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Journal Objectives

International Surveying Research Journal (ISrJ) is an international journal dedicated to the publication of theoretical and empirical refereed articles, case studies or critical literature surveys in the field of surveying research and policy. The scope of the journal is international in two aspects: it presents to a worldwide readership a view of the surveying practices of particular countries, and it encourages knowledge sharing among researchers, policy makers and practitioners.

The purpose of the **International Surveying Research Journal (ISrJ)** serves to provide a forum for discussion and research to keep abreast of the new technologies developments and to stimulate research in the various surveying disciplines.

Editor Message

Welcome to this International Surveyor Journal (ISrJ) Vol. 9, Issue December 2021 for the Royal Institution of Surveyors Malaysia (RISM).

This Journal gathers publication of all four divisions in RISM namely Quantity Surveying (QS), Property Surveying (PS), Geomatic and Land Surveying (GLS), and Building Surveying (BS). The publication of ISrJ gives opportunity to the academicians, practitioners as well as students to share their research outcome. We have covered many topics in the last few volumes under the current editorial but there is a vast area within the four divisions still waiting to be explored.

This particular issue consists of five selected papers reviewed by the editorial committee and international experts which include BIM in construction, geomatic land surveying issues, property issues, smart cities and block chain in construction.

Do drop a message and request if there are specific surveying topics of particular interest. Thank you for the readership and hope it is beneficial to all.

Sr Wan Ainon Zuraiha W. A. Khalid
Editor
December 2021

BIM Adoption in Improving Accuracy for Cost Estimating Practice Amongst Malaysian Quantity Surveyors

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Abstract
Cost estimating is important in ensuring the proposed project could meet the client's budget. The implementation of BIM technology can make the process cost estimating becomes easier. A lot of benefits that BIM provides are such as cost and time saving, reduced human resource, quality and performance improvement, clash detection, improved accuracy, increased profitability and enhanced collaboration and communication. However, its implementation amongst Malaysian Quantity Surveyors for cost estimating practice is still low. Thus, this study was conducted to explore BIM adoption amongst Malaysian Quantity Surveyors towards improving accuracy for their cost estimating practice by identifying the challenges in the implementation and to recommend ways to increase the level of BIM adoption. A survey by questionnaire was conducted with 100 respondents and distributed amongst Malaysian Quantity Surveyors. The responses obtained from the survey were then analyzed using SPSS software. The results indicate that amongst the challenges of the BIM implementation is because of lack of industry standards and protocols in BIM model. Hence, majority of respondents agreed that initiative from government can help to improve the implementation of BIM. The outcomes of the study provide some insights on how the implementation of BIM in cost estimation could be improved by managing the challenges faced by the Quantity Surveyors and considering potential solutions to increase the technology's adoption level.

Keywords: *Building Information Modelling, Cost Estimating Practice, Quantity Surveyors, Malaysian Construction Industry*

INTRODUCTION

The Malaysian construction industry acts as an important instrument for national income. Construction activities can help in many ways such as give building and facilities to fulfil persons' necessities, give a job to the unemployed directly or indirectly (through different enterprises that related to the construction industries such as tourism industry, manufacturing industry, and commercial industry) and contribute toward national economy (Zuo and Zhao, 2014).

Completing the construction project within the time, cost and achieve the quality becomes criteria for the project to be called successful. Successful project has good management behind it, especially cost estimating. Cost estimating is important as it will help the clients to prepare the total costs involved in the construction project at the early stage (Whitby, 2017) and helps to keep up the projects within the budget and limitation of the project (Clarizen, 2017). Accuracy of the cost estimating depends on the scheduling, taking-off and costing for the labour and materials rates. Accuracy of cost estimating also important to make sure the actual cost of the projects is within the budget.

All these cost estimating tasks for the projects are done by the Quantity Surveyor (QS). Quantification, bills of quantities preparation, estimation and pricing of construction projects are the major services that QS provides (Raphael & Priyanka, 2014). Alhasan, et al. (2017) described that the QSs play important roles in every phase of construction such as estimating the building cost, providing services that cover all aspects of procurement, contractual and project cost. Before Building Information

Modelling (BIM) existed, the QS had done the estimation with traditional methods where excel spreadsheet and 2D Computer Aided Design (CAD) are used. Although there was some taking-off software already applied, it was at minimal usage with limited features. This traditional method caused the estimation to become tedious and time-consuming tasks and this led to the inaccuracy (Raphael & Priyanka, 2014).

With BIM, tedious tasks in traditional methods such as measurement, take offs and the production of bills of quantities (BOQ) can be eliminated. It is believed that BIM can give 77% for the information flow, 67% improvement of productivity, and produce 65% cost efficiencies. A lot of benefits BIM can provide are such as cost and time saving, reduced human resource, quality and performance improvement, clash detection, improved accuracy, increased profitability, enhanced collaboration and communication, better presentation and documentation process, improved planning and design, better visualization, and improved information (Ismail et. al, 2018).

However, the adoption of BIM for cost estimating practice amongst Malaysian Quantity Surveyor is still low. Ghaffarianhoseini et al. (2017) said that BIM is still new and in its early phase of implementation in Malaysia. Besides, Quantity Surveyors believed that there are a lot of challenges to implement BIM in cost estimating practice. In Malaysia, the financial constraints have been acknowledged to be one of the issues in influencing the contributions of BIM technology (Hamid & Embi, 2020). Additionally, Construction Research Institute of Malaysia (CREAM) found that implementing BIM for SMEs in Malaysia is difficult due to expensive investment in hardware, software, staff training, hiring BIM experts, obtaining certifications and licenses, as well as additional overhead costs (Kong et al., 2020). Therefore, this study aims to explore BIM adoption amongst Malaysian Quantity Surveyors towards improving accuracy for their cost estimating practice. The challenges in implementing BIM for cost estimating and solution in improving the adoption of BIM for cost estimating are considered.

Literature Review

BIM Usage in the Construction Industry

According to Smith (2014), the development of BIM has been driven by United State (US). As BIM brings more benefit, many developed countries adopted BIM in their construction. The developed countries that use BIM includes United Kingdom (UK), US, France, Germany, Japan, Korea, Australia, Europe, New Zealand, Canada, and Brazil (McGraw Hill, 2014). In the National BIM Report 2019, Bain (2019) said that adoption of BIM in UK reached up to 69% with 29% aware of it. After all, in April 2016 the Government of UK had mandated uses of BIM Level 2 on the government projects. As a result, contractors that wanted to construct the government projects need to change their organization to achieve BIM Level 2. Most of the contractors and consultants believe that BIM can make the cost estimation more efficient and increases the speed to construct the project. This will lead to increase the profitability and motivate them to work internationally. Even in Ireland, the uses of BIM reached up to

76% even though the government introduced the BIM in late 2017 where it can be considered at earlier stage (Archer, 2019). In Germany, the clients themselves demand for the uses of BIM although the government have not yet mandated it. Whilst, the commitment and implementation of BIM showed a positive return on investment or ROI, particularly for contractors in Japan (Smith, 2014). These will lead the contractor to use BIM in their projects.

