project's productivity. This is very relevant when specified information is required when developing the conceptual design of a building project with cost estimation and project scheduling as discovered by Ramaji et al. (2017). Moreover, IBS construction involves a high level of standardization that provides information based on a standard design for instance, which ease the process of project's decision-making. In addition, Abanda et al. (2017) and Lee et al. (2017) also discovered that the implementation of Building Information Modeing (BIM) complements the adoption of IBS technology in building projects. The respondents believed that IBS manufacturers play their important role to provide reliable information to meet the specifications of building projects to ensure the efficient management of construction site, logistic issues and the speed of building projects. Consequently, this situation contributes towards the productivity improvement of building projects.

The productivity of IBS project related to manpower was perceived by the respondents as the fifth important productivity factor with relative importance index, RII of 3.57. It is a common notation that the demand of IBS technology adoption is often associated with the condition of reducing the recruitment and dependency on cheaper foreign workers. However, the respondents perceived that the most important aspect of projects productivity related to manpower factor is the replacement of human operators in construction tasks that involve hard physical or monotonous work. This result is similar to the findings of Chen et al. (2020). It is discovered that the nature of IBS construction and operations requires a higher level of manpower skills as the installation methods of IBS components require precision and accuracy to meet the project's specifications and improve productivity, besides to perform better work quality. In this case, Ahmad et al. (2019) also highlighted on the specific skill

areas of building projects like the integration, coordination and assembly of construction activities in IBS adoption pertaining productivity improvements.

Lastly, the findings also reveal that materials factor was perceived as the least important as ranked at the lowest among all six factors of IBS technology adoption pertaining productivity with the relative importance index, RII of 3.37. This result reflects that prefabricated and off-site manufacturing to a certain extent is related to the material aspects of IBS adopting in relation to the productivity improvements of building projects in term of the use of lightweight materials, besides the faster installation of building components. From the perspective of sustainability, for instance IBS technology adopts building materials with a high thermal mass of IBS components thus, reducing the demand for natural resources for building materials and substituted with more environmentally friendly materials.

CONCLUSION

Based on this study, it can be concluded that productivity-related factors associated with building projects that influenced the adoption of IBS technology in building projects are based on a hierarchy or ranking as time aspect was considered as the most significant factor, followed by other factors namely machines, financial, information manpower and materials. These factors that are significant according to their hierarchy can be guiding criteria in the decision-making of IBS technology adoption in relation to productivity development in the construction industry. By referring and using these criteria in the adoption of IBS technology in managing building projects, the final outcomes of project performance will be improved in terms of the overall project quality and the productivity improvements of construction projects with the adoption of IBS technology. Hence, these criteria can be used as a guideline to assist policy makers in the construction industry to increase the productivity of building and other construction projects through the acceleration of IBS technology adoption.

REFERENCES

Abanda, F. H., Tah, J. H. M., & Cheung, F. K. T. (2017). BIM in off-site manufacturing for buildings. *Journal of Building Engineering*, *14*, 89-102.

Ahmad, S., Soetanto, R. and Goodier, C. (2019), Lean approach in precast concrete component production, *Built Environment Project and Asset Management*, Vol. 9 No. 3, pp. 457-470.

Akmam Syed Zakaria, S., & Amtered El-Abidi, K. M. (2020). Economic effects of migrant labor on industrialized building system (IBS) adoption in the Malaysian construction industry. *Architectural Engineering and Design Management*, 1-17.

Ali, M., Abas, N. H., Affandi, H. M., & Abas, N. A. (2018). Factors impeding the industrialized building system (IBS) implementation of building construction in Malaysia. *International Journal of Engineering & Technology*, *7*(4), 2209-2212.

Alinaitwe, H., Apolot, R., & Tindiwensi, D. (2013). Investigation into the causes of delays and cost overruns in Uganda's public sector construction projects, *Journal of Construction in Developing Countries*, 18(2), 33.

Aljohani, A., Ahiaga-Dagbui, D., & Moore, D. (2017). Construction projects cost overrun: What does the literature tell us? *International Journal of Innovation, Management and Technology*, *8*(2), 137.

Allen, E., & Iano, J. (2019). *Fundamentals of building construction: materials and methods*. John Wiley & Sons.

Antunes, R., & Gonzalez, V. (2015). A production model for construction: A theoretical framework. *Buildings*, *5*(1), 209-228.

Arashpour, M., Wakefield, R., Abbasi, B., Lee, E. W. M., & Minas, J. (2016). Off-site construction optimization: Sequencing multiple job classes with time constraints. *Automation in construction*, *71*, 262-270.

Azam Haron, N., Abdul-Rahman, H., Wang, C., & Wood, L. C. (2015). Quality function deployment modelling to enhance industrialised building system adoption in housing projects. *Total Quality Management & Business Excellence*, *26*(7-8), 703-718.

Baharuddin, M. N., Bahardin, N. F., Zaidi, M. A., Yusof, M. R., & Lokman, I. (2015, October). Identification of Critical Factors and Difficulties for Industrialised Building System (IBS) Formwork in Malaysian Construction Industry–A Literature Review. In *2nd International Conference on Science and Social Research (CSSR 2015)*.

Banihashemi, S., Hosseini, M. R., Golizadeh, H., & Sankaran, S. (2017). Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries. *International Journal of Project Management*, *35*(6), 1103-1119.

Cao, X., Li, X., Zhu, Y., & Zhang, Z. (2015). A comparative study of environmental performance between prefabricated and traditional residential buildings in China. *Journal of Cleaner Production*, *109*, 131-143.

Chel, A., & Kaushik, G. (2018). Renewable energy technologies for sustainable development of energy efficient building. *Alexandria Engineering Journal*, *57*(2), 655-669.

Chen, J. H., Hsu, S. C., Chen, C. L., Tai, H. W., & Wu, T. H. (2020). Exploring the association rules of work activities for producing precast components. *Automation in Construction*, *111*, 103059.

Chen, J. H., Yang, L. R., & Tai, H. W. (2016). Process reengineering and improvement for building precast production. *Automation in Construction*, *68*, 249-258.

Cho, K., Shin, Y. S., & Kim, T. (2017). Effects of half-precast concrete slab system on construction productivity. *Sustainability*, *9*(7), 1268.

CIDB (2016). Assessed from: http://www.cidb.gov.my/index.php/my/

Construction Industry Development Board Malaysia (CIDB) 2015. Construction Industry Transformation Programme 2016-2020.

Dabla-Norris, M. E., Guo, M. S., Haksar, M. V., Kim, M., Kochhar, M. K., Wiseman, K., & Zdzienicka, A. (2015). *The new normal: A sector-level perspective on productivity trends in advanced economies*. International Monetary Fund.

de Soto, B. G., Agustí-Juan, I., Hunhevicz, J., Joss, S., Graser, K., Habert, G., & Adey, B. T. (2018). Productivity of digital fabrication in construction: Cost and time analysis of a robotically built wall. *Automation in Construction*, *92*, 297-311.

Dixit, S., Mandal, S. N., Sawhney, A., & Singh, S. (2017). Relationship between skill development and productivity in construction sector: A literature review. *International Journal of Civil Engineering and Technology*, *8*(8), 649-665.

Durdyev, S., & Ismail, S. (2016). On-site construction productivity in Malaysian infrastructure projects. *Structural Survey*. Vol. 34 Iss 4/5 pp. 446 – 462

Esa, M. R., Halog, A., & Rigamonti, L. (2017). Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *Journal of Material Cycles and Waste Management*, *19*(3), 1144-1154.

Faghirinejadfard, A., Mahdiyar, A., Marsono, A. K., Mohandes, S. R., Omrany, H., Tabatabaee, S., & Tap, M. M. (2016). Economic comparison of industrialized building system and conventional construction system using building information modeling. *Jurnal Teknologi*, *78*(1).

Fateh, M. A. M., Mohammad, M. F., & Abd Shukor, A. S. (2017). Review in formulating the standard form of contract for Industrialized Building System (IBS) construction approach in Malaysia. In *MATEC Web of Conferences* (Vol. 87, p. 01001). EDP Sciences.

Finkel, G. (2015). *The economics of the construction industry*. Routledge.

Fleischman, R. B., & Seeber, P. K. (2016). New construction for resilient cities: The argument for sustainable low damage precast/prestressed concrete building structures in the 21st century. *Scientia Iranica. Transaction A, Civil Engineering*, *23*(4), 1578.

Forsythe, P. (2018). Extending and operationalizing construction productivity measurement on building projects. *Construction Management and Economics*, *36*(12), 683-699.

Gao, S., Low, S. P., & Nair, K. (2018). Design for manufacturing and assembly (DfMA): a preliminary study of factors influencing its adoption in Singapore. *Architectural Engineering and Design Management*, *14*(6), 440-456.

Hajdukiewicz, M., Goggins, J., de la Torre, O., Holleran, D., & Keane, M. M. (2019). An automated standard-based life cycle quality inspection methodology for smart precast concrete solutions in buildings. *Journal of Structural Integrity and Maintenance*, *4*(3), 123-134.

Halil, F. M., Mohammed, M. F., Mahbub, R., & Shukur, A. S. (2016). Trust attributes to supply chain partnering in industrialised building system. *Procedia-Social and Behavioral Sciences*, *222*, 46-55.

Haslinda, A. N., Xian, T. W., Norfarahayu, K., Hanafi, R. M., & Fikri, H. M. (2018, April). Investigation on the factors influencing construction time and cost overrun for high-rise building projects in Penang. In *Journal of Physics: Conference Series* (Vol. 995, p. 012043).

Hiyassat, M. A., Hiyari, M. A., & Sweis, G. J. (2016). Factors affecting construction labour productivity: a case study of Jordan. *International Journal of Construction Management*, *16*(2), 138-149.

Holla, R., Anant, S., Muhammad, M. A., Periwal, A., & Kapoor, A. (2016). Time, cost, productivity and quality analysis of precast concrete system. *International Journal of Innovative Science, engineering and technology*, *3*(5), 252-257.

Holla, R., Anant, S., Muhammad, M. A., Periwal, A., & Kapoor, A. (2016). Time, cost, productivity and quality analysis of precast concrete system. *International Journal of Innovative Science, engineering and technology*, *3*(5), 252-257.

Hong, J., Shen, G. Q., Li, Z., Zhang, B., & Zhang, W. (2018). Barriers to promoting prefabricated construction in China: A cost–benefit analysis. *Journal of cleaner production*, *172*, 649-660.

Hwang, B. G., Shan, M., & Looi, K. Y. (2018). Key constraints and mitigation strategies for prefabricated prefinished volumetric construction. *Journal of Cleaner Production*, *183*, 183-193.

Jarkas, A.M., (2012). Analysis and measurement of buildability factors influencing rebar installation labor productivity of in situ reinforced concrete walls, *Journal of Architectural Engineering*, 18(1), pp.52-60.

Jia, M., Komeily, A., Wang, Y., & Srinivasan, R. S. (2019). Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications. *Automation in Construction*, *101*, 111-126.

Kamali, M., & Hewage, K. (2017). Development of performance criteria for sustainability evaluation of modular versus conventional construction methods. *Journal of cleaner production*, *142*, 3592-3606.

Kong, L., Li, H., Luo, H., Ding, L., & Zhang, X. (2018). Sustainable performance of just-in-time (JIT) management in time-dependent batch delivery scheduling of precast construction. *Journal of cleaner production*, *193*, 684-701.

Lee, J., & Kim, J. (2017). BIM-based 4D simulation to improve module manufacturing productivity for sustainable building projects. *Sustainability*, *9*(3), 426.

Li, C. Z., Xu, X., Shen, G. Q., Fan, C., Li, X., & Hong, J. (2018a). A model for simulating schedule risks in prefabrication housing production: A case study of six-day cycle assembly activities in Hong Kong. *Journal of cleaner production*, *185*, 366-381.

Li, L., Li, Z., Wu, G., & Li, X. (2018b). Critical success factors for project planning and control in prefabrication housing production: A China study. *Sustainability*, *10*(3), 836.

Luo, L. Z., Mao, C., Shen, L. Y., & Li, Z. D. (2015). Risk factors affecting practitioners' attitudes toward the implementation of an industrialized building system: A case study from China. *Engineering, Construction and Architectural Management*., Vol. 22 No. 6, pp. 622-643.

Malmqvist, T., Nehasilova, M., Moncaster, A., Birgisdottir, H., Rasmussen, F. N., Wiberg, A. H., & Potting, J. (2018). Design and construction strategies for reducing embodied impacts from buildings–Case study analysis. *Energy and Buildings*, *166*, 35-47.

Manikandan, M., Adhiyaman, M., & Pazhani, K. C. (2018). A study and analysis of construction equipment management used in construction projects for improving productivity. *International Research Journal of Engineering and Technology*, *5*(3).

Molavi, J., & Barral, D. L. (2016). A construction procurement method to achieve sustainability in modular construction. *Procedia engineering*, *145*, 1362-1369.

Musa, M. F., Mohammad, M. F., Yusof, M. R., & Mahbub, R. (2015). The way forward for industrialised building system (IBS) in Malaysia. In *InCIEC 2014* (pp. 163-175). Springer, Singapore.

Musa, M. F., Yusof, M. R., Mohammad, M. F., & Samsudin, N. S. (2016). Towards the adoption of modular construction and prefabrication in the construction environment: A case study in Malaysia. *Journal of Engineering and Applied Sciences*, *11*(13), 8122-8131.

Naoum, S.G. (2016), Factors influencing labor productivity on construction sites: A state-of-the-art literature review and a survey, *International Journal of Productivity and Performance Management*, Vol. 65 No. 3, pp. 401-421.

Nasir, H., Haas, C. T., Rankin, J. H., Fayek, A. R., Forgues, D., & Ruwanpura, J. (2012). Development and implementation of a benchmarking and metrics program for construction performance and productivity improvement, *Canadian Journal of Civil Engineering*, 39(9), 957-967.

Navaratnam, S., Ngo, T., Gunawardena, T., & Henderson, D. (2019). Performance review of prefabricated building systems and future research in Australia. *Buildings*, *9*(2), 38.

Noor, S. R. M., Yunus, R., Abdullah, A. H., Nagapan, S., Syahir, S. M., & Mazlan, S. (2018). Insights into The Adoption of Lean Management in Industrialised Building System (IBS) Implementation: The Drivers and Challenges. *International Journal of Engineering & Technology*, *7*(3.23), 22-31.

Ofori, G. (2015). Nature of the construction industry, its needs and its development: A review of four decades of research. *Journal of construction in developing countries*, *20*(2), 115.

Pan, M., & Pan, W. (2019). Determinants of adoption of robotics in precast concrete production for buildings. *Journal of Management in Engineering*, *35*(5), 05019007.

Pheng, L. S., & Meng, C. Y. (2018). *Managing productivity in construction: JIT operations and measurements*. Routledge.

Pozin, M. A. A., Nawi, M. N. M., Lee, A., & Azman, M. N. A. (2018). Improving Communication in Managing Industrialised Building System (IBS) projects: virtual environment. *Malaysian Construction Research Journal*, *2*(2), 1-13.

Rahim, A. A., & Qureshi, S. L. (2018). A Review of IBS Implementation in Malaysia and Singapore. *Planning Malaysia*, *16*(6).

Rahim, F. A. M., Yusoff, N. S. M., Chen, W., Zainon, N., Yusoff, S., & Deraman, R. (2016). The challenge of labour shortage for sustainable construction. *Planning Malaysia*, *14*(5).

Ramaji, I. J., Memari, A. M., & Messner, J. I. (2017). Product-oriented information delivery framework for multistory modular building projects. *Journal of Computing in Civil Engineering*, *31*(4), 04017001.

Ramli, M. Z., Hanipah, M. H., Zawawi, M. H., Abidin, M. Z. Z., Zainal, N. A., & Halim, N. S. A. (2016). Cost comparison on industrialized building system (IBS) and conventional method for school construction project. *Journal of Scientific Research and Development*, *3*(4), 95-101.

Rashidi, A., & Ibrahim, R. (2017). Industrialized construction chronology: The disputes and success factors for a resilient construction industry in Malaysia. *The Open Construction & Building Technology Journal*, *11*(1).

Razkenari, M., Fenner, A., Shojaei, A., Hakim, H., & Kibert, C. (2020). Perceptions of offsite construction in the United States: An investigation of current practices. *Journal of Building Engineering*, *29*, 101138.

Rumane, A. R. (2016). *Quality management in construction projects*. Crc Press.

Tam, V. W., Fung, I. W., Sing, M. C., & Ogunlana, S. O. (2015). Best practice of prefabrication implementation in the Hong Kong public and private sectors. *Journal of Cleaner Production*, *109*, 216-231.

Trung, N. T., Shahgoli, A. F., Zandi, Y., Shariati, M., Wakil, K., Safa, M., & Khorami, M. (2019). Moment-rotation prediction of precast beam-to-column connections using extreme learning machine. *Structural Engineering and Mechanics*, *70*(5), 639-647.

Tsehayae, A.A. and Fayek, A.R. (2016), System model for analysing construction labour productivity, *Construction Innovation*, Vol. 16 No. 2, pp. 203-228.

Ullah, K., Abdullah, A. H., Nagapan, S., Suhoo, S., & Khan, M. S. (2017, December). Theoretical framework of the causes of construction time and cost overruns. In *IOP Conference Series: Materials Science and Engineering* (Vol. 271, No. 1, p. 012032). IOP Publishing.

Wang, S., Tang, J., Zou, Y. and Zhou, Q. (2019), Research on production process optimization of precast concrete component factory based on value stream mapping, *Engineering, Construction and Architectural Management*, Vol. 27 No. 4, pp. 850-871.

Wang, Z., & Hu, H. (2017). Improved precast production–scheduling model considering the whole supply chain. *Journal of computing in civil engineering*, *31*(4), 04017013.

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

Wu, P., Xu, Y., Jin, R., Lu, Q., Madgwick, D., & Hancock, C. M. (2019). Perceptions towards risks involved in off-site construction in the integrated design & construction project delivery. *Journal of Cleaner Production*, *213*, 899-914.

Wu, Z., Ann, T. W., & Poon, C. S. (2019). An off-site snapshot methodology for estimating building construction waste composition-a case study of Hong Kong. *Environmental Impact Assessment Review*, *77*, 128-135.