In Malaysia, BIM has been introduced by Director of the Public Works Department (PWD) in 2007 and has been implemented by a lot of private sectors (Haron, et al., 2017). However, it took a long time for Malaysia to implement BIM in its construction industry completely and the first project that used BIM was National Cancer Institute in 2010 (Latiffi et al., 2016). Haron et al. (2017) added that two projects were chosen as pilot projects for BIM, namely Healthcare Center at Sri Jaya Maran, Pahang and Administration Complex for Malaysian Anti-Corruption Commission (MACC) at Shah Alam, Selangor in 2013. It was emphasized by Latiffi, et al. (2013) and Zakaria, et al. (2013) that Malaysia is still struggling to change the environment working from 2D to 3D drawings. Therefore, to encourage the implementation and adoption of BIM among the construction industry players, the Construction Industry Transformation Programme 2016 – 2020 (CITP) agenda was initiated. It was aimed to transform the Malaysian construction industry by 2020 with the implementation of stage 2 BIM maturity, with a minimum implementation rate of 40% of public projects valued at RM 100 million and above implementing the corresponding approaches and processes. Prior to that, the Construction Industry Development Board (CIDB) has introduced seven pillars for the BIM Roadmap in 2014 for the purpose to ease the organisations to implement and adopt BIM in their projects (Haron et al., 2017).

BIM for Cost Estimating Practice

Raphael & Priyanka (2014) explained that traditional Quantity Take Off (QTO) process for CAD drawings involves selecting individual elements in CAD drawings, using the software to do the taking-offs and measurements automatically, and inserting the quantities in the QTO database. This process requires Quantity Surveyors to spend more time producing the whole drawing's QTO. With BIM, tedious tasks in traditional quantity surveying, such as measurements, taking-offs and producing of BOQ can be avoided. According to Olsen & Taylor (2017), 3D models built in BIM systems are data rich, smart models that are capable to connect individual elements to the material represented in the model. This system has the potential to speed up the QTO for a construction project while improving accuracy in estimation. BIM can reduce the time spent as much as 80% while offering quantity takeoff and forecasts that are reliable within 3%. Some of the Building Information Software (BIM) software used by QSs to estimate the cost include Naviswork, Autodesk QTO, CostX, Innovaya, iTWO, d-profiler, Vico, ProjectWise Navigator, and Glodon (Abanda, et al., 2017). It is easier to capture the quantity of objects in BIM as BIM models are object-based with built-in parametric data and QTO with BIM drawing will be more accurate with fewer errors and omissions (Raphael & Priyanka, 2014).

As compared to the traditional method to take off, BIM gives a better process for the take-off. According to Raphael & Priyanka (2014), if changes happen, traditional methods need manual editing and updating for all drawing views that are time-consuming and error prone. The traditional method requires a great deal of time and energy to update the quantity to accommodate design changes. This process is time-consuming and has serious consequences if the changes have not been detected as the QSs have to constantly checked what has been updated, added, omitted, and make sure there are no overlapped measured item. With BIM, the estimators can derive sums from the BIM models for cost estimations automatically using software application. Upon developing a BIM model, information is collected on the structures/elements sorted according to the building material with the aid of the quantity take-off function. As a result, this extraction will serve as a basis for the creation of quantity take-offs in the building output classification system chosen. From there, after the allocation of building materials to the specific building work (items), it will then arrive at the quantity of take-offs. Subsequently, the quantity take-off is included in the building output estimation system and the allocation of the unit and maximum costs for individual items is achieved, thereby providing a budgetary basis for the construction works.

The Challenges of Building Information Modelling (BIM) Implementation for Cost Estimating Practice

Technology

As the BIM software builds a spreadsheet designed correspondingly to the construction components with automatic or semi-automatic take off included, the QS does not need to manually input all the information. However, the automation is only effective if the software is generated in compliance with the requirements set by the cost estimator and similar to the programs used to estimate costs. Without the requirements set by the cost estimator, the automation might give incorrect values and it would be impossible to obtain the values. According to RICS (2015) the accuracy and quality of data could be at risk as data is transmitted using various formats. Some of the software vendors do not follow a recognized method of measurements. The lack of consistent modeling criteria means that QS must comply with a variety of methods that lead to the negative effect such as inconsistencies and inaccuracies (Smith, 2016). Selecting the right combination of cost estimating BIM application seems very difficult (Forgues et al., 2012). This is because a lot of applications for the 5D BIM are still being developed. There is no interoperability between the software as these applications depend on one or more different external cost databases. Difficult decisions must be made between the implementation of an application that is consistent with the company's existing expense database and the choice of BIM-based software that better suits the needs. As explained by Harrison & Thurnell (2014), the design used in the BIM model is not consistent with the QS format for estimation or quantity schedules. This was agreed by Sattineni & Macdonald (2014) where the 'Detail Level' (LOD) used by the design team to create a model may not be adequate to obtain accurate quantities for cost estimation purposes.

People

Golaszewska & Salamak (2017) emphasized that communication between the members of the working group is the crucial thing for the entire process of cost estimates by using BIM technology. For the cost estimation, individual working scheme in the BIM technology will lead to inaccuracies. Any variations and problems or the compatibility of the created model with other BIM methods need to be informed to other members. It has been explained that each modeled element had to be coordinated between the members of the team, as its explanation of the properties could potentially be related to the possibility of automating data transfer between programs. Since cost estimation is typically carried out at the end of the project phase by different stakeholders using heterogeneous datasets and information, the process is highly fragmented, resource intensive and inefficient, particularly in large or complex project (Forgue et al., 2012). Czmoch & Pekala (2014) explained that even the smallest errors in modelling either 'parameters' or 'construction elements' hierarchy can lead to major miscalculations and lead to major faults and complications. The experience and skill level of the estimator is the most important factor influencing the accuracy of the pre-tender cost estimate. Alumbugu et al. (2014) highlighted that the experience and skill level of the consultants, project teams experience on construction type are the factors that affect the accuracy of the estimating. Lack of experienced staff also leads to poor estimates.