Wuni, I. Y., & Shen, G. Q. (2020). Critical success factors for modular integrated construction projects: a review. *Building Research & Information*, *48*(7), 763-784.

Xue, H., Zhang, S., Su, Y., & Wu, Z. (2018). Capital cost optimization for prefabrication: A factor analysis evaluation model. *Sustainability*, *10*(1), 159.

Yu, X., Dosi, G., Grazzi, M., & Lei, J. (2017). Inside the virtuous circle between productivity, profitability, investment and corporate growth: An anatomy of Chinese industrialization. *Research Policy*, *46*(5), 1020-1038.

Yun, S., Cho, H., Tae, Y., Ahn, B., An, S.H. and Huh, Y., (2012). Productivity analysis of steel works for cost estimation of public projects in Korea, *KSCE Journal of Civil Engineering*, 16(1), pp.1-7.

Zabihi, H., Habib, F., & Mirsaeedie, L. (2013). Definitions, concepts and new directions in Industrialized Building Systems (IBS), *KSCE Journal of Civil Engineering*, 17(6), 1199-1205.

Zakaria, S.A.S, Gajendran, T., Skitmore, M., & Brewer, G. (2018). Key factors influencing the decision to adopt industrialised building systems technology in the Malaysian construction industry: an inter-project perspective. *Architectural Engineering and Design Management*, *14*(1-2), 27-45.

ENHANCING PRODUCTIVITY IN CONSTRUCTION THROUGH THE APPLICATION OF MECHANISATION, AUTOMATION AND ROBOTICS TECHNOLOGIES

Rohana Mahbub
Centre of Studies for Quantity Surveying, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Malaysia.

Abstract
Productivity enhancement through the use of emerging technologies such as mechanisation, automation and robotics is a significant aspect in addressing the need to improve the performance of the construction industry. This research aims to appraise and develop a broad base perspective on productivity improvement through the use of automation and robotics technologies in context of several selected areas where these technologies are more predominantly used; including automation of design, planning and costing; the application of off-site automation and robotics technologies through IBS and prefabrication; and the use of task-specific, dedicated machines in specialised on-site construction work. The findings indicate that for the perceived productivity improvement for the three selected areas, construction industry players are aware of the benefits of using these technologies in terms of increasing productivity and making the construction process more efficient. However, the perceived benefits of time reduction, cost savings, higher quality products and process efficiency improvement differ according to the areas under investigation, with automation of design, planning and costing consistently agreed upon as the main productivity advantage. As the cost of technologies becomes cheaper and more affordable over time, the economic benefits that can be reaped through the use of these technologies may further encourage its adoption in construction, which could result in achieving a more efficient and sustainable construction industry of the future.

Keywords: *Productivity; mechanisation; automation and robotics technologies; construction industry.*

INTRODUCTION

The application of technology has changed the landscape of most industries throughout the world, including the construction industry. As construction is one of the most significant sectors in the Malaysian economy, an increase in the efficiency and productivity of the construction industry could generally enhance the overall economic outlook of the nation. In Malaysia, the construction industry recorded value of gross output was RM204.4 billion in 2017 with an annual growth rate of 7.2% per annum, before contracting by 44.9% in the second quarter of 2020 due to the Covid-19 pandemic which has impacted economies globally (Department of Statistics Malaysia, 2020). Emerging technologies in the construction industry that supports data automation and documentation in design, planning, scheduling, costing and project management; and tools and machines that facilitate the installation and construction of building structures, if appropriately implemented, would enable the whole construction process to be performed more effectively. The use of innovative technologies has a direct impact on employers, workers and their organisations, especially in terms of contributing to the more efficient use of capital and resources which can ultimately increase quality and productivity.

The need to improve the performance of the construction industry and to address the inherent problems relating to productivity and workmanship performance, construction

processes and delivery, quality of materials and products, organisation and supply chain management, have advocated the need for innovation and adoption of new construction methods and technologies in the industry. This has paved the way for increasing use of innovative technologies in the Malaysian construction industry, as addressed under the Construction Industry Transformation Programme 2016-2020 Strategic Thrust 3 where productivity is stated to be "the primary engine of growth towards Malaysia's high income target. As a vital sector to the nation's advancement, the construction industry will lead with high productivity levels through efficient adoption of new technologies and modern practices coupled with high-skilled, highly paid workforce" (CITP, 2020). Its focus area 6 includes aligning with changing technologies, which corresponds with exploring a more immersive use of various innovative technologies including Industrialised Building Systems (IBS) and prefabrication, Building Information Modelling (BIM), mechanisation, automation and robotics, and modular construction . An important consideration in the implementation of these technologies is in ensuring that the process is comprehensively planned and managed so that the technologies adopted for the construction projects are appropriate and can be economically feasible and sustainable in terms of the resource management and execution.

SIGNIFICANT TERMINOLOGIES AND CONCEPTS

Technology

The concept of technology has been defined in many ways by numerous authors (Drewer, 1982; Simkoko, 1992; Ganesan and Kelsey; 2006; Cena and Wood, 2016) but basically it embodies the following elements: 1) Knowledge (including knowledge of techniques and human skills; expertise; organisation and management methods); 2) Tools, techniques or methods and 3) Product or process (materials and equipment resources/elements). Knowledge can be considered as ***soft technology*** whilst skills and tools can be considered as ***hard technology***. As such, if the concept of technology is superimposed on the various facets of the construction process, all the elements of technology applicable at the different stages of construction would emerge.

Mechanisation, Automation and Robotics

Mechanisation can be defined as the implementation of equipment or machines for carrying out a process or the act of enhancing the control of equipment or plants with advanced technology, usually involving electronic hardware. Simply described, this is basically *equipping a process with machinery*. ***Automation*** is a self-regulating process performed by using programmable machines to carry out a series of tasks. In effect, the machinery used may be so technologically advanced that it would render the whole process *automatic*.

Robotics is the usage of task specific, dedicated robots performing discrete tasks on simplified building technology. The robots would effectively take over from humans in performing a series of tasks, either inter-related or otherwise, to enable standardised work to be performed efficiently with minimal or no human intervention. The level of technology sophistication embedded within each stage can be described as the definition spectrum, that is, the lower end (mechanisation) or the higher end of technology application (robotics), as illustrated in Figure1.

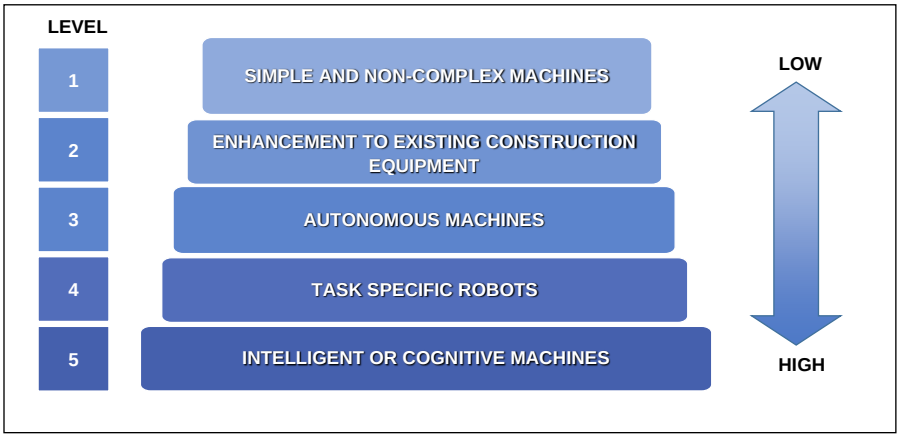


Figure1. Definition Spectrum: Level of Mechanisation, Automation and Robotics Implementation versus Degree of Technology Application

For the purpose of this paper, construction automation and robotics is defined as the use of self-governing mechanical and electronic devices that utilises intelligent control to carry out construction tasks and operations automatically. The construction work tasks and operations are regulated through programmable controls and sensors; set up as a series of individual computer-controlled or robotic equipment with electro-mechanical links (Mahbub & Humphreys, 2006; Mahbub, 2008).

Productivity

Productivity is generally defined as a ratio of a volume measure of output to a volume measure of input use. The objectives of productivity measurement could include: 1) Technology -where productivity growth is measured to trace technical change; 2) Efficiency - where a production process has achieved the maximum amount of output that is physically achievable with current technology, given a fixed amount of inputs; 3) Real cost savings – where productivity measurement is in identifying cost savings in production; 4) Benchmarking production processes – where typically, the relevant productivity measures are expressed in physical units (e.g. cars per day, passenger-miles per person) and highly specific; 5) Living standards – where measurement of productivity is a key element towards assessing standards of living, such as through per capita income (OECD Manual, 2001). Achieving productivity therefore requires efficient use of labour, complete and accurate drawings, no delays, quality workmanship, and safe work. (Hughes & Thorpe, 2014).

CONSTRUCTION MECHANISATION, AUTOMATION AND ROBOTICS IMPLEMENTATION

Factors to Consider in Facilitating the Use of Mechanisation, Automation and Robotics

In order to reinforce the concept of productivity improvement through the use of the technologies, there is a need to briefly highlight the barriers to implementation and how this could be overcome to facilitate their implementation in the construction industry (based on research by Mahbub, 2008, 2012 and 2017). The subsequent section will then further discuss the correlation between technology application and productivity.

Economic and Cost

The main barrier is the high cost incurred and the need for a substantial financial commitment for the required investment in research & development for the implementation of these technologies in real terms. As some of the machines are not fully developed with the relevant technologies still evolving, keeping up with the advances in technology can prove costly for construction firms. For the construction industry, the primary motivation in adopting new technologies is the prospect of gaining a competitive advantage through lower input costs. The willingness for construction firms to invest will happen if they feel that there are greater economic advantages to be gained by using these technologies, which will differ according to the construction industry climate and practices in different countries. In terms of diffusing the costs of acquiring and maintaining these technologies, large international construction companies may have the economic capacity for taking these technologies on board. In Malaysia, adoption of these technologies is more prevalent in larger companies such as Gamuda and Sime Darby. Globalisation and participation in international projects is a niche with which the construction industry can take further advantage of automation and robotics technologies, as these technologies might be a worthwhile investment if there is a need to gain the competitive edge by operating more efficiently while reducing construction time.The economies of scale that can be gained through the widening of the operating market and repetitive use of the technologies will enable higher investments to be made in acquiring the technologies.

Structure and Organisation of the Construction Industry

The fragmentary nature and the size of the construction industry make it unreceptive to revolutionary changes. For construction automation and robotics to work, there is a need for compatibility with the existing design, management capabilities, labour practices and site operations. The multi-point responsibility, where different organisations are responsible for the different phases of construction, makes it difficult for automation and robotics applications to be effective. For these technologies to work in construction there is a need for a higher degree of integration within the phases; to enable the design process to facilitate the use of these technologies by incorporating repetitiveness and constructability within the design itself, and to ensure that this is followed through to the construction process. Also, with single point responsibility, greater research and development commitments can be made, which will be more economically viable as the technology's investment is taken up by a single construction firm rather than many. However, automation of a single phase, such as automation of design through the use of CAD, is quite commonplace, and it is when automation and robotics is to be applied throughout the construction life cycle that multi-point responsibility becomes a hindrance. There are also opportunities for greater implementation of automation and robotics technologies within specific areas of construction, such as design or specialist sub-contracting work. Automation of the design, planning or costing process is quite commonplace in the construction industry nowadays as software and products are readily available with high capacity-to-cost ratio; thus, providing consultants with the tools needed to produce designs or schedules economically and efficiently. The use of automation and robotics technologies on-site may be more applicable if emphasis is placed on the assembly and installation of components.

Construction Product and Work Processes

Nearly every construction product is unique in that it is custom designed and constructed and is built to last for a long time. The work processes is also complex and non-repetitive, generally performed over a large area or site and the work performed is peculiar to that site i.e. each project is site specific. As work is closely related to the site, its execution is influenced by locational conditions such as weather, labour supply and local building codes; and the project also requires a long time to complete. The complexity and non-standardisation of the construction product is an inhibitor to greater automation and robotics applications. The difficulty in control and maintenance if these technologies are used in the "open" and unstructured environment of the construction site, such as uncertain terrains in which the machines have to work, also mitigate against greater implementation. For the technologies to work in construction, there is a need to re-evaluate the work processes and working conditions or environment in the production of a structure or building. This may include encouraging simplified work processes on site by bringing the main part of components manufacturing to factory-controlled settings, as in the case of prefabrication or Industrialised Building System. As such, the components can be mass-produced under the more efficient factory environment using automation and robotics technologies, with on-site work dedicated to mostly installation only.

Technology

Developments of construction robots are technologically difficult because of the nature of the construction work processes itself. The cheapest option is usually to adapt these technologies from other industries, but the obvious differences between work processes across the industries form a crucial barrier. To work in construction, the robots need to be robust, flexible, with high mobility and versatility. To overcome this, there is a need to review how construction tasks are performed to encourage repetition, and the construction environments need to be much more structured and controlled. Technology is therefore very much related to the structure and work process in the construction industry. That is why in areas of construction where repetition is prevalent, such as concreting, steelwork positioning, masonry and finishing, automation and robotics is more highly used compared to other areas. The use of modular, standardised construction products and greater off-site prefabrication also facilitates the use of these technologies as the work processes involved are usually modified and regulated to suit the technology attributes.

Culture and Human Factor

The different work cultures between countries also play an important role as barriers to implementation. In some countries there are institutional barriers as well as active workers unions that look upon these technologies as a way to replace the workers. For robots to become more commonplace on the work site, a new breed of workers is needed; who has a strong academic background with special training in areas of robotics engineering and control. To maintain a high utilisation rate for construction automation and robotics, there is a need to ensure an adequate supply of appropriately skilled operators to operate the sophisticated machinery. Training needs to be provided, for formal learning of new skills (such as programming) and onsite upgrading of skills. However, other than the cost factors to be considered in re-training, there is also the consideration of workers not willing to participate,

possibly the older generations, who might not be interested or might not have the aptitude to learn the necessary skills to handle sophisticated equipment. In countries like Malaysia where the workforce depends on migrants to meet the demand of the market, there is also the possibility of communication barriers or unwillingness of employers to spend money on re-training of these workers. The culture and human factor may be different from one country to another, but factors to consider include institutional barriers, government labour policies, labour and safety regulations and workers union. In most developing countries, labour-intensive practices are still commonplace because of the cost factor, i.e. it is cheaper to hire man rather than invest in a machine. The large number of small-scale contractors operating in these countries may also be another reason impeding the infiltration of advanced technologies, as these contractors usually operate on a relatively small turnover and would not have the revenue to invest in major cost expenditure, such as acquiring the relatively expensive machineries. Government policies advocating the adoption of new technologies and modern practices to increase productivity, for example as asserted in CITP,will further facilitate the use of these technologies in construction.

Technology Application and Productivity

If technology application within construction is readily accepted by the industry and suitable mechanisation, automation and robotics technologies are extensively implemented throughout the construction phases, this would enable the whole construction process to be performed more effectively and thus increase productivity. Hughes and Thorpe (2014) studied the factors affecting construction productivity on building construction projects in the state of Queensland, Australia; and concluded that the top three primary factors affecting the productivity of the Australian construction industry were rework, poor supervision, and incomplete drawings. Pheng et al. (2016) investigated Singapore's issues of low construction productivity and concentrates on how the utilisation of Organisational Learning in labour effectiveness activities, Building Information Modelling (BIM), Constructability Appraisal System (CAS) and Buildable Design Appraisal System (BDAS), can prompt productivity improvement in construction.

In terms of an example of specific technology application onsite, Safa et al. (2016) studied the use of automated rebar tying machine to improve construction labour productivity and to reduce the probability of accidents associated with rebar yard workers. It was concluded that rebar tying is labour intensive and costly, with a high learning curve that confines capability and the speciality to a high level of construction field involvement. The study has shown that the programmed rebar tying machine could bring down the learning curve, subsequently decreasing preparation times and limit excess schedules. The findings demonstrate that the programmed rebar tying machine could possibly save time and money and reduce economic liabilities whilst enhancing labour productivity.

If the numerous advantages of technology application in construction work processes can be harnessed to improve efficiency and effectiveness of the overall work performance, then this can result in higher quality products and greater productivity. Enhancing productivity could also have economic benefits, which in turn may encourage further use of the relevant emerging technologies. However, to effectively measure productivity within the construction industry based on technology application, the scope has to be specific to its use within specific phases of construction, such as in design, planning, scheduling, costing, on-site construction

or project management. This research takes a more holistic approach, in that the productivity measure is based on *factors facilitating technology* as variables, from the perspective of industry players. As this is the first phase preliminary research on the subject area, the more generic approach is taken to explore the overview of the industry in terms of productivity related to automation and robotics technologies, before a more comprehensive approach could be conducted in subsequent phases of the research for measuring productivity in the specific areas of construction.

RESEARCH METHODOLOGY

The first phase quantitative method as described in this paper forms the basis of the research, where primary data is gathered through a questionnaire survey. The focus of this phase of research is to develop a broad base perspective on whether the use of automation and robotics technologies would enhance productivity in context of several selected areas where these technologies are more predominantly used. These selected areas include 1) automation of design, planning and costing (either through BIM or other design software) 2) the application of off-site automation and robotics technologies through IBS and prefabrication 3) the use of task-specific, dedicated machines in specialised on-site construction work. As this is a preliminary study, the sampling frame is relatively small targeting 100 respondents, with 38% response rate. These respondents include consultants, developers and contractors who have used the technologies in one form or other. Section A of the questionnaire, on the demographic information, sets out questions on background information regarding the respondents, including type of business, sectors of the industry in which they operate, gross annual revenue and number of years established. Sections B, C and D of the questionnaire outline questions on the three selected areas, in terms of the technologies used within these areas, the duration in which the technologies have been used, measure of effectiveness and whether there is an increase in productivity through the use of the stated technologies. The questionnaire consists of a combination of structured and semi-structured questions to better facilitate the data analysis process and augment on the comprehensiveness of the data collection and comparison methods.

DATA ANALYSIS AND DISCUSSION ON FINDINGS

In terms of the demographic information, the spread of business type is fairly equal, where 36% are consultants, 28% are developers and 36% are contractors; involved in mostly residential (45%) and commercial (35%) work. The majority of respondents at 47% have been established between 11 to 15 years, whilst others are relatively new organisations, being established 5 years and below at 25% and 6-10 years at 28%. Most of the respondents use some form of automation technologies, especially in the use of software for automation of design, planning and costing (60%), the use of machineries for off-site prefabrication of components (25%), and to a lesser extent, the use of robotics technologies and highly specialised machineries for factory work processes and specific work areas. Awareness on enhanced productivity through the application of technology was gauged from the perspective of the respondents based the ordinal 5-point Likert scale. The mean index score indicates that the majority of respondents are aware of the benefits of using the technologies in terms of improving productivity and making the construction process more efficient. Awareness also comes from regular periodic dissemination of information by governing bodies such as CIDB and various government policies that encourage the usage of these technologies. This phase

of research seeks to establish a broad base perspective only and true measure of productivity will be done in the second phase of the research, through a more comprehensive modelling and comparisons of input and outputs benchmarked against pre- and post-technology usage.

The percentage of perceived productivity improvement, evaluated against time reductions, cost savings, higher quality products and overall efficiency of work process from the three focus areas of 1) automation of design, planning and costing, 2) the application of off-site automation and robotics technologies through IBS and prefabrication, and 3) the use of task-specific, dedicated machines in specialised on-site construction work, are as shown in Figure 2, Figure 3 and Figure 4 below.

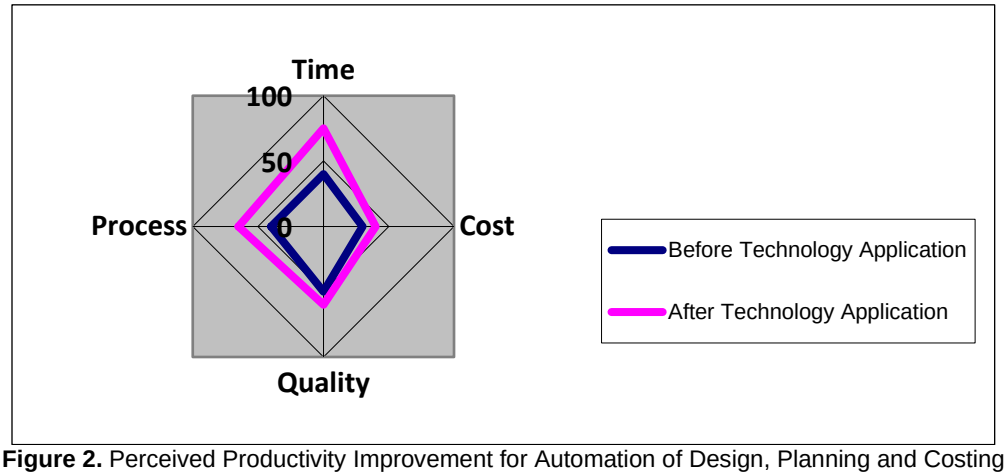


Figure 2. Perceived Productivity Improvement for Automation of Design, Planning and Costing

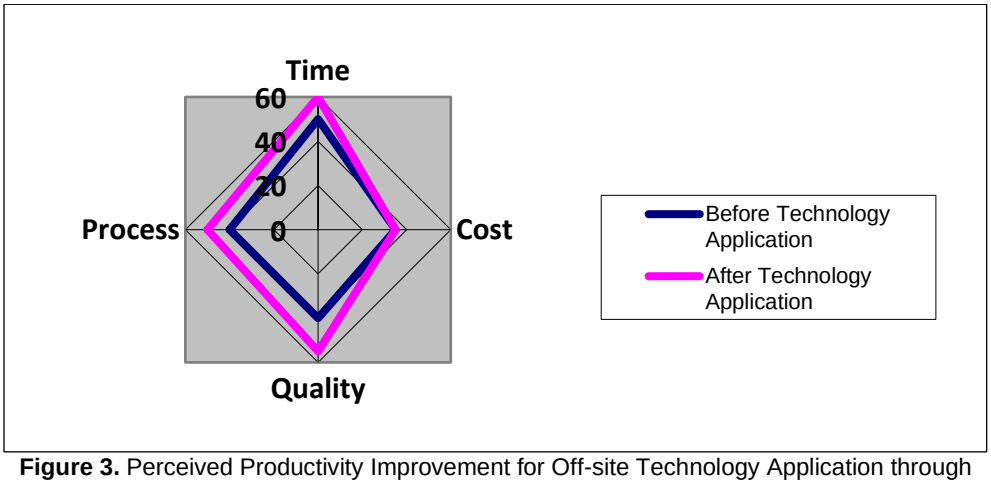


Figure 3. Perceived Productivity Improvement for Off-site Technology Application through Prefabrication

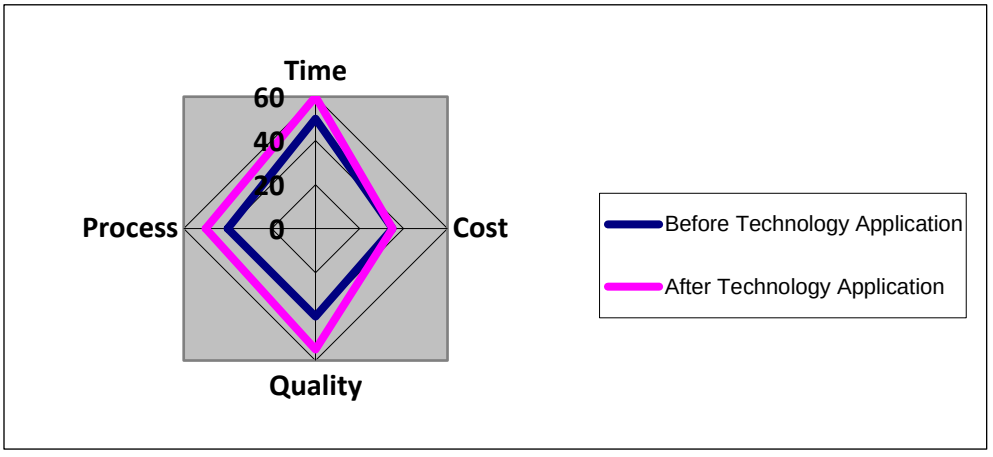


Figure 4. Perceived Productivity Improvement for On-site Task Specific Dedicated Machines

Based on the findings, the majority of respondents, at this point in time, do not find major cost savings in the enhancement of productivity through the application of technology in most areas under study, with no cost savings for off-site prefabrication and on-site task specific machineries, and very low (10%) cost savings perceived for design, planning and costing. This may be due to the fact that, aside from the high capacity to cost ratio of some software used in design, planning and costing, the technologies are still expensive to acquire, especially in terms of economic returns for initial cost outlay of most automation and robotics technologies. The advantages gained in the long term through economies of scale may prevail over this perception, but in the short term, the technologies are not seen to give economic advantages to the users. Time reduction and overall improved efficiency of work processes are consistently agreed upon as the main productivity advantages to be gained through the use of technologies. As the cost of acquiring the technologies for automation of design, planning and costing is seen to be considerably cheaper than off-site prefabrication and on-site machineries, overall, the perceived productivity improvement for this phase of construction is significantly higher compared to the other areas.

CONCLUSIONS

Recognising the productivity improvements that can be gained through the application of technologies in construction is an important aspect to consider towards improving the overall efficiency of the construction industry. This is in line with the aspirations of the government towards nation building by increasing productivity levels through the efficient adoption of new technologies and modern practices coupled with high-skilled, highly paid workforce. As emerging technologies in the construction industry that supports data automation and construction of building structures are becoming readily available, it is an appropriate time for the Malaysian construction technology to embrace these technologies to harness the advantages of higher productivity and efficient use of capital and resources whilst addressing sustainability aspects in construction.

The findings of this research highlighting the perceived productivity improvement for the three selected areas of automation of design, planning and costing; the application of off-site automation and robotics technologies through IBS and prefabrication; and the use of task-specific, dedicated machines in specialised on-site construction work, has confirmed that

construction industry players are aware of the benefits of using the technologies in terms of improving productivity and making the construction process more efficient. However, the perceived benefits of time reduction, cost savings, higher quality products and process efficiency improvement differ according to the areas under investigation, with automation of design, planning and costing consistently agreed upon as the main productivity advantage. As the costs of technologies becomes cheaper and more affordable over time, the economic benefits that can be reaped through the use of these technologies may further encourage its adoption in construction, which consequently will enable the construction industry to be more efficient and sustainable in the long term.

REFERENCES

Cena, C. and Wood, D. (2016) What Is Technology? - Definition & Types <Retrieved from https://study.com/academy/lesson/what-is-technology-definition-types.html, 1 August 2020>.

Department of Statistics Malaysia, Official Portal (2020) Annual Economic Statistics 2018 : Construction <Retrieved from https://www.dosm.gov.my, 1 August 2020>

Department of Statistics Malaysia, Official Portal (2020) Quarterly Construction Statistics: Second Quarter 2020 < Retrieved from https://www.dosm.gov.my, 1 August 2020>

Drewer, S. (1982) The Transfer of Construction Techniques to Developing Countries: The Role of Expatriate Architects, Consultants and Contractors, LCHS Publications, Sweden

Ganesan, S. and Kelsey, J. (2006) Technology Transfer: International Collaboration in Sri Lanka, *Construction Management and Economics, Volume 24, Issue 7*, pp 743-753

Hughes, R and D. Thorpe, D. A review of enabling factors in construction industry productivity in an Australian environment, Constr Innovation, 14 (2) (2014), pp. 210-228

Mahbub, R (2017), Enhancing the Adoption of Mechanization and Automation Technologies for Small Medium Enterprises (SMEs) Contractors in Malaysia, *Proceedings of the 5th Annual International Conference on Architecture and Civil Engineering (ACE 2017)*, Singapore, 251 – 254

Mahbub, R (2008), An Investigation into the Barriers to the Implementation of Automation and Robotics Technologies in the Construction Industry, PhD Thesis, Queensland University of Technology, Australia < eprints.qut.edu.au/26377/1/Rohana_Mahbub_Thesis.pdf>

Mahbub, R and Humphreys, M. (2006), Barriers to Construction Automation and Robotics Implementation in Australia and Japan. In Brown, K, Hampson, K and Brandon, P (eds) *Clients Driving Construction Innovation: Moving Ideas into Practice*, CRC Australia and CIB publication, Icon.Net Pty Ltd

OECD Manual (2001) Measuring Productivity < Retrieved from http://www.oecd.org/sdd/productivity-stats/2352458.pdf, 1 August 2020>

Pheng, L.S., Shang, G. Foong, W.K. (2016) Enhancing Construction Productivity Through Organizational Learning in The Singapore Construction Industry, *International Journal of Construction Project Management, Volume 8, Issue 1*, pp. 71-89

Safa M., Cardenas, J.G., Leblanc, D.G., Rose, D., Shahi, A. (2016) Improving Construction Labor Productivity Using Automatic Rebar Tying Gun, *Proceedings of the 33rd International Symposium on Automation and Robotics in Construction (ISARC 2016)*, pp. 1–5.

Simkoko, E.E. (1992) Managing International Construction Projects for Competence Development within Local Firms, *International Journal of Project Management, Volume 10, Issue 1*, pp 12-22

PRODUCTIVITY MEASURING TOOL TO EVALUATE PRODUCTIVITY PERFORMANCE OF BUILDING CONSTRUCTION PROJECTS BETWEEN INDUSTRIALISED BUILDING SYSTEM (IBS) AND CONVENTIONAL METHOD OF CONSTRUCTION

Intan Diyana Musa[1], Mohammad Faedzwan Abdul Rahman[1], Maria Zura Mohd. Zain[1], Zuhairi Abd. Hamid[2] and Gerald Sundaraj[2]
[1]Centre For Advance Construction Technology and Innovation, Construction Research Institute of Malaysia (CREAM)
[2]Construction Industry Development Board, Malaysia (CIDB)

Abstract
This paper aims to identify the productivity difference between conventional construction method and non-conventional construction method or Industrialised Building System (IBS). The study conducted a case study through questionnaires to measure productivity rate of building construction projects using IBS and conventional building system using Productivity Measuring Tool (PMT). The productivity rate of building construction projects was measured at two working stages namely overall work stage and construction work stage. The findings suggest that IBS has a higher productivity rate than that of conventional building system at both overall and construction work stages as it uses minimum number of manpower and requires a shorter time to complete the project. The study provides some valuable evidence that the adoption of IBS in building construction projects is important in productivity improvement of building construction projects and simultaneously will improve productivity of the construction industry. The study concludes by proposing the implementation of PMT to measure productivity of building construction projects as one of the initiatives to serve as a benchmark and guidance for industry players to measure and monitor productivity of building construction projects to drive the productivity of the industry towards excellence.

Keyword: *Productivity; Productivity Measurement; Industrialised Building System; Conventional; Construction Industry.*

INTRODUCTION

Construction is one of the largest sectors in the world economy. It is axiomatic that the construction industry is a vital component in enhancing a nation's productivity, and it plays a significant role in the economic growth of the nation. The industry accounts for about 6% of global GDP and is expected to continue growing with estimated revenues of $15 trillion by 2025 (Philipp Gerbert, 2016). However, it is still struggling to evolve in its approaches as other industries, causing its productivity to lag behind. According to the McKinsey Global Institute (MGI), the gap between the construction industry and other industries amounts to $1.6 trillion in terms of monetary value (Barbosa et al., 2017).

However, the industry is suffering deep-seated problems in terms of productivity for decades and although it has been discussed in numerous studies, there appears to be no silver-bullet solution to put the industry among other productive sectors. One of the reasons behind this unimpressive track record is that the industry has been hesitant about fully embracing the latest technological opportunities.

The industry has huge potential for productivity improvements, thanks to new and innovative construction technologies. Construction technologies have become the main driver of construction industry to improve efficiency and productivity, as well as to give the industry a dramatic productivity boost. They have the potential to improve productivity by shifting many aspects of construction works away from conventional construction sites and into factories with off-site manufacturing. Additionally, the introduction of non-conventional methods of construction such as the use of structural steel, system formwork, pre-casting techniques, pre-fabrication and component manufacture, which will reduce the number of labour hours required can increase productivity of the industry (Naoum, Dejahang, Fong, & Jaggar, 2006).

Industrialised Building System is recognised as one of the construction technologies to replace the conventional method of construction that can boost the productivity of the construction industry. The industry has long been acquainted with IBS and yet it has not been adopted at the scale needed for productivity improvement which is hardly news considering the number of cheap labours available, especially in developing countries such as Malaysia. According to Chan & Kaka (2015), the construction industry remains one of the few most labour intensive industries in the developed world. Failure to innovate and adopt technology is a festering problem that seems to be holding the industry back. While the other sectors have fully adopted innovative technologies, construction refrained its craft method of operation, resulting the productivity of the industry to fall further and further behind.

It is worth mentioning that before productivity can be improved, there is a need to measure and quantify the existing situation. Productivity measurement is a systematic process which can continuously measure and compare performances to gain information that will help an organisation to take action to improve its performance (Alinaitwe, Mwakali, & Hansson, 2005). This study introduces the latest tool known as Productivity Measuring Tool (PMT) to measure productivity of building construction projects in Malaysia. PMT is used in this study to measure productivity of building construction projects using either conventional method of construction or non-conventional method of construction i.e., IBS and compares the productivity difference between the two methods of construction. This is an evidence-based study that proves IBS is needed to increase the productivity of the industry while at the same time reducing the amount of site labour involved.

CONVENTIONAL AND NON-CONVENTIONAL METHODS OF CONSTRUCTION

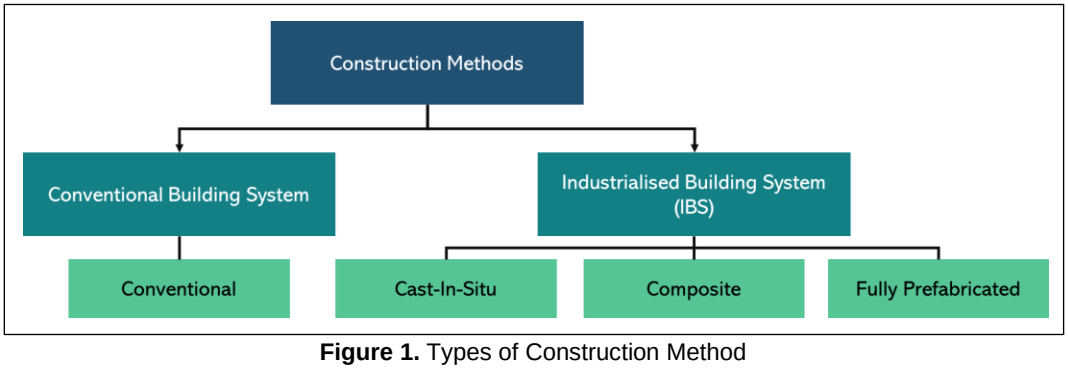


Figure 1. Types of Construction Method

Generally, there are two methods of construction namely, conventional building system and Industrialised Building System or commonly known as IBS. Conventional building system is a traditional construction method that has been used over the years. It is a system of current practice using in-situ concreting with temporary wooden formwork. Building construction projects that use conventional building system basically fabricate their building components on site through the processes of timber or plywood formwork installation, steel reinforcement, and cast in-situ. Conventional building system is very labour-intensive and has relatively low speed of construction time as compared to non-conventional building system (Haron, Hassim, Kadir, & Jaafar, 2005).

Non-conventional building system is also known as Industrialised Building System (IBS) is a construction method that produces building components in a controlled environment before being transported, positioned, and assembled at construction site (Abd Hamid, Mohamad Kamar, & Alshawi, 2011). IBS is also defined as a construction system that is built using pre-fabricated components that are systematically manufactured using machine, formworks, and other forms of mechanical equipment, and then delivered to site for assembly and erection (Baharuddin, Rahman, & Omar, 2006). There are six types of IBS (Construction Industry Development Board Malaysia (CIDB), 2020):

1. Precast concrete system – a form of concrete prepared, cast, and cured off-site by using reusable moulds. Precast concrete components are joined to other components to produce a complete structure.
2. Metal framing system – a fast-structural system designed for panel construction and continuous walls, individually standing low-rise buildings, and high separation walls.
3. Reusable formwork system – consists of prefabricated modules with a metal frame and is covered by material with the desired surface structure (steel, aluminium, timber, etc.) on the application side (concrete).
4. Blockwork system – the construction of concrete or concrete blocks larger than standard clay or concrete bricks. The blocks are rectangular and made of concrete with hollow cores. They are produced in an automated manufacturing process that consists of mixing materials, laying the material in mould, and are later transferred to the curing operation. Blockwork consists of lightweight block and concrete masonry block.
5. Timber framing system – forms a skeletal structure to support the weight and the number of loads carrying member.
6. Innovative system – a range of innovations that implements the use of IBS.