Process

According to Smith (2015), Quantity Surveyors need to adapt to a variety of approach if there is lack of consistent in modelling standard as each database has its own structure and the lack of standardization will lead to the inaccuracies of the cost estimating (Matejka & Vitasek, 2018). This problem will create to obvious inefficiencies and waste time. In Malaysia, many of the organizations are trying to be champions of BIM by creating their own version of the BIM implementation guidelines. As there are many standards of BIM created with no proper guidelines from the expert, it leads to confusion among construction players (Zakaria et al., 2013). Thurairajah & Goucher (2013) described that without industry guidelines demonstrating how BIM can directly relate to database estimation products, issues with the synchronization of the two system are likely to occur, making it difficult to generate accurate estimation. In the 5D BIM, if the elements including the description are prepared in the same base design software, the process of modelling can be easy. However, the choices of elements are very limited if downloaded or copied from other programs (Golaszewska & Salamak, 2017). Sattineni & Macdonald (2014) also mentioned that models may have errors in them as some element not been estimates and models need to be checked to ensure that estimate can be obtained accurately. Shen & Issa (2010) further claimed that the BIM models do not include 'Process Construction Quantities' for items that depends on the construction process, as opposed in 'Product Procurement Quantities,' which are design components that are present in the BIM model and can thus be easily quantified, e.g., concrete volumes or steel mass.

The Solutions in Improving BIM Adoption Level for Cost Estimating Practice

Initiatives by the Government

The BIM standard code of practice and guideline is a prerequisite for standardizing new adoption and allowing effective communication and collaboration between stakeholders (Haron et al., 2017). Smith (2015) eloborated that the development of a global BIM Modelling Standards for Project Cost Manager and QS can be the best approach to cope the problem in lack of consistent in BIM. The establishment of international standard must be made through the input and ownership of professional cost management association around the world and must be acknowledged by world bodies and national governments. Besides the standard guidelines, the government also need to take full advantage of their administrative function and participate actively in the promotion process. Haron et al. (2017) further explained that the governments should play a guiding role in the implementation of BIM and inspire the development of industry. A lot of awareness and motivation programs, such as seminars and workshops for different level of industry players, may be strategically organized by the government.

Top Management Efforts

It is vital for organizations to have strong support from the top management to adopt BIM technology in the firm. Top management can be a 'Change Agent' for the firm as they able to change the existing work culture and their mindset will affect the employer's acceptance of BIM (Zakaria et al., 2013). The firm should provide the level and type of training that are suited to the firm's goal (Zakaria et al., 2013). This training will help the employer to gain knowledge about BIM technology especially in 5D BIM and enhance the skills in cost estimating. Subsequently, that motivation and good support from management will enhance the education and training for workers to embrace and use BIM technology and create new roles for them. In order to speed up the adoption of BIM, the management should monitor the recruitment process by evaluating qualifications, experience and skills of the applicants in handling of BIM technology. Ramasubbu & Balam (2012) suggested that manager should provide an expert guidance on automatic metric-driven and regression-based estimation techniques so that important contextual information like project type, configuration of dispersed project teams and nature of client is considered in appropriate ways. By recruiting employers that can handle and have knowledge of 3D software, the firm can create the capable team which consist of BIM Manager, BIM Coordinator, BIM technologist and BIM Modeler (Eastman et al., 2011; Zakaria et al., 2013). Zakaria et al. (2013) emphasized that working with the BIM experts is a must process and can minimize risk in implementing the new technology. Data management software should be used as each database has its own structure and it involve a large amount of the data for one project. Data management tools should be used to manage the large volumes of data that can be created during BIM process (RICS, 2014).

Research Methodology

This study explored BIM adoption amongst Malaysian Quantity Surveyors towards improving accuracy for their cost estimating practice. There are six phases of research methodology involved in this study including preliminary stage, data collection, data analysis, findings and discussion, and conclusion. In the preliminary stage, literature review was done in which problem statement, aim and objectives were identified accordingly. The reviewed literature was obtained from the books, articles, journal and proceeding papers. This study employed quantitative method by using questionnaire survey to obtain the data. Based on the literature, the questionnaire items were developed by sections of background information, BIM implementation challenges for cost estimation and its solutions, and lastly a recommendation section allowing any related suggestion from the respondents regarding the surveyed topic. Closed ended questions used Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) for the respondents to state their level of agreement towards statements available in the questionnaire. The survey was conducted by distributing the questionnaire to 100 respondents, amongst Quantity Surveyors in Malaysia regardless they are BIM users or non-BIM users. A google form for the survey was created and the link to the survey form was distributed and disseminated online using emails, WhatsApp, Facebook, LinkedIn, and other possible online platforms. The data gathered were then analyzed using SPSS software adopting descriptive analysis and Average Index to get the mean values in ranking the items outlined in the questionnaire. Ultimately, findings were discussed and conclusion was made underlining the significance of the study and further recommend potential future research based on the study results.

Findings and Discussion

From the total of 100 surveyed respondents, they aged between 25 years and below (48%), 26-35 years (42%), 36-45 years (3%) and 46 years and above (7%). They have working experience in estimating costs of 1-5 years (83%), 6-10 years (7%), 11-15 years (3%), 16-20 years (3%) and more than 20 years (4%). The respondents whether work with contractor's firms (54%), QS firms (25%), developers (8%), architect's firms (2%), government agencies or local authorities (5%), or others (6%). They considered their organization's scale of business as small (29%), medium (39%) and large (32%) with types of projects involved are government (19%), private (36%) or both government and private (45%). From overall respondents, 51% of them did not practice BIM and 49% practice BIM in their cost estimation. From the 49% of respondents practicing BIM in their projects, the type of projects involved are commercial (12.3%), residential (12.3%), mixed development (14.2%), infrastructure (7.8%) and others (2.5%).

The Challenges in Building Information Modelling (BIM) Implementation for Cost Estimating Practice Amongst Quantity Surveyors in Malaysia

Table 1 ranks the findings on the challenges of BIM implementation for cost estimating practice amongst Quantity Surveyors in Malaysia. It can be divided into three categories which are technology, people, and process.