IBS aims to improve productivity and quality of construction work through the adoption of better construction machinery, equipment, technology, and materials.

PRODUCTIVITY PERFORMANCE OF BUILDING CONSTRUCTION PROJECTS

Productivity has been the subject of much debate in the construction industry in many countries for many decades. The concept of productivity is not well understood in construction. It is complex and difficult to understand. However, productivity is growing even more important now in the construction industry. Productivity is important to be used as benchmarking to search for the best practices that will lead to excellent performance of an organisation or in this context, construction project.

Productivity is generally defined as the ratio of output to input. Higher productivity means gaining more output with the same or lesser amount of input (Malaysia Productivity Corporation (MPC), 2019). Construction Industry Development Board Malaysia (CIDB) and Construction Research Institute of Malaysia (CREAM) recently developed a tool called Productivity Measuring Tool (PMT) specifically to measure productivity of building construction projects. PMT identifies total gross floor area constructed as the output of productivity in building construction projects and number of manpower and length of construction period as the input. In other words, PMT defines productivity as the total gross floor area constructed per total man-days where man-day is described as the total number of manpower times with the total length of construction period. PMT focuses on man-day as the input as labour productivity improvements in a labour-intensive sector will have a bigger overall effect.

The PMT consists of productivity measurement calculation (Equation 1) for the purpose of measuring and calculating productivity rate of a certain building construction project, and a grading system to grade and rank construction projects according to the productivity rates as shown in Table 1 (CIDB Malaysia, 2020).

Equation 1: Productivity Equation

$$\text{Productivity Rate} = \frac{\text{Total gross floor area (sq ft)}}{\text{Total man-days}}$$

$$= \frac{\text{Total gross floor area (sq ft)}}{\text{Total number of manpower} \times \text{Total length of the construction period (days)}}$$

Table 1. Grading System Used to Rank the Productivity Rates Measured

GRADES	PRODUCTIVITY RATE, *x* (sq. Ft./man-day)
A	$x \geq 10.0$
B	$7.5 \leq x < 10.0$
C	$5.0 \leq x < 7.5$
D	$2.5 \leq x < 5.0$
E	$0 \leq x < 2.5$

This research aims to identify the productivity difference between two construction methods, conventional building system and industrialised building system (IBS), using PMT. The objectives of this research are to measure the productivity of building construction projects using the PMT developed and compare the productivity difference between conventional building system and IBS.

RESEARCH METHODOLOGY

This research used a case study method through questionnaires to measure productivity rate of building construction projects using IBS and conventional building system. Questionnaires were distributed to collect at least 90 building construction projects. The questionnaire includes eight sections to provide sufficient information for the study. The first section is the main section which is compulsory, and it includes two sub sections: respondent background and project background. Personal information of the respondent background

includes name, contact number and organisation. Project background gathered information on the project name, IBS Score (if any), project sector, project type, number of working days per month, construction period in months, GFA of the project, total no of house units, unit size, and types of IBS used in the project (limited to IBS projects only). The other seven sections gathered information on different types of building system namely, precast concrete, metal framing, reusable formwork, blockwork, timber framing, innovative, and conventional. The respondents were asked to only answer sections according to its type of building system used in their projects. Each section gathered the information on number of manpower involved and duration of each construction stage involved. Different types of building system have different construction stages as shown in Table 2 below.

Table 2. Types of Stages Involved in Different Building Systems

BUILDING SYSTEMS	STAGES
Precast concrete	Design Production Installation Architectural works & finishing
Metal framing	Design Production Logistics Installation Architectural works & finishing
Reusable formwork	Design Installation Construction Architectural works & finishing
Blockwork	Design Production Construction Architectural works & finishing
Timber framing	Design Installation Logistics Construction Architectural works & finishing
Innovative	Design Production Logistics Installation Architectural works & finishing
Conventional	Design Construction Architectural works & finishing

Table 3. Data Gathered for Case Study via Questionnaires

BUILDING SYSTEMS	NO. OF PROJECTS
Industrialised Building System	
Precast concrete	3
Metal framing	7
Reusable formwork	5
Blockwork	3
Timber framing	4
Innovative	6
Conventional Building System	**28**
Total building construction projects	**56**

A response rate of 100% was achieved for this research where a total of 90 building construction projects were gathered but only 56 data were valid (62% validity). The other 34 data were invalid as they are insufficient to measure the productivity rate. The following Table 3 summarises the number of projects successfully collected for every type of building system.

The productivity rates of these 56 building construction projects were then measured using the PMT developed at two work stages which are:

1) overall work stage that takes into consideration all construction stages including design, production, logistics, installation, construction as well as architectural works and finishing; and
2) construction work stage that only considers works at construction site which are installation, construction as well as architectural works and finishing.

RESEARCH ANALYSIS

In total, there are 56 building construction projects collected for this research, whereby 28 of them are IBS projects and the rest 28 projects are conventional projects. The average productivity rate for each project was measured using PMT. The average productivity rates for both IBS projects and conventional projects were then measured at overall work stage and construction work stage to identify the productivity difference between the two methods of construction.

Table 4 below tabulates the average productivity rates and grades of both building systems at overall work stages and construction work stages.

Table 4. Average Productivity Rates of IBS and Conventional Method of Construction for Overall and Construction Work Stages

WORK STAGES:	OVERALL		CONSTRUCTION	
Building Systems	**Average Productivity Rates, x (sq. ft./man-day)**	**Grade**	**Average Productivity Rates, x (sq. ft./man-day)**	**Grade**
IBS	8.25	B	19.54	A
Conventional	5.27	C	6.96	C

Table 4 shows that IBS has higher average productivity rate than conventional at both work stages. At overall work stage, the average productivity rate of IBS is 8.25 sq. ft/man-day while conventional has average productivity rate of 5.27 sq. ft./man-day. When the average productivity rate was measured at construction work stage, its value for IBS is 19.54 sq. ft./man-day whereas conventional only achieved 6.96 sq. ft./man-day.

The average productivity rate of IBS construction method achieved grade B at overall work stage and its grade showed an improvement to grade A when its average productivity rate was only measured at construction work stage. Meanwhile, although the average productivity rate of the conventional construction method at construction work stage is higher than that at overall work stage, its grade did not improve and remained at grade C. This shows that the increment is not as significant as that of IBS construction method.

This study also measured the average productivity rate of 6 types of IBS at overall work stage and construction work stage. From 28 IBS projects, there are 3 projects that are using

precast concrete system, 7 projects using metal framing system, 5 projects using reusable formwork system, 3 projects using blockwork system, 4 projects using timber framing systems and 6 projects using innovative system.

Table 5. Average Productivity Rates of Different Types of Building Systems at Overall and Construction Work Stages

WORK STAGES:	OVERALL		CONSTRUCTION	
Building Systems	**Average Productivity Rates, x (sq. ft./man-day)**	**Grade**	**Average Productivity Rates, x (sq. ft./man-day)**	**Grade**
Precast Concrete	7.81	B	16.95	A
Metal Framing	6.49	C	15.85	A
Reusable Formwork	9.68	B	21.56	A
Blockwork	3.39	D	12.02	A
Timber Framing	5.85	C	13.43	A
Innovative	7.98	B	20.22	A
Conventional	5.27	C	6.96	C

Table 5 summarises the average productivity rates of each type of IBS at overall and construction work stages. At overall work stage, reusable formwork system has the highest average productivity rate of 9.68 sq. ft./man-day followed by innovative system with average productivity rate of 7.98 sq. ft./man-day. Precast concrete system comes in third with an average productivity rate of 7.81 sq. ft./man-day followed by metal framing system with an average productivity rate of 6.49 sq. ft./man-day. Next, timber framing system achieved an average productivity rate of 5.85 sq. ft./man-day and blockwork system achieved the lowest average productivity rate which is 3.39 sq. ft./man-day.

Table 5 also presented the average productivity difference between each type of IBS and conventional building system. Conventional building system has an average productivity rate of 5.27 sq. ft./man-day at overall work stage and only blockwork system has lesser average productivity rate. However, when the average productivity rates were measured at construction work stage, the average productivity rates of all types of IBS grew significantly as compared to the conventional construction method. For, reusable formwork system, the average productivity rate increased to 21.56 sq. ft./man-day. Meanwhile, innovative system has gained its average productivity rate at construction work stage to 20.22 sq. ft./man-day, followed by precast concrete system with an average productivity rate of 16.95 sq. ft./man-day. Likewise, the average productivity rate of metal framing system increased to 15.85 sq. ft./man-day. The average productivity rate of timber framing system also improved at construction work stage which is 13.43 sq. ft./man-day as well as the average productivity rate of blockwork system which is 12.02 sq. ft./man-day. Meanwhile, the average productivity rate of conventional building system at construction work stage is 6.96 sq. ft./man-day.

When measured at overall work stage, none of IBS projects managed to achieve grade A of the average productivity rate. Only 3 types of IBS have average productivity rates of grade B which are precast concrete system, reusable formwork system, and innovative system. Meanwhile, metal framing system and timber framing system have average productivity rates of grade C, and blockwork system achieved the lowest average productivity rate (grade D) which is lower than that of conventional construction method (grade C). However, when measured at construction work stage, the average productivity rates of all types of IBS

improved significantly and achieved grade A while conventional construction method remained its grade C.

Table 4 and Table 5 indicate that IBS is a more productive building system as compared to conventional building system and it especially gains productivity at site as compared to conventional construction method. This is because IBS uses less manpower at site and construction works at site can be completed fast as shown in the following Table 6. Table 6 indicates that the average no of manpower of IBS is less than that of conventional which are 68 pax and 75 pax, respectively. IBS also has a shorter average construction period as compared to conventional which are 10 months and 13 months, respectively. Based on PMT, this study proves that when man-day is less i.e., manpower and construction period are less, to construct a certain size of GFA, productivity of the project is high.

Table 6. Average No of Manpower and Construction Period of IBS and Conventional Construction Methods

Construction Methods	Average No of Manpower (pax)	Average Construction Period (Months)
IBS	68	10
Conventional	75	13

DISCUSSION

This study provides evidence that IBS is more productive than conventional building system and IBS especially gains productivity at site. This is due to the fact that IBS reduces number of manpower at site and shorten construction time of a project at site. Othuman Mydin, Sani, & Phius (2014) identified the strengths and weaknesses of IBS and conventional building system through a case study and it indicated that IBS could cut down on overall construction period by saving up to 30% in time compared to the conventional method. The case study also showed that the respondents agreed that construction works at site can be completed fast as manufacturing and assembling of precast components are done earlier in factories. Alaghbari, Salim, Kadir, & Asonway (2015) pinpointed that high productivity of structural elements and the use of moulds, new techniques and technology are the some of the factors that contribute to the high speed of IBS as compared to conventional. Additionally, IBS is relatively less labour-intensive at construction sites as compared to conventional building system which requires more manpower to complete works such as formwork fabrications and installations, reinforcement bars fabrications and installations, as well as concrete placements (Othuman Mydin et al., 2014). On top of that, Hanafi, Abdullah, Razak, & Nah (2015) also concluded that construction site productivity improvement, reduce time for in-situ concrete mixing activities, and reduce overall construction duration are one of many benefits of IBS.

CONCLUSION AND RECOMMENDATIONS

This study concludes that non-conventional construction method or IBS is a more productive construction method as compared to the conventional construction method. As most of building components of IBS are prefabricated offsite, IBS simplifies construction works at site and therefore requires less manpower and time to complete construction project at site. As defined by PMT, the productivity rate of a construction project depends on number of manpower involved and the time to complete the construction project. The smaller number

of manpower and time needed to complete a construction project, the more productive the project is. PMT developed by CIDB Malaysia and CREAM is a good starting point to measure productivity rates of building construction projects. The tool can be used by the industry to keep track of its productivity and serve as benchmark and guidance to improve productivity of building construction projects as well as to act as a driver to bring productivity of construction industry towards excellence.

As IBS is evidently more productive than the conventional method, this study recommends the industry to fully adopt and implement IBS in building construction projects to boost productivity of the industry and put the industry among other best productive industries. Government needs to play its role to enforce all government and private construction projects to implement construction technology, especially IBS, to help raise the productivity of construction industry. IBS can help eliminate the poor image of work in construction industry as "dirty, difficult, and dangerous", and guide the industry to be on the right track towards productivity excellence. As one of the most vital industries, a productive construction industry benefits the whole world. Advances in productivity contribute to economic growth and improve the quality of life.

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REFERENCES

Abd Hamid, Z., Mohamad Kamar, K. A., & Alshawi, M. (2011). *Industrialised Building System (IBS): People, Strategy and Process*. Construction Research Institute of Malaysia (CREAM).

Alaghbari, W., Salim, A., Kadir, M. R. A., & Asonway, A. (2015). Factors Affecting Speed of Industrialized Building System (IBS) Projects in Malaysia. *2nd International Conference on Built Environment in Developing Countries (ICBEDC 2008)*, (June), 418–431.

Alinaitwe, H., Mwakali, J., & Hansson, B. (2005). Labour Productivity in the Building Industry. *Understanding the Construction Business and Companies in the New Millenium. Volume I*, 210–220. Retrieved from http://www.irbnet.de/daten/iconda/CIB6202.pdf

Baharuddin, A., Rahman, A., & Omar, W. (2006). Issues and Challenges in The Implementation of Industrialised Building Systems in Malaysia. In *Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006)* (pp. 5–6).

Chan, P., & Kaka, A. (2015). Construction Productivity Measurement: A Comparison of Two Case Studies, (January 2004).

CIDB Malaysia. (2020). *Road Towards Productivity Excellence: Productivity of Building Construction using Industrialised Building System (IBS)*. (R. Ibrahim, R. Md.Jusoh, M. Z. Mohd Zain, I. D. Musa, M. F. Abdul Rahman, N. Mat Kilau, … Y. Mohamed, Eds.).

Construction Industry Development Board Malaysia (CIDB). (2020). *Report on Residential Housing Cost: A Comparison Between Industrialised Building System (IBS) and Conventional System*.

Green, B. (2016). *Productivity in Construction: Creating a Framework for the Industry to Thrive*. Chartered Institute of Building (CIOB).

Hanafi, M. H., Abdullah, S., Razak, A. A., & Nah, F. M. (2015). Contractors ' Perspective on the Benefits of Implementing Industrialized Building System (IBS), *6*(1), 44–51.

Haron, N. A., Hassim, S., Kadir, M. R. A., & Jaafar, M. S. (2005). Building Cost Comparison Between Conventional and Formwork System: A Case Study of Four-storey School Buildings in Malaysia. *American Journal of Applied Sciences 2*, *2*(4), 819–823.

Kadir, M. R. A., Lee, W. P., Jaafar, M. S., Sapuan, S. M., & Ali, A. A. A. (2006). Construction performance comparison between conventional and industrialised building systems in Malaysia. https://doi.org/10.1108/02630800610712004

Malaysia Productivity Corporation (MPC). (2019). *26th Productivity Report 2018/2019*.

Naoum, S., Dejahang, F., Fong, D., & Jaggar, D. (2006). A New Framework for Determining Productivity Factors on Construction Sites, 109–121.

Othuman Mydin, M. A., Sani, N. M., & Phius, A. F. (2014). Investigation of Industrialised Building System Performance in Comparison to Conventional Construction Method. *MATEC Web of Conferences*, *10*, 1–6. https://doi.org/10.1051/matecconf/20141004001

Philipp Gerbert, S. C. C. R. and A. R. (2016). Shaping the Future of Construction: A Breakthrough in Mindset and Technology. *World Economic Forum (WEF)*, (May), 1–64. Retrieved from https://www.bcgperspectives.com/Images/Shaping_the_Future_of_Construction_may_2016.pdf.

PRODUCTIVE AND EFFICIENT CONSTRUCTION PUBLIC HOUSING PROJECTS USING INDUSTRIALISED BUILDING SYSTEM (IBS)

Maria Zura Mohd. Zain[1], Zuhairi Abdul Hamid[2], Intan Diyana Musa[1], Mohamad Faedzwan Abdul Rahman[1], Nurulhuda Mat Kilau[1], Natasha Dzulkalnine[1], Mohd Ikhwan Abdullah[1], Syed Hamad Naguib Syed Azmi[1] and Gerald Sundaraj[2]

[1]Construction Research Institute of Malaysia (CREAM), Level 29, Sunway Putra Tower, No. 100 Jalan Putra, 54200 Kuala Lumpur.

[2]Construction Industry Development Board (CIDB) Malaysia, Level 23, Sunway Putra Tower, No. 100 Jalan Putra, 54200 Kuala Lumpur.

Abstract

Productivity is a key driver for economic growth and prosperity in every country. Construction industry is one of the most essential industries which contributed to the biggest economic growth. The pursuit of productivity growth requires an understanding of the factors affecting productivity. Measuring productivity growth in construction has been a classic challenge, predominantly due to the scarce of reliable output deflators. The aims of this research to give a fresh perspective to the construction productivity research agenda. This is to be corresponding with the demands in the construction industry and its transforming nature in the Malaysian construction industry. To achieve the aims of the study, 6 case studies had been conducted on the public housing program in Klang Valley. From the case studies, the productivity rate had been measured and analysed. The productivity rate as higher as 12.7 sqft/man-day had been achieved for the Industrialised Building System (IBS) project. Besides that, to formulate efficient construction housing projects, focus group discussion (FGD) has been formed to discuss current issues and challenges in the construction industry to increase the productivity of the industry. From the analysis of FGD found that with emerging application of technologies, especially Building Information Modelling (BIM) become the main support for IBS project to be more effective.

Keywords: *Productivity; Efficient; Public Housing Project; Industrialised Building System (IBS); Building Information Modelling (BIM).*

INTRODUCTION

The construction industry plays a significant role in support the economic development of the country. It contributes more than to the economic perspective but also promotes growth, provide employment to the masses, and act as a linkage between economy and other industries (Dixit et al., 2019). The construction sector also is the engine of growth for a country and creates a flow of services and goods with other sectors (Chia et al., 2014). On the other hand, the construction industry as one of the most essential sectors needs to sustain the rapid evolution for the benefit of the society, environment, and economy.

An insight on the factors underlying productivity growth across economy, including construction industry, is important for helping policymakers and practitioners to take effective action that would support to increase the performance of productivity. A plausible way for understanding the drivers for productivity growth is to draw up cross-country productivity comparisons for the construction sector, though it is often plagued by difficulties in obtaining adequate and consistent data (Abdel-Wahab and Vogl, 2011).

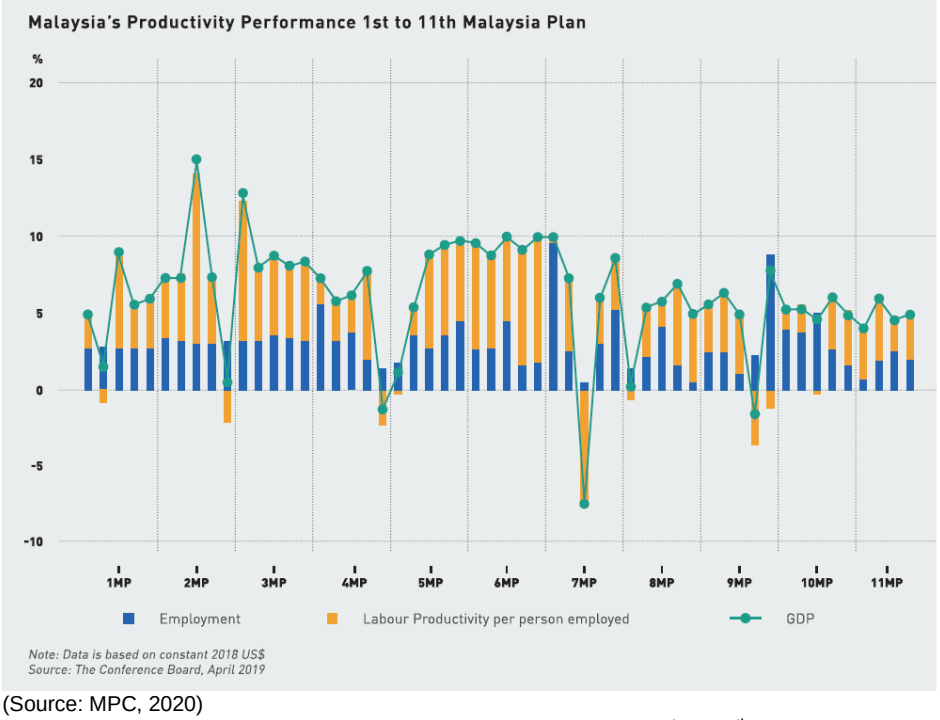
In global economy GDP, total annual revenues almost $10 trillion and added value of $3.6 trillion, the construction industry accounts for about 6% of global GDP and expected to

keep on growing with estimated revenues of $15 trillion by 2025. Besides that, Construction also cooperates with other sectors of buildings, infrastructure or other constructed assets. For example, Residential housing alone accounts for 38% of global construction volume, followed by 32% of transport, energy, and water infrastructure, 18% institutional and commercial buildings, and 13% of industrial sites (World Economic Forum 2016). However, according to the McKinsey Global Institute (MGI), the construction sector are still struggling to progress rapidly compared with other industries and there is a $1.6 trillion opportunity to close the gap (Filipe Barbosa et al., 2017).

Productivity in construction industry has much debate in the for decades. The concept of productivity is poorly recognised in construction; mostly perceived it as complex and difficult to understand. The nature and inherent features of the construction industry and constructed items, cause of difficult to define, measure, interpret and compare indicators of construction productivity it the main reasons. But still, productivity is growing and valuable in today's construction industry (CIDB Malaysia 2020).

PRODUCTIVITY LANDSCAPE IN MALAYSIA

In Malaysia, increasing productivity leads to prosperity for the nation. It is thus grateful to all stakeholders to seize opportunities in the form of new technology or knowledge in order to improve productivity to create resilience. The building of resilient organisations enables flexibility in its operations, concomitantly delivering the result results in a world that continues to be overwhelmed by volatility, complexity and ambiguity (MPC, 2020).



(Source: MPC, 2020)

Figure 1. Malaysia's Productivity Performance 1st to 11th MP

Productivity has long been the go-to reference for a country or sector's efficient use of resources and potential. Malaysia has benchmarked its productivity levels against both international standards as well as individual countries, as key growth sectors which identified to expand upon and guided by the Comprehensive 5-year national development plans that also known as "Malaysia Plan" (MP). 1st MP has been established in the year 1966-1970, while the11th MP established in the year 2020. MPC (2020) published data of Malaysia Gross Domestic Product (GDP) growth achieved 6.2 percent per annum from 1966-2019, its productivity growth wear down in recent years, pertaining to a competitive standpoint (Figure 1). In 2019, MPC (2020) also reported that the construction sector productivity remains the least productive at RM45,293 in terms of value-added per employment (3.3%) and indicated the sector's high reliance on low-skilled labour. For the reason, of high dependency of labour in the construction sector, the productivity in construction reduced by 1.6% in Q1 2020 due to Movement Control Order (MCO) obligated to control the spread of pandemic Covid-19. As a matter of fact, Covid-19 affected all sectors globally including, economy, education, social etc. Therefore, high-productivity nations need to quickly adapt to the changes in macroeconomic challenges, as well as fundamental shifts brought on by technological innovations.

However, this condition is also contrasting with the thinking that higher productivity growth should be attained by following Malaysia's transition to a predominantly capital-driven economy compared to labour-driven. Construction industry sector still reliance on unskilled labours, which prevent the companies from investing in technologies such as advanced machinery and equipment to improve productivity. IBS is the modern method of construction as an innovative process of building construction using the concept of mass-production of industrialised systems, produced at the factory or on-site within controlled environments, thus including logistic and installation aspect of it, executed in proper coordination with systematic planning and integration in the construction projects (Hamid et al., 2008). In that event, IBS able to lead to the increased productivity in construction projects.

CONSTRUCTION PRODUCTIVITY

The construction industry is an essential industry to the society, environment, and economy. It is one of the first businesses that humankind developed and essential as other businesses rely on the construction industry to provide and maintain their accommodations, plants, and infrastructures. Construction is vital to society as it determines where and how almost everyone lives, works, and plays (World Economic Forum, 2016). The construction industry is one of the most labour-intensive industries worldwide. Construction labours significantly contributed to the project performance and quality, considering them as a valuable asset for each construction company. These workers have a significant risk of injuries and fatalities (Ghodrati et al., 2018). Therefore, labour productivity and safety are important in the construction industry.

Construction projects involved long-term investment and long-term risks as states by (Chia et al., 2014). The construction sector is the first to be suspended at the first sign of economic downturn, and the last to be revived during the economic upturn. The flexible demand for new construction work, together with the long life and expense of construction output, in which lead to long periods of recession for the construction sector whenever a general business cycle is experienced. However, with today's economic changes, not all

demands by construction organization influenced market forces. The government accounted for most of the infrastructure construction procured and used its development programmes as an influential tool for economic stabilisation to compensate for the cyclical changes in private sector building activity.

In Malaysia, there is a regulatory interference in the construction industry through the introduction of the Industrialized Building System (IBS) Strategic Plan in 1999 and IBS Roadmap 2003–2010. Both regulatory interferences aimed to work towards the adoption of the system in both private and public sectors. All government projects were mandated to contain IBS content of not less than 70 IBS Score by 2008. In 2018, the government mandated and encouraged all the private construction projects to be at least achieved 50 IBS Score with project construction that worth RM 50million. This intervention by the government is mainly to urge the construction industries in Malaysia to accelerate the adoption of IBS and implicitly in order to increase the performance of constructions' productivity, as a whole.

Productivity in IBS projects had been discussed lengthy including the labour usage, equipment and machineries, projects time taken and also the constructed gross floor area. IBS construction projects include various procedures-technological and managerial-for the production and assembling of these elements in the construction site (Raheleh R. et al., 2015). This construction system with the combination and assembly of components that promotes simplified and minimise on-site works. Productivity performance will increase with the aid of technology such as equipment and machinery used in the IBS construction project (Razak, F and Awang, H., 2014). This statement also support by Azman, N.S. et al. (2018) which is equipment, machinery and labours is the main factors to increase the productivity performance. Time taken to complete the certain construction projects from design phase until getting the certificate of practical completion (CPC) will portray the performance of productivity of building projects predominant in IBS.

Table 1. Average Annual Growth Rates of GDP, Construction, Construction Employment, GDP Per Capita and Construction Productivity (1970–2011)

Year	GDP	Population	GDP per Capita	Construction	Construction Employment	Construction Productivity
1970 – 2011	6.53	2.39	3.88	5.80	6.65	0.00
1975 – 1985	6.36	2.48	3.65	7.79	10.65	–2.62
1985 – 1998	6.38	2.72	3.38	5.19	4.41	–0.01
1998 – 2009	3.91	2.13	1.65	–0.47	2.21	0.35

Source: Chia et al., 2014

The implementation of IBS moving away from labour-intensive work towards more factory-built for components and assemblies. Table 1 indicates the average construction employment that had reduced to 2.2% for the cycle of 1998–2009 compared to 4.4% of the 1985–1998 cycle. Labour productivity also improved from –0.01% in the 1985–1998 cycle to 0.4% in the 1998–2009 cycle. The economic growth of Malaysia in the period of 1998–2009 was fuelled by aggregate demand, especially from the public sector, through a few stimulus packages during that time. The stimulus packages included the construction of low- and medium-cost houses; maintenance and refurbishment of public amenities such as schools, hospitals and roads; reviving abandoned housing projects; improving public infrastructure; and the implementation of new infrastructure projects. The average annual growth rate of GDP and GDP per capita for the 1998–2009 cycle weakened to 3.9% and 1.7%, respectively

after the intensive growth of 6.4% and 3.4% in the previous cycle. Despite the marginal contraction of construction activity (–0.5%) and increase in construction employment (2.21%), the construction labour productivity still recorded a growth of 0.4% during this period (Chia et al., 2014).

Construction Productivity Measurement

There is no standard method to define the productivity for construction operations. However, generally, there is three productivity measurement used in the command construction industry. First productivity measurement in the scope of an economic model. Productivity is defined as total factor productivity (TFP) or Multi-factor Productivity (MFP), which is the ratio between total outputs expressed in dollars and total inputs also expressed in dollars. The total inputs include labour, materials, equipment, energy, and capital. This definition is applied by policy-maker agencies to formulate the policy and evaluate the state of the economy of the country. On the other hand, the second productivity measurement is the project-specific model that describes productivity as total productivity (TP), which referred to as the ratio between the outputs expressed in a physical unit (for example square feet) and the inputs expressed in dollars. The inputs include labour, equipment, materials, and management. This model is more accurate, and it can be applied by both governmental agencies and private sector. While the third is the activity-oriented model that defines productivity as labour productivity, which is the ratio between outputs expressed in specific physical units (for example tons of steel) and inputs expressed in man-hours. The input consists of labour only. This model is useful for producers in calculating the project cost and monitoring field activity (Arditi and Mochtar, 1999; Organisation for Economic Co-Operation and Development, 2001).

Hence, construction productivity can be simply illustrated by an association between output and input, as shown in Equation 1.

$$Productivity = \frac{Output}{Input} \qquad \text{(Equation 1)}$$

Panas and Pantouvakis (2010) stated that equation 1 had been widely used in the construction industry and also highlighted in OECD Manual (Organisation for Economic Co-operation and Development, 2001). Labour productivity is a good starting point for the analysis of productivity. Labour productivity relates to the single most important factor of production. It reflects how efficiently labour is combined with other factors of production, how many of these other inputs are available per worker and how rapidly embodied and disembodied technical change is proceeding (Chia et al., 2014). For instance, labour productivity is the determination of labour work hours associated with measured output because it can be measured in different input times which required different productivity measurements. Labour productivity measured in terms of the paid time which provides useful information to contractors for scheduling and estimating purposes. Labour productivity measurements based on time available for work provides the basis to analyse the effects of weather conditions on labour productivity. Meanwhile, labour productivity measures are based on productive time that assists to determine the effect of various factors on productivity such as constructability and delays (CIDB Malaysia, 2020).

RESEARCH METHODOLOGY

In this study, labour productivity is applied for productivity measurement, which commonly used in the industry. It is assessed by the ratio of the total output to the labour input. Labour productivity rates are used as indicators of construction time performance. It is used in construction planning and scheduling, controlling the cost and worker's performance, as well as in estimating and accounting (Alinaitwe 2005). Productivity researchers stated that it is difficult to obtain a standard method to measure construction labour productivity because of project complexity and unique characteristics in every construction projects. The uniqueness and non-repetitive operations of construction projects make it difficult to develop a standard productivity definition and measurement.

Therefore, in this study, a mixed-method approach is conducted using; (1) Archival Study and; (2) Focus group discussion (FGD) with the expert. The researcher team performed Archival studies based on secondary data document sources from the public housing samples. 6 real case studies completed IBS projects of public housing from different contractors are analysed. The second method of this study is organised FGD with the expert. The team researchers design the FGD in a structured and directed flow to gather in-depth information about experts' thoughts and opinions. There are 15 experts are participated in this FGD. The experts encompass academicians, consultants, contractors, IBS manufacturers, and developers.

ANALYSIS AND DISCUSSION

PRODUCTIVITY MEASUREMENT RATE IN PUBLIC HOUSING PROJECTS

In this study, public housing project using IBS are analysed using the archival case study. Productivity, in general, is defined as the total Gross Floor Area (GFA) constructed per total man-days, where GFA includes the total property square footage incorporating finished areas inside the property such as common areas, lobbies, stairwells, etc. One man-day, in this context, is defined as 1 manpower working for 1 day. In other words, man-days can be calculated using the total number of manpower involved in the project and the total length of the construction period of the project. Therefore, the productivity rate in this study represents how many GFA that 1 manpower able to construct in 1 day. The more output, in terms of gross floor area, constructed that manpower capable to produce within a day, hence the manpower be more productive. Equation 2 represents the formula developed in this study to calculate the productivity of certain IBS projects.

$$Productivity = \frac{Total\ Gross\ Floor\ Area\ (sqft)}{Total\ man - days} \qquad \text{(Equation 2)}$$

$$Productivity = \frac{Total\ Gross\ Floor\ Area\ (sqft)}{Total\ number\ of\ manpower\ x\ Total\ lenghth\ of\ the\ construction\ period\ (days)}$$

A project is deemed to be more productive based on more square feet of gross floor area can be constructed with the same number of man-days (CIDB Malaysia, 2020). Without a doubt, the factors affecting labour productivity can be classified into 4 categories, which is

design, manpower, management and environment. Figure 2 describes some main factors that affecting the labour productivity of building construction project.

DESIGN	ENVIRONMENT
Design complexity Design changes Design quality	Harsh working condition Construction volume Regulatory requirements Economic conditions Social factors
MANPOWER	**MANAGEMENT**
Worker motivation Skills of workers Recruitment of workers and supervisors Communication problems Labour disruptions	Material shortages Delays in materials delivery Power/water services disruption Stop-work orders because of layout/access and construction methods

Sources: (CIDB Malaysia 2020)

Figure 2. Factors Affecting Labour Productivity

Productivity Rate

Based on the archival study from the case study approach, the structured questionnaire-based survey with local IBS contractors was conducted to retrieve data from their real-life IBS projects to calculate the productivity rate. Out of 8 IBS contractors, only 6 of them responded. Hence, these 6 IBS contractors participated and a total of 6 IBS projects were gathered, as samples for this study. All samples are public housing project and strata category. The respondents provided the answers on data-based of their real completed IBS projects via e-mails as well as phone and face-to-face interviews. The questionnaire is divided into two main sections: (A) background information of the respondents; and (B) project information where the respondents required to choose one building construction project. The questions in Section B are related to the productivity measurement of IBS projects as follows:

1. *Specifying the project title, location, and project status of the chosen building construction;*
2. *Stating the project name, gross floor area (GFA), the total number of house units, and unit size of the chosen building construction project; and*
3. *Stating the total manpower, total construction period, and total working days/month of the chosen building construction project. It should be noted that the productivity rate calculated in this study is assumed that every manpower works for 26 days per month and the total manpower, as well as total construction period in this sense, are taken from the beginning of piling work until the Certificate of Practical Completion (CPC) is issued.*

Table 2 illustrates the productivity rates for all 6 IBS projects that had been analysed. Project B showed the highest productivity rate of 12.7 sqft/man-day and project E showed the lowest productivity rate of 1.3 sqft/man-day. From the result, Project B achieved 12.7sqft/man-day with 70 workers involved in the project and it was completed within 22 months. In contrast, Project E required 180 workers for the project, and it took 48 months to complete the project and only achieved 1.3 sqft/man-day. Thus, these results validated the hypothesis that the productivity rate is high when less manpower is involved to complete the

project within a short period, whereas more manpower and a longer time needed to complete a building project lower the productivity rate.

Moreover, the result indicated that Project C revealed the second higher productivity rate 11.6 sqft/man-day with GFA of 1,370,364 sqft, which employed 189 workers in 24 months to complete the housing project. On the other hand, Project A took 24 months to complete the housing construction project with 256 manpower with of GFA 1,089,394 sqft. The productivity rate achieved is 6.8 sqft/man-day. Project D demonstrated the achievement of 4.6 sqft/man-day productivity rate, completed the project in 30months and 40 pax of manpower used in this project. Project F revealed the second lower productivity rate with only 1.9 sqft/man-day but employed 100 workers to finish 182,000 sqft GFA. This project takes 36 months to complete the construction project.

Table 2. Output on Productivity Measuring Rate

Project	GFA (sqft)	Manpower (No. of Pax)	Construction Period (Months)	Productivity Rate (sqft/man-day)
Project A	1,089,394	256	24	6.8
Project B	508,197	70	22	12.7
Project C	1,370,364	189	24	11.6
Project D	143,095	40	30	4.6
Project E	302,000	180	48	1.3
Project F	182,000	100	36	1.9

*Total man-days = no of manpower x construction period (months) x (26 days/month)
Assuming every worker works for 26 days per month

Productivity Grading System

Through analysis, the grading system to further emphasized the productivity rate of IBS project in Malaysia was explored. The proposed grading system developed together by researchers with industry players involved in this study, which from validation and verifying exercise. The grading system had been developed based on the productivity rate to recognise the productive construction projects. Table 3 tabulates the grading system used to grade the calculated productivity rates.