Table 1. BIM challenges in cost estimating practice

Rank	Description	Mean Value	Standard Deviation
	a) BIM challenges in term of technology		
1	BIM automation is only effective if similar BIM programs used to estimate the cost within project team	3.84	0.801
2	Interoperability can be difficult to achieve due to the team's expectations of implementing one BIM system	3.71	0.820
3	The accuracy and the quality of data could be at risk	3.50	0.937
4	BIM model is not compatible with elemental estimating and schedules of quantities format	3.46	0.881
5	The data collected is limited and did not reflect the BIM program's full capabilities	3.45	0.925
	b) BIM challenges in term of people		
1	Cost estimation depends on all other project management skills and requires multitude of tasks	3.93	0.756
2	Lack of experience in the estimation and BIM model	3.87	0.849
3	Lack of communication between the designers and cost estimators	3.76	0.889
4	Different stakeholders use heterogeneous datasets and information	3.76	0.780
5	Failure to provide information that needed in BIM	3.71	0.868
	c) BIM challenges in term of process		
1	Lack of industry standards and protocols in BIM model	3.73	0.886
2	The descriptions choice in software are limited	3.68	0.886
3	Tendency for some elements not to be counted in the BIM model	3.54	0.846
4	Not 100% precision of the virtual representation of the designed building achieved in daily practice	3.46	0.809
5	5D BIM does not allow for wastes, jointing and lapping	3.43	0.856

The challenges were divided into three categories which are technology, people, and process. The results show that BIM automation is only effective if similar BIM programs used to estimate the cost within project team is the most-ranked challenges in term of technology with mean value 3.84. Golaszewska & Salamak (2017) stated that BIM is only effective if the software is generated in compliance with the requirements set by the cost estimator and similar BIM programs used to estimate cost. Without the cost estimator's specifications, the automation could generate incorrect results, making it difficult to obtain the results. The choices of elements are also very limited if downloaded or copied from other programs. For example, if the users use AutoCAD and wanted to download the element from the REVIT, the choices may be limited. Elements need to make in other program because the elements may have the complicated geometry and may be easy and suitable to model with different software. Quantity Surveyors need to adapt to a variety of BIM programs as each database has its own structure and these will lead to the inaccuracies of cost estimating.

In term of people, the highest ranked obstacle to the implementation of BIM for cost estimating is cost estimation depends on all other project management skills and requires multitude of tasks (mean value=3.93). The cost estimation depends on all other project management skills which are scope, time, quality, and risk management. According to previous study by Torp & Klakegg (2016), cost estimation is an iterative method to create an estimate and requires a multitude of tasks. Estimating the costs of complex projects also add more complexity in the estimation. Additionally, lack of industry standards and protocols in BIM model becomes the main barrier to the BIM implementation in term of process (mean value=3.73). This is supported by the previous study where lack of standardization will lead to the inaccuracies of the cost estimating (Matejka & Vitasek, 2018; Harrison & Thurnell, 2014). It also leads to confusion among construction players if there are no proper BIM standard guidelines as they do not know the right procedure to implement BIM system.

The Solutions in Improving BIM Adoption Level for Cost Estimating Practice Amongst Quantity Surveyors in Malaysia

Table 2 shows the findings on recommendation of solutions in improving BIM adoption level for cost estimating practice amongst Quantity Surveyors. The solutions are grouped and ranked into initiative by the Government, and top management efforts.

Table 2. Solutions to improve BIM implementation level in cost estimating practice

Rank	Description	Mean Value	Standard Deviation
	a) Solutions in term of initiatives by the Government		
1	Promote BIM technology and give inspiration to the industry development	4.23	0.737
2	Prepare a standard code of practice and guidelines for BIM technology	4.22	0.705
3	Develop BIM Modelling Standards for Project Cost Manager and QS	4.19	0.720
	b) Solutions in term of top management efforts		
1	Provide an expert guidance on BIM and estimation techniques	4.29	0.671
2	Give motivation and good support to the workers	4.29	0.686
3	Use data management software	4.18	0.687
4	Collaborate with 5D BIM technology expert	4.14	0.697
5	Monitor the recruitment process to include BIM knowledge and skills requirement	3.99	0.870

For the solutions towards the challenges, the Government and top management play important roles in improving BIM adoption level for cost estimating practice. In term of initiatives by the Government, the results show that the highest ranked statement stated that Government needs to promote BIM technology and give inspiration to the industry development (mean value=4.23). In line with Haron et al. (2017), it was emphasized that the Government should play a guiding role in the implementation of BIM and inspire the development of industry. The government can organize the awareness and motivation to the different level of industry player. Meanwhile, to give motivation and good support to the workers and provide an expert guidance on BIM and estimation techniques, are the highest ranked statements as the ways to improve BIM implementation level in cost estimating practice in terms of top management with mean value 4.29, respectively. Zakaria et al. (2013) explained that motivation and good support from management will enhance the education and training for workers to embrace and use BIM technology. The guidance from BIM expert can minimize risk in adopting new technologies. As for that, top management can provide some motivation programs such as seminar and workshop as part of BIM adoption improvement efforts.

Conclusion

The adoption of BIM for cost estimating is still low as Quantity Surveyors believed that there are a lot of challenges to implement BIM in cost estimating practice. In this study, the challenges for BIM adoption can be grouped into three categories which are technology, people, and process. In term of technology, Quantity Surveyors found that BIM automation is only effective if similar BIM programs used to estimate the cost within the project team. Moreover, in term of people, cost estimation depends on all other project management skills and required multitude of tasks. Whilst lack of industry standards and protocols in BIM model becomes the main implementation barrier in term of process. These challenges need to be coped accordingly to improve the BIM adoption in cost estimating practice amongst Malaysian Quantity Surveyors. Thus, there are some potential solutions to increase the level of BIM adoption for cost estimating practice. The government and top management specifically play important roles to overcome the low adoption of BIM in cost estimating practice. The Government needs to promote BIM technology and gives inspiration to the industry development, and the top management must give motivation and good support to the workers and provide an expert guidance on BIM and estimation techniques. Perhaps these solutions can help the Malaysian Quantity Surveyors to adopt BIM widely in the future to improve accuracy for cost estimating.

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Anomalies On Intrinsic and Extrinsic Micro Camera Parameters Based on Different Sizes of Calibration Pattern on Checkerboard

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Abstract
The purpose of camera calibration is to acquire the intrinsic and extrinsic camera parameters. A previous researcher has introduced the checkerboard pattern for camera calibration. Parameters are then acquired and used to balance the bowling and dooming effects of the image, thus ensuring the accuracy of the photogrammetry product as well as establishing the decision making for geographic information system (GIS) application and other mapping analyses. The requirement has revolutionised the technique of calibration by using images. This study investigates the camera parameter change in value by increasing the number of checkerboard points and the effect on control/known points in acquiring the camera parameter. The value of camera parameters based on different checkerboards were studied. The cameras used for this study are Phantom 4, Mavic 2 Pro and Huawei Nova 3i. All the camera positions ranged about 1 m to 1.5 m in distance from the checkerboard. The size of the checkerboard was fixed to an A1 paper size, but the square sizes on the checkerboard varied 15 × 15, 25 × 25, and 50 × 50 mm. There were five calibration results of 20 images for each square size. It was found that the 50 × 50 mm square size gave the lowest reprojection mean error as compared to the 15 × 15 mm and 25 × 25 mm sizes.

Keywords: Camera calibration, Unmanned aerial vehicle (UAV), MATLAB, non-metric camera

Introduction

The geometric information of three-dimensional features is acquired from the photogrammetric procedure. The accuracy of measurement is at millimetre-resolution level for close-range photogrammetry and centimetre-resolution level for aerial photogrammetry, depending on the ground scale distance. Therefore, it is important to perform camera calibration, as it provides accurate measurement by utilising the camera parameter onto the bundle adjustment calculation. In most conditions, these parameters must be obtained through experiment and calculation. Image based mapping are non-invasive technique, thus widely used in archaeology, robotic navigation, machine vision, biomedicine, and visual surveillance. Camera calibration is used to evaluate the performance of camera lens and lens stability besides determining geometrical and optical parameters. It is also used to determine the geometrical and optical parameters of imaging data acquisition (Fraser, Cronk, & Stamatopoulos, 2012; Remondino & Fraser, 2006).

Camera parameters consist of principal distance, focal length, radial distortion, and tangential distortion. All these parameter values are used to correct distortion, measure the size of an object in world units, and determine camera locations in the scene. Detchev, Mazaheri, Rondeel, and Habib (2014) explained that the distortion of images could be eliminated or reduced by using self-calibration bundle adjustment. All parameter values were used as the input for interior orientation during image processing. Therefore, the parameter value affects the photogrammetric accuracy of the final output. Camera calibration can be divided into three categories, namely traditional calibration techniques (DLT method, non-linear optimisation technique, and two-step method), self-calibration techniques (active vision camera and fundamental matrix calibration), and calibration techniques based on active vision (Wang Qi, 2010). Two calibration methods were presented by Hieronymus (2012) for large focal lengths that employed goniometer with collimator and used diffractive optical elements (DOE) to project holograms of well-known patterns, while bundle-block-adjustment technique was used for small focal lengths. Tahar and Ahmad (2011) explained three types of methods known as on-the-job calibration, self-calibration, and analytical plumb-line calibration.

The camera calibration parameters consist of focal length (*f*) value, principal point c*x cy* coordinate, tangential distortion T1, T2, and radial distortion R1, R2, R3 values. Automated pipelines nowadays provide high quality spatial data. By using structure from motion (SFM) techniques, especially in unmanned aerial vehicle (UAV) based platforms, the phenomenon (photogrammetry technique) triggered a wide application, attracting experts and non-experts. Therefore, a crucial factor for 3D modelling is camera calibration, which is also renewed by several studies. This is particularly so for autonomous camera calibration that is preferred by users due to acceptable results and accuracy. Self-calibration with reliable accuracy was presented by James, Robson, d'Oleire-Oltmanns, and Niethammer (2017) and Hastedt and Luhmann (2015). The requirement is to add oblique image, sufficient scale variation, multiscale nadir image, adequate number of imagery, ground control points accuracy, grid flight pattern, and strong geometric features. However, it is impossible to expect users to comply with the requirement, especially users from the surveyor background.

For example, to have an accurate ground control point (Chibunichev, Kurkov, Smirnov, Govorov, & Mikhalin, 2016; Chibunichev et al., 2016) and to acquire a similar image configuration for all UAVs (Hardner & Schneider, 2019), James et al. (2017) stated that optimal network schemes for camera calibration (similar scale image) were unachievable because several UAV operational situations were infeasible. Furthermore, uneven terrain, ground control points configuration, and corridor configuration always make it impossible (Hastedt & Luhmann, 2015). Pre-calibration is advised due to the problems stated above and by ignoring the ground control point (GCP), whereby a simple planar object needs to be prepared for the process. Although it is limited to long focal length cameras, it is promising due to its significant accuracy and the presence of several studies on how to cope with the situation (Yanagi & Chikatsu, 2015; Gašparovic & Gajski, 2016).

The study on planar objects for calibration purposes is still on-going (Hieronymus, 2012; Adduci, Amplianitis, & Reulke, 2014), especially for autonomous calibration purposes that use different features of planar object (graffiti wall) (Adam, Kalisperakis, Grammatikopoulos, Karras, & Petsa, 2013) and multiple planar checkerboards (Grammatikopoulos, Adam, Petsa, & Karras, 2019). Planar checkerboard pattern is mostly used for calibration. It is cheap and can be printed quickly at any scale. Others use several batches and special markings that are identified by their software, such as PhotoModeler. Freeware is also available for researchers; for example, camera calibration toolbox from MATLAB, Agisoft Lens, and OpenCV. Many studies on planar checkerboard usage have been conducted (Zhang & Member, 2000; Luhmann, Ohm, Piechel, & Roelfs, 2011; Wohlfeil, Grießbach, Ernst, Baumbach, & Dahlke, 2019). A deep learning process helps with the edge detection of checkerboard corners, whereby a number of calibrations was reported to have relied on planar checkerboard. A different level of accuracy is considered whereby a 2D planar method is acceptable if the process adapts a strong configuration of image block.

Today, due to the high potential of UAVs, many studies have been conducted with regards to camera calibration, especially in the aspects of flight parameter (Yusoff, Mohd Ariff, Idris, Majid, & Chong, 2017; Yusoff, Mohd Ariff, Idris, Majid, & Chong, 2015; Mitishita, Barrios, & Centeno, 2014; Radford & Bevan, 2019). Different methods of camera calibration were produced through different platforms, whereby UAV platforms require a spacious area for calibration and flying configuration that has enough variations in altitude to produce a good focal length solution (Radford & Bevan, 2019; Ahmad, 2011). Therefore, it is motivated from the different tests to acquire the best camera parameter calculation result. The study proposed to increase the calibration target point in order to find the projection of camera parameter values. The mean projection errors were used to evaluate the accuracy of the results. Yet, the previous study of a particular experiment on the checkerboard used with a different number of calibration points has not been investigated from the UAV platform (Liang, B, Zhang, & Gao, 2018). The aim of this study is to determine the optimum square size from the projected mean error result and analyse radial and focal length values for data consistency. Enlightened by the previous studies above, this study evaluates the micro UAV camera parameters on photogrammetry-based mapping quality. The degree of calibration influence on the final data is investigated.