Table 3. Grading System Used to Rank the Productivity Rates

GRADES	Productivity Rate, X (Sqft/Man-Day)
A	$x \geq 10.0$
B	$7.5 \leq x < 10.0$
C	$5.0 \leq x < 7.5$
D	$2.5 \leq x < 5.0$
E	$0 \leq x < 2.5$

At the moment in time, Malaysia has not defined the highest productivity rate of IBS projects to be used as a benchmark in this study. However, from the literature studies, it was found that the overall site labour productivity for public housing in Singapore was 1.0 m2 per man-day, which is approximately equivalent to 10 sqft/man-day (Joo et al., 2006). As public housing in Singapore at that time was built by using the IBS method, it is therefore relevant and appropriate to use 10 sqft/man-day as a benchmark to be applied in Malaysia.

Despite that, the productivity rate level of highest or lowest for building construction is not defined in Malaysia. On the contrary, Hamid et al., 2008; Kamaruddin et al., 2013; M.R. Abdul Kadir, W.P. Lee, M.S. Jaafar, 2006; Nasrun et al., 2015 and several other researchers was abundantly found that IBS projects should have a higher productivity rate compared to conventional projects. Therefore, the lowest productivity rate in the grading system developed should represent the productivity rate of conventional projects.

Table 4 shows the grades of IBS projects based on the productivity rates calculated. It is worth noting that the grading system was developed for this study. If it is intended to be practised in the industry, the grading system can be portrayed the adoption and implementation of IBS in Malaysia construction projects.

Table 4. Productivity Grade Achieved by the Projects Base on Productivity Rate

Grade	Project	GFA (sqft)	Manpower (No. of Pax)	Construction Period (Months)	Productivity Rate (sqft/man-day)
A	Project B	508,197	70	22	12.7
A	Project C	1,370,364	189	24	11.6
C	Project A	1,089,394	256	24	6.8
D	Project D	143,095	40	30	4.6
E	Project E	302,000	180	48	1.3
E	Project F	182,000	100	36	1.9

EFFECTIVENESS CONSTRUCTION PROJECT IN PUBLIC HOUSING PROJECT

One of the factors to consider that increase the productivity is the effectiveness of the construction projects. The FGD was conducted to discuss the issues in detail and challenges to increase the productivity in the construction of the IBS project. During the workshop, the discussion context was designed that consists of the construction life cycle from design stage, production of IBS component and installation. Equipment and education (skilled and training) also had been discussed to know how to increase the productivity in IBS projects. Issues, challenges, way forward as well as recommendation had been debated and captured in Table 5.

Table 5. Results Gathered During the Discussion on Current Issues and Challenges of The Construction Industry as Well as A Way Forward and Recommendations For The Industry

DESIGN	**Issues & Challenges**	1. Acceptance and realisation of BIM usage in projects (government and private) 2. No awareness on using BIM among decision-makers and industry leaders 3. Leadership decision - transition from CAD to BIM 4. Low adoption of BIM in projects 5. Changes and revolution must be holistic, not a single party 6. Poor ecosystem in construction project 7. Small budget for planning in the construction industry 8. Decisions are made by the consultants/designer 9. During pre-contract, BIM execution plan (BEP) is not being implemented 10. In a conventional way, every stakeholder knows their roles and responsibilities, but in precast construction, everyone (stakeholders) is not clear with their roles (process)

		11. Everyone puts full responsibility on the architect to pull out the project outcome 12. Awareness of procurement and decision making 13. Different procurement approaches 14. Lack of integration and interoperability between stakeholders 15. Disclosure of project problems 16. No funds are given to support BIM implementation in projects 17. Affordability issue of software and hardware as well as maintenance 18. Architects do not adopt IBS/modular in the early stage 19. Operation and maintenance are not included in early stage 20. Different 3 tiers in governance structure requirement 21. Quality of design 22. Issues in procurement methods
	Way Forward	1. Employing technology to achieve high productivity 2. Change the ecosystem 3. Design must be done virtually (so that the risk in a construction site can be reduced as the new law imposes) 4. Authorities are the bodies involved in decision-making law regarding design 5. An architect must start going for digitalisation, followed by C&S and MEP 6. Must follow and have BEP in every project in construction (which defines the project brief and project 7. The main stakeholders should take responsibilities for leading the project and project outcome 8. The ecosystem should be revolutionised 9. BIM for costing analysis can link the scheduling and model to come out with the costing for the projects — save a lot in costs can track delay 10. A post-mortem on the failures or success of previous projects 11. Cost allocation should be provided to implement BIM in projects 12. Operation and maintenance should be included in an early stage 13. All compliance must comply with overall requirement and law — waiting and approval time can be reduced (process for submission) 14. Open tender projects can increase competitiveness in terms of quantity 15. Linkage of design and cost during the early stage can be monitored and calculated
	Recommendations	1. Changes in data sharing (integrity) 2. Research on ROI for architects, C&S, MEP, and QS 3. The owner must drive the use of BIM, otherwise, no changes can be made 4. Minimum LOD 200 if using BIM
PRODUCTION	**Issues & Challenges**	1. Pre-casters need to redesign IBS/modular design (double handling work) 2. Initial cost of using IBS in a construction project — the mould 3. No incentives from the government to enhance the usage of IBS 4. Imported technologies affect the business model and development of IBS production in Malaysia 5. Certain developers or contractors do not want to implement BIM — high cost 6. BIM Family library is not ready to implement BIM (not enough capacity and numbers) 7. Manufacturers are not BIM-ready (not providing data to the designer) 8. Quality of production

		9. Economic of scale (in terms of standard design) 10. Compliance regulation - 6 months to wait for the approval
	Way Forward	1. Incentive for using IBS system 2. Provide suppliers with BIM family library 3. Already stated National Housing Policy — IBS & BIM, QLASSIC for affordable housing 4. Incentives can be given to the user of BIM 5. Reduction of wastages can be monitored through BIM
	Recommendations	1. Own Malaysian BIM family library to be shared with the public 2. Minimum LOD 300 if using BIM
INSTALLATION	**Issues & Challenges**	1. Not enough certified installers - cannot comply with government requirement i.e., 1 million affordable houses 2. Perception of the owner, stick to the conventional way 3. Not many local skilled workers in IBS 4. Poor coordination for the logistics (operational wise) - slow down the installation process 5. Poor planning of production and installation sequence - slow down the construction process 6. Lack of QAQC 7. Different manufacturers and installers
	Way Forward	1. Incentive in using IBS system 2. Increase the standard of a factory (consideration of distance to the site and closed yard) 3. Need to apply Just-in-time (JIT) concept 4. Mandate on OSHCIM
	Recommendations	1. Mandating BIM – adopt BIM 4D
EQUIPMENT	**Issues & Challenges**	1. Different installers have different equipment and skills 2. Design does not ensure the safety of contractors during construction 3. Training a certified person to run the equipment 4. High cost of purchasing, operation, and maintenance 5. Decision making in types of equipment to be used 6. Limitation on cranes capacity 7. Technology evolvement ie. renting equipment instead of buying
	Way Forward	1. Incentive in using IBS system 2. Design should be safely constructed by using simulation (need to tackle the issue on how to bring in the equipment 3. Mandate on OSHCIM
	Recommendations	1. The government should allow contractors, practitioners, or installers to have incentives on renting/buying cranes that are suitable for IBS or Prefabrication Prefinished Volumetric Construction (PPVC) 2. Review existing policies on incentives of IBS and introduce incentives for BIM.
EDUCATION/ SKILL	**Issues & Challenges**	1. No allocation for research in project improvement 2. No information sharing for future improvement 3. The missing link (less collaboration between industry and academia — using new construction technology 4. Different stages of education level and level of exposure of BIM to students 5. Mismatch of place for industrial training 6. Low adoption and knowledge on digitalisation in SMEs 7. Lack of cooperation from industry to access data for education and research purposes

Way Forward	1. Education cost/training must be included in the contract eg. SL1M 2. Data comparison on IBS/modular vs Conventional — to prove that by implementing BIM, projects are more profitable 3. More training on local skill workers 4. Close collaboration with industry to provide training /certified competence 5. Enhancing TVET-3 6. Industrial training/attachment at colleges and industry on using technology — to meet the real issue in the industry 7. Enhance the education syllabus to meet the requirement of industries 8. Industrial training (2 years in the industry, 2 years in academic)
Recommendations	1. Prove BIM implementation can show profits to the organisation 2. BIM course for the students in college and university

From the result, the lack of integration and interoperability between stakeholders as well as low adoption of BIM in projects are inhibiting the productivity of projects. In implementing BIM and IBS in construction projects, integration and collaboration are the key points that need to be tackled and solved to ensure the benefits of implementing both can be reaped towards effectiveness when the construction project is operating.

A few solutions were suggested during the discussion such as technology adoption to assist the project implementation and BEP needs to be prepared early in the projects. BEP is crucial to ensure that every stakeholder plays their role at various construction phases. This leads to good coordination, integration and collaboration as it delivers a stronger project execution and less time needed for data sharing (Yu-Cheng, Lin et al., 2016). Some recommendations on the design perspective also highlighted the need for IBS and BIM agenda to be established for project implementation, early involvement and collaboration between all stakeholders, and data transparency between stakeholders.

The high initial cost of moulds has always been listed as one of the major barriers to implementing IBS in projects because different projects need different mould specifications according to design drawings. Apart from that, the economics of scale, as well as design complexity and standardisation, are also the challenges faced in the IBS production. For BIM implementors, it is important to have the BIM family libraries in IBS production, otherwise, it would take some time for the designers to create objects.

There is a need for high competency skilled workers to be equipped at a site to ensure IBS installation safety. Lack of competent IBS installers has been identified as one of the main issues and challenges for installation. Furthermore, the lack of BIM integration in the IBS projects is also highlighted as part of the main issues. Hence, it is important to have the involvement of SMEs in IBS installation which create an end-to-end construction ecosystem, and hence, lead to an increased competency level of skilled workers in Malaysia, especially local workers.

One of the most crucial parts of IBS is the use of the concept of Just-in-time (JIT) to improve productivity in construction. To leverage the full benefits of BIM, BIM must be part of the project implementation requirements. It can help the concept of JIT to be achieved in the construction project. Otherwise, the industry unlikely to take the opportunity to explore the BIM implementation.

Machinery and equipment also play important roles in the project implementation. However, there are several issues and challenges faced by the industry such as the limitation on machinery and equipment available in the industry and a limited number of high-capacity cranes for IBS projects. As most IBS components are heavy, it would require the contractors to buy or rent the high-capacity cranes which are limited in the industry. Indirectly, this consequently affect the time taken to complete the projects and make the contractors stick to the conventional method as it is more convenient and cheaper. Moreover, the high cost of machinery and equipment, as well as its operation and maintenance, are also identified as one of the main issues and challenges faced by developers and contractors in ensuring business continuity.

To improve the construction industry thoroughly, it must start from the root level, in this context, which is education at university and industry levels. The main issue faced by the industry nowadays is the lack of exposure to digitalisation in the education syllabus, especially in universities. Apart from that, low competency among local authorities in technology adoption has also been identified as one of the main factors that delay productivity in construction. The missing link between academician, industries, and the government is the main issue that needs to be tackled to improve collaboration and integration. During this time in the new era, digitalisation constructed as an ultimate purpose and an all-encompassing matter in education and thus, it is important to produce the student that well-prepared for industry towards digitalisation (Vivitsou, 2019). Therefore, a syllabus revision needs to be completed by the responsible party to suit the current situation in the construction industry.

The level of competency in technology adoption among local authorities needs to be increased as well through training and some industrial engagement. Providing training or certified competency to the graduates needs to be done to prepare them with at least the basic knowledge up to certified skills gains throughout the industrial training and syllabus.

Finally, legal or regulatory aspects have been proposed to be included by the participants as some of them are facing issues of lack of the project management system and common data environment. In BIM environment, data sharing is important to enhance the project delivery to be more efficient and faster. However, there are certain legal issues on data sharing which inhibit the data-sharing platform as it is a risk to data security and integrity. To counter this problem, an open access data platform between industry should be established but controlled in a limited way by a single party. Through this, project delivery can be more efficient throughout the digital platform.

CONCLUSION

Construction productivity rates and grade varies between projects because of the varying method of construction, environments, characteristics, and level of management efforts and implementation. This study proposed a productivity measurement tool to rate the macro construction project productivity at the site. Hence, the overall productivity of a construction project can be defined. The method of grading system is to illustrate a level of productivity performance each construction project that can be achieved. The grading system shows a good impact to increase the willingness and determination of project to highlight their level of productivity. The factors of effectiveness and productive construction public housing project are the management implementation of IBS and BIM in the projects. The decision-maker and

project team such as owner, consultants, contractors, manufacturing team, logistic, and installers are important to boost the productivity and efficiency in the construction projects. In implementing BIM and IBS in construction projects, key points like integration, interoperability, coordination and collaboration are needed to be tackled and solved to ensure the benefits of implementing both systems can be gained towards effectiveness when the construction project is still operating.

Further study is needed on the productivity rate using 6 different IBS systems such as precast concrete, reusable formwork, metal framing, blockwork, timber framing and innovation. The trade productivity in micro is needed for comprehensive measurement to develop a construction productivity estimation for each projects' performance. Every trade throughout the construction life cycle such as implement technological innovation including emerging technology in Construction 4.0 or digitalisation and design improvement have the most significant impact because of its' effectiveness through the measurement of labour used in the construction process. Besides that, to improve labour effectiveness, various factors can be addressed including motivation, job safety, environmental factors and physical limitations. The productivity measurement tool in micro need to establish in order to assess the public housing construction project from the planning and design stage until the project completion and management factor in a holistic approach.

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REFERENCES

Abdel-wahab, Mohamed, and Bernard Vogl. 2011. "Trends of Productivity Growth in the Construction Industry across Europe , US and Japan Trends of Productivity Growth in the Construction Industry across Europe , US and Japan." *Construction Management and Economics* 29(August 2013): 635–44.

Alinaitwe, Henry. 2005. "Labour Productivity in the Building Industry." *Understanding the Construction Business and Companies in the New Millenium* 1: 210–20.

Arditi, David, and Krishna Mochtar. 1999. "Trends in Productivity Improvement in the US Construction Industry Trends in Productivity Improvement in the US Construction Industry." *Construction Management and Economics* 18(2000): 15–27.

Azman, N S, M Z Ramli, and M H Zawawi. 2018. "Factors Affecting Quality Management of Construction Project Using Industrialized Building System : A Review." *International Journal of Engineering and Technology* 7(4.35): 307–11.

Chia, Fah Choy, Martin Skitmore, Goran Runeson, and Adrian Bridge. 2014. "Construction Management and Economics Economic Development and Construction Productivity in Malaysia Economic Development and Construction Productivity In." *Construction Management and Economics* 32(9): 874–87.

CIDB Malaysia. 2020. *Road Towards Producivity Excellence: Productivity of Building Construction Using Industrialised Building System (IBS)*.

Dixit, Saurav, Satya N Mandal, Joseph V Thanikal, and Kinshuk Saurabh. 2019. "Evolution of Studies in Construction Productivity : A Systematic Literature Review (2006 – 2017)." *Ain Shams Engineering Journal* 10(3): 555–64. https://doi.org/10.1016/j.asej.2018.10.010.

Filipe Barbosa, Jonathan Woetzel, Jan Mischke, Maria Joao Ribeirinho, Mukund Sridhar, Metthew Parsons, Nick Bertram, Stephanie Brown. 2017. *Reinventing Construction: A Route to Higher Productivity*.

Ghodrati, Nariman, Tak Wing Yiu, and Suzanne Wilkinson. 2018. "Unintended Consequences of Management Strategies for Improving Labour Productivity in Construction Industry." *Journal of Safety Research* 67(December 2018): 107–16. https://doi.org/10.1016/j.jsr.2018.09.001.

Hamid, Zuhairi Abd. et al. 2008. "Industrialised Building System (IBS) in Malaysia: The Current State and R&D Initiative." *Malaysia Construction Research Journal* 2(1): 1–14.

Joo, Lau et al. 2006. "Construction Technology." In *Blue Prints for Successful Public Housing Development*,.

Kamaruddin, Siti Syariazulfa, Mohammad Fadhil Mohammad, Rohana Mahbub, and Khairani Ahmad. 2013. "Mechanisation and Automation of the IBS Construction Approach: A Malaysian Experience." *Procedia - Social and Behavioral Sciences* 105: 106–14. http://dx.doi.org/10.1016/j.sbspro.2013.11.012.

M.R. Abdul Kadir, W.P. Lee, M.S. Jaafar, A.A.A. Ali. 2006. "Construction Performance Comparison between Conventional and Industrialised Building Systems in Malaysia." *Structural Survey* 24(5): 412–24.

MPC. 2020. *Malaysia Productivity Report 2020*.

Nasrun, Mohd et al. 2015. "Malaysian Industrialised Building System (IBS): A Review of Studies Malaysian Industrialised Building System (IBS): A Review of Studies." *Australian Journal of Basic and Applied Science* 9(7): 99–101.

Organisation for Economic Co-Operation and Development. 2001. *Measuring Productivity OECD Manual*. OECD.

Panas, Antonis, and John-paris Pantouvakis. 2010. "Evaluating Research Methodology in Construction Productivity Studies." *The Built & Human Environment Review* 3(Special Issue 1): 63–85.

Park, Hee-sung. 2006. "Conceptual Framework of Construction Productivity Estimation." *KSCE Journal of Civil Engineering* 10(5): 311–17.

Raheleh, Seyed Meysam K, Rasoul R and Hasanuddin L. 2015. "Green and Sustainability Policy , Practice and Management in Construction Sector , A Case Study of Malaysia." *Research Journal of Applied Sciences, Engineering and Technology* 9(3): 176–88.

Razak, F, and H Awang. 2014. "The Contractors ' Perception of the Implementation of Industrialised Building System (IBS) in Malaysia." *MATEC Web of Conferences* 3(10): 3–7.

Vivitsou, Marianna. 2019. "Digitalisation in Education , Allusions and References." *CEPS Journal* 9(3): 117–36.