Methodology

As mapping photogrammetry becomes important, so is the camera calibration of digital cameras. Due to the manufacturing of consumer sensors and imprecise lenses, the radial lens distortion tends to be higher. Camera calibration application nowadays is embedded as a part of photogrammetry software. This complements the mapping procedure as it can be initiated during or before the photogrammetry process. Figure 1 shows a methodology of the study.

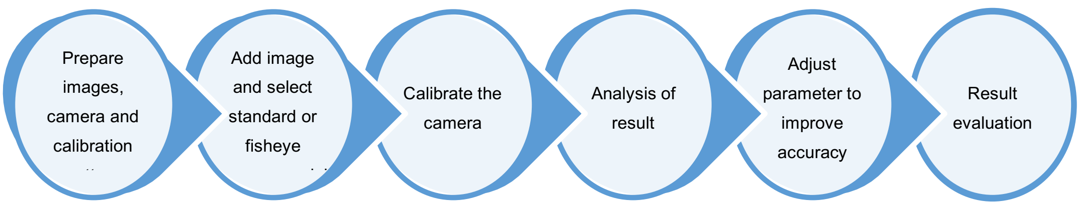

Figure 1. Methodology of proposed camera calibration with a different number of checkerboard size

Several software that provide camera calibration are Agisoft, PhotoModeler, camera calibrator by MATLAB, and Australis. Dedicated for this study, the Single Camera Calibrator application by MATLAB is used to estimate intrinsic, extrinsic, and lens distortion parameters. These parameters are used to eliminate image lens distortion, measure planar objects, or reconstruct objects by using 3D. The image collected from sensor of different checkerboard. While, Table 1 and Table 2 show a specification of checkerboard and Figure 2 shows UAV platforms used in this study.

Table 1. Specification of Checkerboard

Paper size		A1(59.4 x 84.1cm)	
Square size (mm)	50×50	25×25	15×15
No. of target point	150	704	2052
No of processing image		20	
Camera		Phantom 4 & Mavic 2 Pro	
Calibration test		10 times for each square size	

Table 2. Specification of UAV sensor

			Sensor Size		Image Resolution		
UAV	Focal Length (mm)	Pixel Size (micron)	Sensor Width (mm)	Sensor Height (mm)	Width	Height	Effective Pixel (mp)
Phantom 4	3.61	1.6	6.4	4.8	4000	3000	12.4
Mavic 2 Pro	10.26	0.00316	17.3	11.533	5472	3648	20

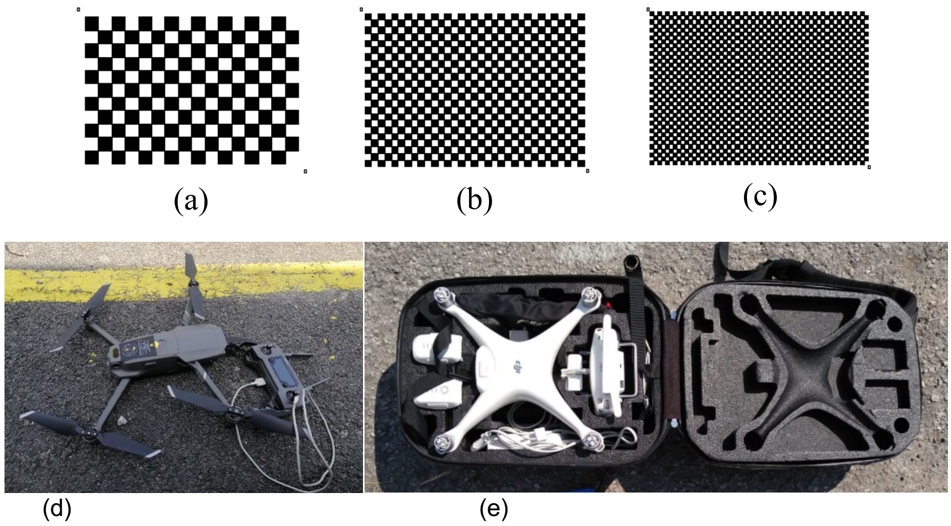

Figure 2. Checkerboard design pattern by square size different; (a) 50x50mm, (b) 25x25mm, (c) 15x15mm, (d) Mavic UAV, (e) Phantom 4 Pro UAV

UAVs were flown manually from 2m height. The image processed using Single Camera Calibrator by MATLAB. The result acquired is projection error of point, radial distortion and tangential coefficient of lens. The mean value each result study meticulously. Figure 3 shows the edge detection represented by the green circle. This so-called projected point was derived from the block bundle adjustment to differentiate the edge detection of the checkerboard before the calibration was initiated.

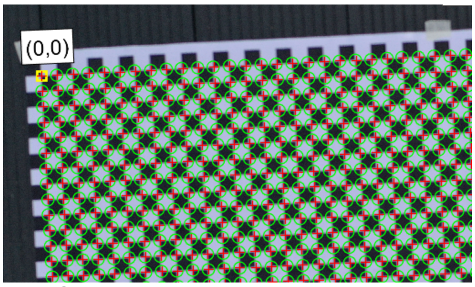

Figure 3: Checkerboard on edge detection marking

Results and Analysis

Several methods were used to evaluate the camera calibration result; for example, plotting relative locations of the camera and the calibration patterns, analysing reprojection error quality, and studying the errors of estimated parameters. There was no comparison analysis of camera parameters with theoretical value except for the focal length information of micro UAV cameras. This study used reprojection error result and focal length error of camera to determine the optimal square size of checkerboard. Reprojection error is the error of detected point before calibration with the reprojected point by using camera parameters data as shown in Table 3. The unit of projection is in pixels. The focal length estimated by the calibrator was converted to millimetre units and compared with the theoretical data provided by the manufacturer in Table 4.

Table 3. Intrinsic camera parameter

		Radial distortion			Focal length (pixel)		
Camera	Rectangle size (mm)	k1	k2	k3	x	y	Reprojection mean error
Phantom 4	15	-0.006241	0.0383484	-0.045368	2,256.25	2285.258	0.47963240
	25	-0.137198	2.7672163	-16.95398	2301.8963	2403.363	1.1794330
	50	0.03139774	0.00835012	-0.030076	2261.4554	2271.5647	0.53670242
Mavic 2 pro	15	0.00651853	0.02954311	-0.153200	3256.298	3,257.99	1.23219406
	25	0.21250641	-2.8819119	20.46489	3456.9136	3,399.16	4.62571564
	50	0.0192177	0.49629188	-4.721974	3259.3597	3,259.70	1.63412100

Table 4. Focal length error

		x	y	Focal length (mm)	Error
P4	15	2,256.25	2285.258	3.610007216	7.216E-06
	25	2301.89633	2403.36346	3.683034128	0.073034128
	50	2261.45542	2271.564753	3.618328672	0.008328672
Mavic	15	3256.298	3,257.99	10.29494799	0.03494799
	25	3456.9136	3,399.16	10.92920418	0.669204181
	50	3259.35971	3,259.70	10.30462774	0.044627738

Figure 4 shows that the 15 × 15 mm size has lowest errors for both cameras, followed by 50 × 50 mm and 25 × 25 mm sizes. 25 x 25mm size of checkerboard has exponential increase from 15 to 50mm of size. Thus, 25mm and 50mm square size is an optimal size of checkerboard for camera calibration. The study compared the results of radial coefficient (Figure 5). It can be stated that the values obtained do not differ much from each other. Focal length error has quite consistent data with projection mean error in Figure 6. It shows that reprojection mean error acquired correlate with the accuracy of focal length estimation. From the holistic analysis, square size gave a different intrinsic parameter quality.

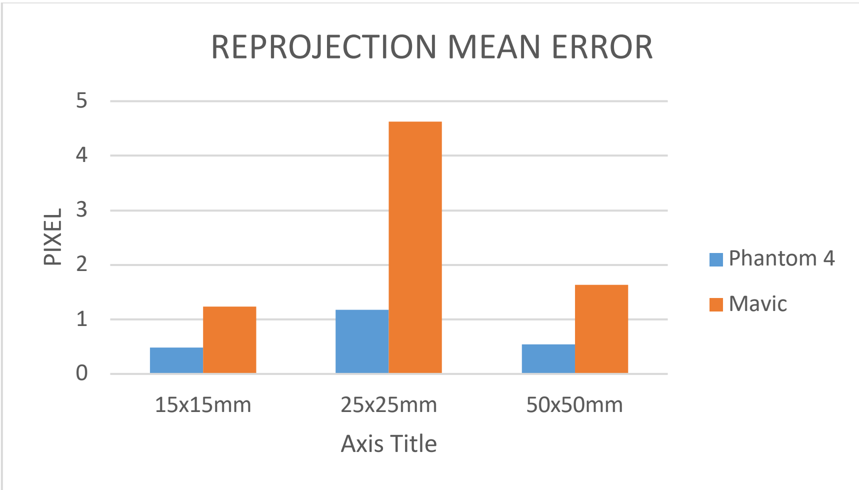

Figure 4. Reprojection mean error

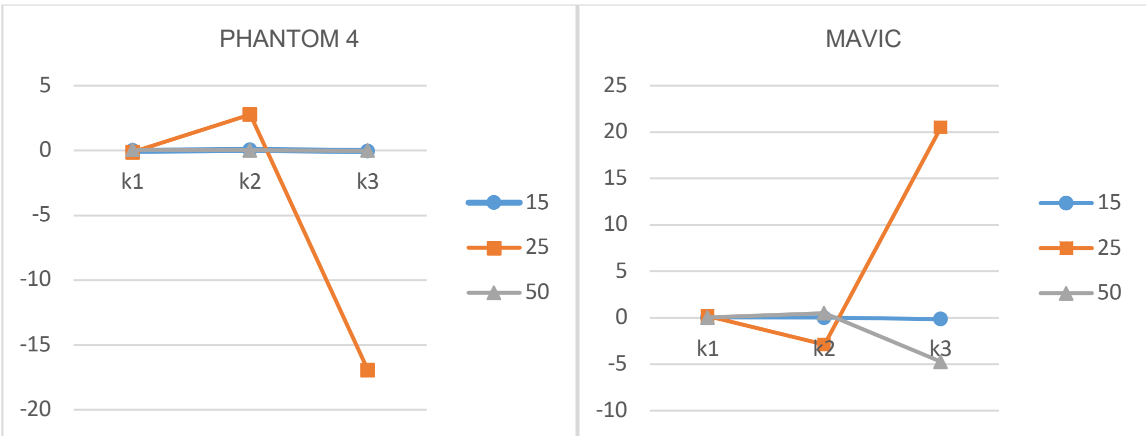

Figure 5. Radial coefficient of Phantom 4 and Mavic

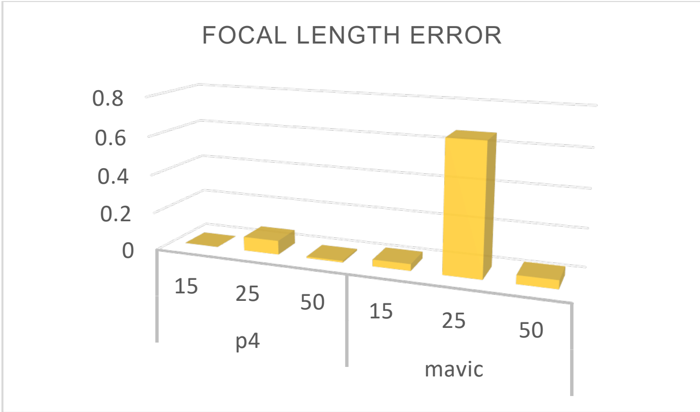

Figure 6: Focal length error

Conclusion and Recommendation

This study investigates the camera parameter change in value by increasing the size of square in checkerboard. The study presented a planar technique which enables a semi-automatic camera calibration. The calibration algorithm and application is provided by MATLAB owing to its simple and user-friendly interface. The result showed that the 15 × 15mm and 50 × 50 mm square sizes gave a persistent and smaller reprojection mean error. More tests of different square sizes needed to map the tendency and projection of error. This study suggests having multiple different square sizes for a calibration test; in fact, from the test, square size significantly affected camera parameters results even though not necessarily proportional. But it is inconclusive, whether size change is indeed better or leads to less accuracy as the error is too small to affect the photogrammetric product. However, it does significantly different if the product captured (Digital Orthophoto Model or Digital Elevation Model) for mega scale projects. Meanwhile, all radial distortion coefficients are consistently close to null distortion for 15 × 15 mm checkerboard. The result confirmed the relationship between intrinsic parameters with square size of checkerboard. Additionally, camera parameter is part of the assurance to have an accurate image mapping. Focal length value must be accurately known. Tested cameras produced focal length accuracy up to ± 0.6 mm. Thus, it is below the Photogrammetry tolerance error, showing a perfect camera calibration procedure that was carried out.