World Economic Forum. 2016. *Shaping the Future of Construction A Breakthrough in Mindset and Technology*.

Yu-Cheng, Lin; Yen-Pei, Chen; Wan-Ting, Huang; Cia-Chun Hong. 2016. "Development of BIM Execution Plan for BIM Model Management during the Pre-Operation Phase :" *Buildings* 6(8): 1–14.

STUDYING THE PRODUCTIVITY OF CONSTRUCTION WORKS FOR RESDENTIAL BUILDINGS AND PROJECTS IN JORDAN

Mohmd Sarireh
Department of Civil Engineering, Tafila Technical University, Tafila, Jordan.
Tafila Technical University, Tafila 66110, Jordan, P.O. 179.

Abstract
Jordanian construction sector has two problems; the prediction of productivity of construction works, and the absenteeism of documents and studies neither at governmental nor at nongovernmental institutes about productivity of construction work. Also, it is not clear if there is a difference in productivity means between project construction and resident building constructions in one region or between different regions (South and North) in Jordan. Current research aims to measure and test means of productivity of construction works for project and residential building construction in similar and different regions in Jordan. Data for productivity were collected from Southern Jordan: Karak and Tafila areas, and from Northern Jordan: East and West of Amman, and Zarqa from project and residential building construction. Means of productivities were tested using t-test for independent samples of one region between areas, and then between Southern and Northern regions by testing the null hypothesis (H_o: $\mu_A = \mu_B$) against the alternative hypothesis (H_1: $\mu_A \neq \mu_B$) on means of productivity of construction works. It is concluded that there is no significant difference between means of productivity in areas (Karak and Tafila) and in (East and West Amman and Zarqa) areas. Also, there is no significant difference between means of productivity of Southern and Northern Jordan regions. Results of productivity values can be used on local and national levels for productivity calculation, quantity surveying, cost estimation, and price bidding for contracts by consultant and contractor firms in Jordan.

Keywords: *Testing of means; productivity; construction; project; management.*

INTRODUCTION

Jordanian economy has a fluctuation in its growth rates (3.1% in 2014, 2% in 2017, and 2.5% in 2019). In addition, the unemployment rates raised from 12% in 2014 to 18.7% in second quarter of 2018. During 2015-2017, Jordan had the least female labor participation rate (14.8%) among 14 countries. During the same period, Jordan had the least overall labor participation rate (39.1%). The improvement in the economic growth and the use of the labor force effectively through training and intensives will improve the productivity of labor to produce work in projects and residential areas. The most productive labor or team will attain lower unit cost, improved competitiveness, higher profits, higher wages, and higher economic growth in the construction sector. According to Jordan Strategy Forum, to improve labor productivity, labor should be better engaged in recruitment, training, good management of time and resources, evaluating rules and regulations for competition, better infrastructure to reduce transportation delay, new technology innovation, and employment of private and foreign investment, openness, education and training (Jordan Strategy Forum 2019). Construction and construction industry are related to be the most significant contributors to the countries' gross domestic product (GDP) (Oesterreich and Teuteberg, 2016).

A construction project can be described as a dynamic structure that is every building is planned and built in a unique conditions and requirements and stakeholder (Mansour et al., 2021a). Also, the construction sector described as a complex sector compared to construction

industry sector. Construction sector has many processes and sub-processes and participants affecting on different stages and sites which increases complexity of sector (Arayici and Coates, 2012). And the evaluation and management of construction sector in a fuly digital manner is difficult as the sector has a segmented nature, site-based activity, and resistance to change compared to the construction industry (Osunsanmi, Aigbavboa and Oke, 2018a). Construction works in Jordan have not enough studies for measurement and prediction of productivity, and it is difficult to predict and expect if the productivity of two places is different or similar. Data gathered on productivity will help contractors and quantity surveying teams in beds' pricing or cost prediction, too. From the beginning, pricing prediction and bidding are important for the firms in their policies and methods according to the investigations done by Shipley (1981) and dependable on the prediction of productivity in order to establish the parameters of pricing policies for the firms in an overall manner. And Hasan (2009) mentions that construction sector depends highly on the productivity of labors which is measured in the volume of work during labor-hour basis through enough frequent observations, as the labor cost estimated to be 30% of total cost of project. It is essential to consider planning factor in project construction in a continuous manner as planning has an impact on quality of project and its performance (Mansour et al., 2021b).

Importance of Research

Studying productivity of construction teams is considered effective, comprehensive, integral performance, and flexible for planning. Also, studying productivity is considered as the skill of timing and cost effectiveness during planning of jobs assigned to resources. So in effective planning capacity building for construction teams will be improved and project will be finished on assigned time and cost (Al Jamaz, 2010). Also, it is considered that network analysis is necessary for project planning and management. Managers avoid prior planning, reports and any mathematical or scientific models such as network analysis, but they considered thinking only, and written down notes and sketches, and personal experience. It is recommended to use critical path method (CPM) in planning the schedule and follow up. Management should concentrate on goals and objectives without wasting time on minimal details. Using computer programs in planning and scheduling and using intensives for early complete of projects will add to productivity and improvements on project performance. For the understanding of nature of time delay in projects in Libia, Six-Sigma method was used to determine the frequent causes of delay in projects. The study concluded that the following are frequent causes for project delay: miss planning, time scheduling, financial difficulties, miss estimation of cost, miss management and supervision, unskilled teams, insufficient volume of equipment and human resources and materials, difficulties in monthly instalments, variation orders, slow response by a supervisor, inefficient subcontractors. Oqaili (1997) showed that planning is a pro-activity for any executive project or job that is objectively implemented at a specific time end on a specific date with specific tools and resources and specific cost. Also, the study showed the importance of expecting as a supportive tool for planning in forecasting and analysis for time and results in previous studies and projects and forecasting of changes in projects. This will keep work on time and detect deviations when they happen.

Prediction of productivity in construction for residential building and project contractions is not a simple matter, especially in the presence of competition, risk and uncertainty during prediction and bidding or construction. Also, productivity study is necessary to estimate cost

and accepted profit for the individual labor or construction company. In the case of no data record or sheets for productivity of many items in construction, its necessary to work on data collection and analysis for productivity of construction items for project and residential constructions. Also, prediction of productivity will be helpful for contractors and consultants and their teams in improving productivity calculations, cost estimation, bidding, and range of profitability. Ai Ling et al. (2021) pointed that construction sector suffers from delays in time and cost through the experience with satisfaction, therefore projects should be completed without delay and within the allocated budget. The planning of cost and so the schedule depend both on studying the productivity of and volume of work that considered highly for planning and scheduling of project. Also, project implementation should be evaluated and corrected according to the original plan of cost and time in order to avoid deviations and delays in plans and schedules.

Current research aims to collect data and study the productivity (work/labor-hour) for individual labor in residential building construction and in project construction in different areas in Jordan in two regions (Northern Jordan: East and West Amman and Zarqa, and Southern Jordan: Karak and Tafila). Also, it aims to test and conduct comparisons between productivity averages between two areas in one region and between two regions (Southern and Northern Jordan).

RESEARCH BACKGROUND

Productivity of Construction

Productivity can be defined as the time management for some works during implementations at a specific time and specific worker or labor. So, management can assign a clear and well-known objective (work) to be finished by a specific team in a company, or self-management to achieve an objective (work) by a convenient team of the company and observing productivity. The self-management technique of productivity will be useful in achieving the assigned goal during a specific time and resources in residential construction. Also, the subcontract management technique that management assigns a scope of work to be finished in a specific time and cost is another approach in project construction. All techniques must be based on real productivity calculations and predictions to expect the time required to finish without delay in time or cost overrun (Jarad et al. 2007). Also, Hasan (2009) assures that productivity management is a challenge to the construction sector, and it is difficult to measure the real productivity in a work- hour for labor in site, and the study, the need to improve managerial efficiency of project. The study employed the application of measurement systems for productivity on the level of job-basis and concluding of mathematical models for typical construction operations help in setting plans for prediction of productivity for these operations. The statistical treatment considered the multi-linear regression in measuring the productivity of construction operations.in the study, the productivity was related to the number of workers, effective and lost work hours. The study figured out that the percent of lost work hours is about 33%, which was considered large in construction work.

In a study of productivity in Gaza District, Enshassi et al. (2011) focused on the measurement of productivity for the construction of concrete block in some projects in Asshiekh Zayed city. The study selected a project of 70 buildings of 5-floor and five buildings

of 11-floor to study the productivity of concrete block construction. The study considered 20cm and 10cm concrete blocks to measure the efficiency of productivity. The pointed out that the efficiency of workers in concrete block construction reached 77%.

Productivity of construction is related to quantity surveying (McDonnell, 2010) and can be used for evaluation of work volumes depending on productivity rates in critical employment of process and techniques (Osman et al., 2015). Also, a study for Thomas (1991) for labor productivity and work sampling to describe labor productivity and work sampling, the study considered investigations for 30 projects data base in seven data bases collected from a nuclear-power plant construction project. The study showed that the relation of direct work time is illogical to be not related to the time of year (considering seasons), or the productivity is better during the start-up and testing phase, or productivity can be improved in an emergency condition. The study concluded that reducing waiting time can improve productivity of direct work, increasing of direct work time increases the productivity and leads to less time wasted in waiting. The correlation coefficient for the proposed model was statistically very poor for the assumptions of the study, and the model has low predictive capabilities. The results also considered 46 data points that yielded a 0.00 r^2 coefficient and a standard error of the estimate that is equal to the standard deviation of the performance measure of productivity. It is concluded that the work sampling studies can show how crafts are busy in direct work time to predict effective productivity of work and not to consider inefficient work hours. Construction works such as plastering and tiles are highly dependent on worker or labor productivity that are needed real measurement. Also, productivity can be defined as the case of promise and wish and the situation of continuous improvement for what exists, it's the individual convenience to work today better than yesterday and tomorrow better than today. Or it is a virtual situation implemented in real work that results in the improvement of everybody. Mathematically, it is an output of work item in percent of inputs of time and resources (work/Labor-Hour) or work/LH (AACE 2004). Del Pico, 2012 presented the "estimating building costs for the residential and light commercial construction professional." The data in this book included specifications of works, rules of calculation and quantity surveying and cost and pricing, quantity and concrete, Masonry including brick and mortar, metals, wood and plastics and composites, finishing including plaster and gypsum and tiles and painting, electric and heating and communication and plumbing and equipment. The cost and pricing considered quantity surveying and productivity calculations and procedures for a high degree in the book for the importance of productivity studies of construction teams to improve the competitiveness of construction and industry. Also, the book sees that productivity studies and procedures and operations are important parts of today's technology and necessary to manage the dollar amounts of project construction. The construction professionals and estimation is the key to successful construction company.

In a study for the reasons for poor labor productivity in construction works, Abdul Rahman (2019) focused on 33 reasons that cause low labor productivity. these reasons were evaluated by 54 respondents through a questionnaire in five categories: Not Occur (No Impact), Slightly Occur (Slight Impact), Moderately Occur (Moderate Impact), Often Occur (High Impact), and Very Often Occur (Extremely High Impact). The highest four reasons for low labor productivity are: the violation of safety precaution, weather changes, payment delay, and working 7 days per week without taking holiday in a range of occurrence of (80-73%). While the lowest reasons for low labor productivity are: unsuitability of materials

storage location, supervision's absenteeism, material shortages, and lack of labor supervision in a range of occurrence of (61-57%).

Aderei (2011) conducted a study to measure the effect of bad planning on delay (less productivity) in construction projects in Dubai in 2006-2010. The study included big and mid companies in all projects (building, roads, sewer, electric and infrastructure). The study concluded that the following are causers for delay in projects: (1) misunderstanding of managerial and engineering planning and shortage of follow up, (2) little recognition of the importance of managerial and engineering planning (time neglect, chance bargain, expectations and surprises, follow principles of planning Qaryouti, 2001), (3) less accreditation of real and correct engineering planning. Also, Dozzi and AbouRizk (1993) presented deviations in schedule and cost in project-plans which makes it necessary to investigate solutions that will correct these deviations and put the project progress on time and project cost within the estimated cost during planning (baseline). Improving project performance and labor productivity needs real studies of the labor and project conditions to describe the current situation and the forward directions of overall project performance and internal productivity of different jobs and putting of suggested solution in a corrective plan for the schedule and the cost. Programs such as MicroCyclon could be employed to study the real cases in projects and their internal operations in order to determine the deviations and the waste in time and cost, and then develop a new program to show improvement in productivity (decrease in time waste) and decrease in cost Sarireh (2013-a), Sarireh (2013-b) and Sarireh (2015).

Concept Measurement in Productivity Study

Most construction works and items are measured in the same manner as in the construction industry. They are measured by counting output units in percent of input units of time and resources. Partial measurement (per hour of work) depending on statistical methods or continuous measurement through all the day of work can be applied to measure the output of work and get productivity. However, in both methods' productivity measurement has a deviation between values of productivity; in hour-basis measurement it has deviations depending on the beginning, mid-day, and end of work through the day, and in the total working day measurement. It has deviations between different days' productivity. The daily-basis productivity is considered in current research (Kemppilä and Lönnqvist 2003). Measurements were taken for work output (m^2 of plastering or tiles or formwork, m^3 of concrete, kg of steel reinforcement per labor-hour) and input (time and resources) during all the day for construction items. Then calculations for productivity were applied as work/Labor-Hour.

Local Conditions of Construction and Productivity

In Jordan, two types of construction are the most common: residential building construction and project construction. Residential construction belongs to people directly as private construction of houses or small investment in buildings, and people get the right to commence building and pay directly to different teams of subcontractors for different works, usually building area is mostly small (140-270 m^2). Usually ground floor is constructed separately and 1st or and/or 2nd floor are added in future separately also depending on the availability of finance process by own savings or from a bank loan. While project construction

belongs to the government and the proposed work is planned and scheduled and bid in competent process for general contractors, commencement given usually for the contractors of lowest price of contract, work continues through implementation of the general contractor and his teams of subcontractors under the supervision of the consultant/engineer of the governmental agency, and payments are planned depending on the stages of construction. In both types of constructions, no records or statistical data are available about productivity of construction works in local construction and industry. Many of the plans and schedules of projects are subject to change and variation during execution. Delays and cost overruns are the expected results in many cases (Sarireh, 2018). Even though productivity is key for planning, scheduling, pricing, estimating, and bidding, contractors, consultants and subcontractors do not rely on theoretical or real calculations for their estimates, pricing, and bidding. In addition to, technology is not highly available or well employed in construction. Residential building constructions and projects have similar techniques and methods for construction works. This is true for most of construction items. In current research, the following work items are the targets to be studied in terms of productivity (MOPH, 1996) and Herubin (1997):

- Block construction: local block has thickness measurement of (10cmX20cmX40cm, 15cmX20cmX40cm and 20cmX20cmX40cm). Units of block are combined and built together using cement mortars. Usually, the minimum crew that is required for block construction is a team consisted of a skilled labor and a worker. The worker prepares the cement mortar, transfer block and mortar to the skilled labor. Block work is measured in squared meters (m^2).
- Plastering: plastering goes on three steps: (1) light spraying of cement mortar, (2) rough plastering which is thicker and has minimum thickness of 8-12.5mm of cement mortar on walls and ceilings, and (3) smooth plastering: by applying fine cement mortar on the rough mortar after curing and drying of the rough face. A crew team of two (skilled labor and a worker), the worker prepares cement mortars and transfer to the skilled labor who will apply fine materials on the wall and seal the rough texture. Usually, a steel mesh is applied on inner and out angles and on the contact lines between concrete columns or beams and block walls to avoid the appearance of cracks in walls in future. Spraying, rough and smooth plastering is measured in squared meters (m^2).
- Tiles: tile units are on house floors/walls and halls, cement and ceramics tiles are used to cover floors. Ceramic tiles (60cmX60cmX8mm) are considered in current study to measure productivity. Usually, the worker prepares a sand layer of 10cm thickness underneath tiles and prepare cement mortar similar to the mix of rough plastering and block construction, also the worker transfer units of tiles and mortar to the skilled labor to fix units on floors or walls. Floor tiles are considered to study productivity of labors. Tiles is measured in squared meters (m^2).
- Wood formwork: construction wood has different measurements (3Mx10cmX5cm, 4Mx10cmX5cm, 3Mx10cmX2.5cm, and 4Mx10cmX2.5cm). Usually, sections of 5cm thickness are used as beams in both directions to spread sections of 2.5cm above them. At least, a skilled foreman, an assistant and two workers are required to fix formwork for a ground floor of 150-200m^2. Wood formwork is measured in squared meters (m^2).

- Steel reinforcement: construction steel has different lengths: 4, 5, 6, 7, 8, 9, 10, 11, and 12m. and steel has different diameters: smooth or mild steel of 8mm, rough or deformed steel of 10, 12, 14, 16, ……, and 32mm. Usually 4 crews are required for fixing construction steel on roofs beams and surface area. Steel is measured in tons and kilograms.
- Roof Concrete Pouring and Placing: concrete is mixed in a round mixer and pulled up to the roof by a mechanical chute that has $0.2m^3$ capacity. A crew of at least 12 workers in addition to a skilled labor and assistant labor are required for the individual operation. Usually, concrete is measured in cubic meters (m^3).

RESEARCH METHODOLOGY

The methodology of current research based on reviewing of literatures and related studies for productivity of construction works, then on interviewing of specialists in construction sector in construction and consultant firms in Jordan. The current study had selected the Northern and Southern regions in Jordan. The Northern region included two areas in main city Amman (East Amman, West Amman, and Zarqa) areas, and the Southern region included Karak and Tafila areas. The current research selected two types of construction to be studies: residential building construction and project construction. Then site visits had been conducted for both construction sites to take direct measurement and practical data for volume of construction works and time elapsed for finishing works. Documentation for location of building, type of construction, area of building, number of skilful and non-skilful labors for both types of constructions were applied in each site. Locations of buildings were selected in the North region of Jordan (East and West of Amman, and Zarqa) and from the South region (Karak and Tafila) in order to be studied and compared through testing of means for productivity in region and between regions. Zarqa is located 20km to the North-East of Amman. While Karak is located 130km to the South of Amman, and Tafila is located 184km to the South of Amman. Then productivity in both construction types (civil works) were calculated as (unit of work per labor-hour) for the number of cases collected in each site. Then means of productivity and standard deviations of construction works in all sites and locations were calculated. Table 1 presents the categories and parameters of residential building and project constructions in the current study included location, area of building, number of skilled and non-skilled (workers) and labors.

Table 1. Parameters and Categories of Residential Building and Project Construction in Jordan

Area/Construction Type		Region in Jordan				
		Northern Region			Southern Region	
		East Amman	West Amman	Zarqa	Karak	Tafila
Area (m^2)	Residential Construction/Floor	140-220	170-270	160-235	165-210	160-210
	Project Construction/Floor	400-800	600-1000	500-900	600-800	600-800
No. of Skilled Labors	Residential Construction/Floor	2	3	2	1	1
	Project Construction/Floor	3	3	3	2	2
No. of Workers	Residential Construction/Floor	4	5	4	4	4
	Project Construction/Floor	6	8	6	6	6

The population of current research consist of 11,000 residential building licenses had been issued during 2019-2020 by the Municipality of Greater Amman of total area of 8,685, 000 m^2. In addition to 675,000 residential building licenses were issued of a total area of 1,365,455nm^2 in the same period in Zarqa. And 368,654 licenses were issued in a total area of 766,487 m^2 in Karak, and in Tafila 825,438 licenses were issued of a total area of 1,835,725 building constructions in 2019-2020 (Jordanian Engineers Association, 2020). Samples of data were collected for number of cases in residential building and project constructions through the site visits and interviews for personnel of supervisors and foremen in construction sites. Table 2 presents cases and number of samples that covered during 2019-2020 period for the construction works in Jordan in the Northern and Southern regions. The selection criteria were dependable on the similarity of floor area, floor style (ground floor), number of workers and skilled labors, and period of study.

Table 2. Number of Cases (Samples) and Type of Construction in Jordan

Number of cases in construction works	Type of Construction	Region in Jordan				
		Northern Region			Southern Region	
		East Amman	West Amman	Zarqa	Karak	Tafila
	Project	8	6	7	8	10
	Residential	14	12	10	14	14

Averages and standard deviations were calculated for productivity of construction works for each area (Karak and Tafila) in Southern region of Jordan and (East and West Amman, and Zarqa) in Northern region of Jordan.

The aims and objectives of testing productivity of each area and region and comparing of productivity of areas in one region (South or North) and comparing of productivity of construction works in different areas and regions (South and North) were conducted on a 3-stage strategy. The results of tests will show if the productivity can be calculated using an individual average for each area or productivity for each region totally to represent productivity values of other areas or regions to be considered representative and applicable?

Testing of Differences Between Averages

The t-test method is a type of inferential statistics used to test if a significant difference exists between two or more means for two or more groups, which may have certain features (treatment levels). It is mostly used when the data sets would follow a normal distribution and may have unknown variances. The test is used as a hypothesis testing mean, which allows testing of an assumption applicable to a population. T-test looks at the t-statistic, the t-distribution values, and the degrees of freedom to determine the statistical significance. To conduct a test with three or more means, one must use an analysis of variance. Mathematically, t-test takes a sample from each of two sets and establishes the statement of the null hypothesis that two means are equal. Based on the applicable formulas, certain values are calculated and compared against the standard values, and the assumed null hypothesis is accepted or rejected accordingly (Investopedia 2020).

Current research selected the testing of means of groups of productivity teams through a quantitative approach after gathering of the data. This approach is well known for researchers in most sciences and applications to conclude a statistical decision about differences between

means of productivity whether significant or not. Differences are accepted as normal differences or that means of data should be reacted differently and considered significantly different. It means that any intolerable difference is known as significant difference (Shukla, 2017). The theory of t-test is based on the assumption of the null hypothesis that rejects the significance of difference (means are equal) and the alternative hypothesis that accepts the significance of the difference between means (means are not equal) of samples considering means, standard deviations, and numbers of data points in each sample and the levels of treatment.

The testing of means actually starts with considering two hypotheses. These are called the null hypothesis and the alternative hypothesis. H_o is the null hypothesis and states that there is no difference between samples' means or populations or that the differences in means equal 0. H_1 is the alternative hypothesis and is contradictory to H_o and is concluded when we reject H_o (Killen, 2005). The null hypothesis: H_o: $\mu_A = \mu_B$ against the alternative hypothesis: H_1: $\mu_A \neq \mu_B$ considering that variance of A sample is S_A and denoting for σ_A and variance of B sample is S_B and denoting for σ_B (Walpole et al., 2007). For example, the null hypothesis: H_o: $\mu_A = \mu_B$ states that the means of productivity of two areas or regions are equal or the difference between means equals 0. While the alternative hypothesis: H_1: $\mu_A \neq \mu_B$ states that the two means of productivity are not equal or there is a difference between means of productivity.

The level of treatment that is considered in current research is the place (region) where the productivity of construction work is selected to be studied. For example, the productivity of construction work in Karak region is compared to the productivity of similar construction work in Tafila, and that construction work conducted in Tafil in South of Jordan is compared to similar construction work productivity in East and West of Amman and Zarqa, and productivity of construction work in Karak will be compared to the productivity of similar work productivity in Tafila, East and West Amman, and productivity in Zarqa.

RESULTS

Data were collected about the specified construction works and items in the Southern region (Karak and Tafila areas) and in the Northern region (East Amman, West Amman, and Zarqa) in Jordan. Table 3 presents the averages and standard deviations for the productivity of construction works in the research area during summer 2018 for the construction teams of projects and residential building construction.

Table 3. Values of Averages and Standard Deviations of Productivity for Construction Works

Work Item	Southern Jordan				Northern Jordan					
	Karak		Tafila		East Amman		West Amman		Zarqa	
	Project	Resident	Project	Resident	Project	Resident	Project	Resident	Project	Resident
Block10cm, m^2/L.Hr.	3.28*	3.26	3.27	3.25	--	3.260	--	3.28	--	3.26
	0.07**	0.09	0.07	0.11	--	0.11	--	0.05	--	0.04
Block15cm, m^2/L.Hr.	3.18	3.16	3.17	3.14	--	3.15	--	3.16	--	3.16
	0.04	0.06	0.04	0.02	--	0.08	--	0.10	--	0.06
Block20cm, m^2/L.Hr.	--	--	--	--	--	3.01	--	3.11	--	--
	--	--	--	--	--	0.03	--	0.03	--	--
Ceramic Tiles, m^2/L.Hr.	7.52	7.41	7.57	7.51	--	7.88	--	7.91	--	7.74
	0.09	0.06	0.07	0.07	--	0.08	--	0.11	--	0.05
Rough Plaster, m^2/L.Hr.	15.55	15.32	15.58	15.43	--	--	16.11	--	--	15.92
	0.58	0.32	0.41	0.24	--	--	0.35	--	--	0.43
Smooth Plaster, m^2/L.Hr.	18.38	18.27	18.41	18.38	--	--	18.63	--	--	18.77
	0.10	0.09	0.10	0.11	--	--	0.21	--	--	0.16
Floor Formwork, m^2/L.Hr.	7.58	7.39	7.60	7.48	--	--	8.41	8.20	--	8.03
	0.16	0.16	0.20	0.10	--	--	0.17	0.16	--	0.22
Floor Reinforcement, Kg/L.Hr.	58.27	56.04	58.36	58.10	--	--	65.82	65.46	--	63.37
	1.94	7.83	3.66	2.23	--	--	2.07	2.61	--	1.84
Floor Concrete, m^3/L.Hr.	0.68	0.64	0.69	0.67	--	--	0.79	0.76	--	0.77
	0.03	0.03	0.04	0.03	--	--	0.03	0.07	--	0.07

*Mean Value **Standard Deviation Value

Comparison and Testing Significance of Differences between Means of Productivity in Construction Works

Stage I: Comparison and Testing of Means of Productivity of Construction Works in Southern Jordan Region (Karak and Tafila Areas)

Data of means for construction works in Karak (μ_A and μ_B as means of productivity of project and residential buildings respectively in Karak area) and Tafila (μ_A and μ_B as means of productivity in project and residential buildings respectively in Tafila area), were tested using t-test for the significance of difference between means of the productivity in both areas, respectively. T-test showed that the means of productivity of construction works do not have significant differences in their means for project and residential buildings in both areas. So, the test fails to reject the null hypothesis as $\mu_A=\mu_B$ with $P>0.05$. This is true, as construction teams usually use similar technology limits and similar operations, procedures, and practices as in projects as in residential buildings construction and engaged in and receive similar traditional training programs. So, for productivity calculation, estimation, pricing and bidding of contracts, researchers, engineers and consultants, contractors, and subcontractors can use either the productivity of construction works in projects or of residential building constructions in Karak and Tafila respectively. This is true because both values of productivity are considered similar. So, all stakeholders and personals of construction can use

one of the two values, or it is recommended to calculate the average of both values and use it in calculations for Karak and Tafila.

Stage II: Comparison and Testing of Means of Productivity of Construction Works in Northern Jordan Region (East Amman and West Amman, and Zarqa)

When the productivity of construction works of East and West Amman and Zarqa areas were tested internally, productivity values have no significant difference between projects and residential building constructions. T-test fails to reject the null hypothesis (H_o: $\mu_A=\mu_B$) with P>0.05. Also, comparing and testing the means of productivity for construction work items in the West Amman area (μ_A and μ_B are means of productivity for project and residential buildings), the results showed that there is no significant difference in means productivity in this area and the t-test fails to reject the null hypothesis (H_o: $\mu_A=\mu_B$) with P>0.05. Similar decision after testing of means of productivity of construction works in Zarqa for project and residential building constructions. And this true for the same reason, that construction teams are using similar technology and instruments, and following similar procedures and operations and have similar traditional training programs.

Stage III: Comparison and Testing of Means of Productivity of Construction Works between Southern and Northern Jordan Regions

Means of productivity of construction works in Southern region (Karak and Tafila) in Jordan were compared to the means of productivity of construction works in Northern region (East and West Amman, and Zarqa) in Jordan. For example, productivity of construction works for project and residential building in Karak is compared of productivity of project and residential building construction works in East and West Amman, and with productivity in Zarqa. Also, productivity values in Tafila are compared similarly with productivity values in East and West Amman and in Zarqa. And here the t-test fails to reject the null hypothesis (H_o: $\mu_A=\mu_B$) with P>0.05, as μ_A and μ_B are the means of productivity of project and residential buildings in Northern and Southern regions in Jordan.

The results had shown that the means of productivity values have no significant differences between Sothern and Northern Jordan, i.e., the test fails to reject the null hypothesis (H_o: $\mu_A=\mu_B$) with P>0.05. So, means of productivity values can be used in construction works for project and residential building constructions. And engineers, estimator, contractors, consultants and subcontractors can use any of productivity values or any of the average values of productivity for project or for residential building constructions for any area or region in Jordan.

CONCLUSIONS

As a result, current research measured the means of productivity of construction works in project and residential building in the Southern and Northern regions of Jordan. Also, current research evaluated the significance of differences between means of productivity in the selected areas and regions in Jordan. Following the major findings about the means of productivity for construction works in Jordan:

- It is found that means of productivity of construction works for residential and project construction in Kark and Tafila for all construction works have no significant difference in productivity when t-test was used. Also, means of productivity in East and West Amman and Zarqa in Northern of Jordan have no significant difference. similarity in techniques, training, and process can give similar productivity values.
- it is found that means of productivity of Southern and Northern regions of Jordan have no significant difference using t-test for residential and project building construction.
- Conclusions showed that there is no advanced technology is employed in construction, construction teams (skilled and non-skilled labors) use similar equipment and techniques and receive similar traditional training programs and instructions of work and can transfer to work in different areas and regions. And what is used in residential areas or construction, is used in project construction.
- Considering results of current research, means of productivity of construction works in Jordan can be used for cost estimation and prediction, and bidding of contracts.

REFERENCES

Abdul Rahman1, Ismail, Aftab Hameed Memon, Abdul Qadir Memon, Mutahar Ali Shaikh and Fida Siddiqui (2019) Reasons of Poor Labour Productivity in Construction Works. Malaysian Construction Research Journal, 8(3): 25-29.

Al Jamaz, T. A. (2010) Evaluation of Managerial Factors That Cause Delay in Construction of Projects.

AACE International Recommended Practice No 22R-01 (2004) Direct Labor Productivity Measurement- As Applied in Construction and major Maintenance Projects. Retrieved on 19/5/2020 from the link: https://web.aacei.org/docs/default-source/toc/toc_22r-01.pdf?sfvrsn=4

Ai Ling, Shirley Chin, Loh Wen Jun, NurulHuda Hashim, Myzatul Aishah Hj Kamarazaly (2021) Factors and Impacts on The Accuracy of Cost Planning: Pre-Contract Stage, Malaysian Construction Research Journal, 12(1): 159-170.

Del Pico, Wayne J. (2012) Estimating Building Costs for The Residential and Light Commercial Construction Professional. Hoboken, New Jersey, John Wiley and sons, 455 pp.

Dozzi, S.P. and AbouRizk, S.M. (1993) Productivity in Construction. National Research Council Canada. Retrieved on 19/5/2020 form the link: http://web.mit.edu/parmstr/Public/NRCan/nrcc37001.pdf.

Enshassi, Adnan, Al-Halaq, Khalid, Abu Mustafa, Zaid (2011) Labor Productivity Measurement in Building Projects. The Islamic University Journal (Serries of Natural Study and Engineering, 19(1): 103-119.

Hasan, Bassam (2009) Measuring Productivity of Construction Activities as A Basis to Improve Productivity Performance of Building and Construction Projects (Local Experience). Tishreen University Journal for Research and Scientific Studies. Engineering Sciences Series 32(2).

Herubin, Charles A. (1997) Basic Construction Materials, Methods and Testing. Englewood Cliffs, New Jersey, Prentice Hall Inc.: 472 pp.

Investopedia 2020. T-test Hypothesis Comparing of Means, Tool of Fundamental Analysis. Retrieved on 22/5/2020 from the Link: https://www.investopedia.com/terms/t/t-test.asp#what-is-a-t-test

Jarad, Fayez, Emran, Jamal, Zagboor, Hadeel (2007) Development Methodology to Avoid Delays in Syrian Construction Projects Tishreen University Journal for Research and Scientific Studies. Engineering Sciences Series 29(3).

Jordan Strategy Forum (2019) The Construction and Housing Sector in Jordan. The Challenge of Demand and Supply Alignment and Financing Mechanisms.

Jordanian Engineers Association (2020) The report of The Institution of Construction and Engineering Firms. https://www.jea.org.jo/portal/office/.

Kemppilä, S. and Lönnqvist, A. (2003) Subjective Productivity Measurement. The Journal of American Academy of Business, Cambridge, 2(2): 531-537.

Killen, Peter R. (2005) An Alternative to Null-Hypothesis Significance Tests. Psychological Science, 16(5):345-535.

Mansour, Husam, Eeydzah Aminudin, Balqis Omar, Rozana Zakaria, Santi Edra Nisa Lau, and Ali Al-Sarayreh (2021a) Industry 4.0 and Construction Performance: From Literature Review to Conceptual Framework. Malaysian Construction Research Journal, 13(2): 53-67.

Mansour, Husam, Eeydzah Aminudin, Balqis Omar, Rozana Zakaria and Nur Izieadiana A. Abidin (2021b) Planning Impact and Mediations on The Quality of Construction Projects: Case Study in Jordan. Malaysian Construction Research Journal, 13(2): 212-228.

McDonnell, F. P. (2010) The Relevance of Teaching Traditional Measurement Techniques to Undergraduate Quantity Surveying Students. Journal for Education in the Built Environment, 5(3): 1–15.

Ministry of Public Works and Housing (MOPH) (1996) Technical Specifications for General Building: Civil and Architectural Works.

Oesterreich, T. D., & Teuteberg, F. (2016) Understanding the implications of digitization and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in industry, 83(4): 121-139. doi:10.1016/j.compind.2016.09.006.

Osman, J., Mazlina, S., Khuzzan, S., & Razaksapian, A. (2015) Building Information Modeling: Proposed Adoption Model for Quantity Surveying Firms. Proceeding of International Conference on Information Technology & Society (IC-ITS). Malaysia, 151-165.

Osunsanmi, T. O., Aigbavboa, C., & Oke, A. (2018a) Construction 4.0: The Future of the Construction Industry in South Africa. International Journal of Civil and Environmental Engineering, 12(3), 206-212.

Oqaili, O. S. (1997) Management: Basics, Principles and Concepts. Amman, Dar-Zahran for Press and Publication, 297 pp.

Qaryouti, M. Qasem (2001) Principles of Management, Theories, Operations and Functions. Amman, Dar-Wael for Press and Publication, 314 pp.

Ro'ya Media (2020) Licenses of Residential Building Construction. https://royanews.tv/news/226649.

Sarireh, Mohmd 2013-a. Cyclic Productivity for Horizontal Directional Drilling (HDD) Operation. International Journal of Construction Engineering and Management, 2(3): 46-52.

Sarireh, Mohmd (2013-b) Estimation of HD drilling time using deterministic and triangular distribution functions. Journal of Emerging Trends in Engineering and Applied Sciences, Jun 2013, 438 - 445.

Sarireh, Mohmd (2015) Minor Time Ratio in HDD Prereaming Time In Clayey Conditions – Case Study. International Journal of Sustainable Construction Engineering & Technology, 6(2).

Sarireh, Mohmd (2019) Historical Geotechnical Study and Evaluation of Project Progress for The Tafila City Center Development Project. The International Scientific Conference of 10th Forum of Ecological Engineering, 9-11 September 2019, Kazimierz Donly, Poland, 247-261.

Shipley, D.D. (1981) Pricing objectives in British manufacturing industry, *The Journal of Industrial Economics*, XXIX, June, (4): 429-443.

Shukla, Satishprakash (2017) Significance of Difference Between Means. DOI: 10.13140/RG.2.2.21228.97924. accessed 20/5/2020.

Thomas, H. Randolph (1991) Labor Productivity and Work Sampling: The Bottom Line. Journal of Construction Engineering and Management, 117(3): 309-329.

Walpole, Ronald E. Myers, Raymond H. Myers, Sharon L. Ye, Keying (2007) Probability and Statistics for Engineers and Scientists. New Jersey, Upper Saddle River: Pearson Prentice Hall, 816 pp.

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