From this research, there are indeed some limitations in conventional camera calibration techniques. For instance, large areas require a large checkerboard, therefore it must be convenient to have checkerboards with longer and larger intervals of rectangle size and add-on values of different altitude/distance from the camera to the checkerboard. Although several studies have come up with multiple coplanar utilisation—which helps to tackle the issue—some of the areas were still not covered by the checkerboard, thus not reflecting perfect distortion condition or parameter value. Checkerboard positioning and orientation also necessitates further study to minimise error of camera parameter results, including rotation, angle of view, positioning for image coverage and multi distance of aperture. As a conclusion to this study, both 15 × 15 mm and 50 × 50 mm sizes of checkerboard offers good accuracy of camera calibration. While, 25 x 25mm size having a ± 4-pixel error which is exceed calibration tolerance (1-pixel). This study will continue to expand other parameters such as distance of aperture, number of images used during calibration, and effects of large-scale versus small-scale checkerboards on accuracy.

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An Initiatives-Based Smart City Assessment of Selected Cities in Taiwan

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ABSTRACT
As many cities are turning into Smart Cities due to the growing prominence and advancement in ICT, many city authorities are looking at sustainable ways for city management and development. With the use of an assessment framework that was adopted earlier by Adnan et.al (2016), this paper attempts to examine and assess the smart city initiatives of five (5) cities in Taiwan. The assessment framework, which was based on the modification of Giffinger's model, has examined the initiatives available at these cities within six (6) dimensions – people, environment, economy, governance, living and mobility. The five (5) cities were chosen as they are city municipalities that have the initiatives that promotes the development of smart cities. They were compared within the framework and the performances based on the initiatives-based smart city assessment which reveals varying achievements for the selected cities. Taipei city leads in three (3) of the Smart City dimensions. It is also revealed that the five major cities in Taiwan have different smart development priorities, mainly because the citizens of these cities have different needs and thus, would require different initiatives

Keywords: Assessment Framework, Dimensions, Initiatives, Smart City

Introduction

The development of smart cities aims at improving the quality of life in the entire city, thereby achieving sustainable management and environmental protection through efficient resource utilization. However, the formation of smart cities requires the integration of technology and information. It can be observed that currently, governments of major cities all over the world are fully committed to the development of smart cities. In anticipation of this inclination towards the development of smart cities, the current cities development needs to reconsider the initiatives that have been planned and realigned them within the dimensions that have been identified. Various researchers have developed smart city assessment framework and they have been adapted from Giffinger et. al. (2007)'s original six dimensions. These dimensions include People, Environment, Economy, Governance, Mobility and Living.

This paper discusses the comparison of the smart city initiatives within five (5) cities in Taiwan. The cities comprise major cities in Taiwan and they have been compared through the alternative framework for assessing city smartness performance that has been developed earlier by Adnan et.al. (2016). In order to provide a qualitative assessment of the Smart City performance, a heuristic approach was adopted. It has been noted that the framework by Adnan et.al. (2016) which adopted this approach had attempted to employ a practical method that provides sufficient accuracy in making assessment of the smart city initiatives within the Giffinger's model. The selection of the Smart Cities in Taiwan is to compare existing Smart City achievements with the initiatives that have been provided and developed. This paper involves an examination of the five cities' Smart City initiatives and programmes against the cities' functions and other institutional factors, taking into account of the city development progress.

Literature Review

The Definition of Smart City

According to IBM (2015), the smart city is an ecosystem, and three aspects of planning management (police security, smart buildings, government agencies), infrastructure construction (energy and water management, reducing environmental impact, and stable communication speed) and citizen satisfaction (social welfare and health, retail customization, education) are included, thereby connecting into an interconnected ecosystem. . To this end, this paper intends to assess the development of smart cities in five cities that had smart cities initiatives in Taiwan through the assessment framework adapted by Adnan (2016).

The public and private sectors has interpreted of the term ‘Smart City’ has in various ways to suit their agenda (Yanrong et. al., 2014). The smart city can be viewed as an urban research center, an urban advancement environment, a living lab displaying the progress within the technology applications (Schaffers et. al., 2012). It can also be viewed as a city that invests in human and social capital, as well as uses ICT-based framework so that further sustainable financial development could be spurred with the aim of generating a high caliber of life. This can only be achieved through an astute administration of regular assets, through participatory government (Caragliu et. al., 2009).

According to the Intelligent Community Forum (ICF) study, smart cities should have the indicators shown in Table 1 to meet the criteria of smart cities.

The European Smart City Index (ESCI) through Giffinger et. al. (2007)’s original six (6) dimensions comprising Smart Governance, Smart Mobility, Smart Environment, Smart People, Smart Living and Smart Economy is another measure of assessment. The initiatives and programmes that have been identified under smart economy that have included flexibility, economic image trademark, innovation productivity, entrepreneurship, labour, international degree of integration etc. are among the important indicators to measure. As for smart people, there are factors such as human capital level, social and ethnic diversity, creativity, lifelong learning, flexibility, worldview, and public affairs participation to consider. In terms of smart governance, it is related to public participation, public and social services, governance transparency, policy strategies and visions of the governing authority of the city. Smart mobility is geared towards secured transportation systems, national urban accessibility, local accessibility, ICT infrastructure availability and sustainable innovation. The smart environment is oriented towards pollution control, natural resource attraction, environmental protection, and sustainable resource management. Smart living includes housing quality, educational facilities, health conditions, cultural facilities, personal safety, tourism attractiveness, and social cohesion.

Table 1. Six indicators of ICF selection of smart cities

Term	Index
Broad Band	Policies and plans to improve the infrastructure of broadband networks
Knowledge work	The educational level of urban residents and the proportion of higher education talents. And the proportion of research-based industries in cities
Innovation	Includes government e-innovation services or through the provision of principal, bursaries and loans.
Digital Inclusion	Broadband network deployments may result in uneven resource allocation due to regional or economic conditions. Skills training should be implemented to open computers to the public and arrange digital literacy.
Sustainability	Sustainable resource management
Marketing & Advocacy	Marketing and advocacy capabilities

Source: https://www.intelligentcommunity.org/

Taiwanese smart city assessment system have included the following indicators: smart city capacity (Smart Enterprise, Smart Environment, Smart Government, Smart Citizen), citizen satisfaction (Tourism Development, Medical Care, Housing Market Information, Recreation, Natural Disaster Reporting, Mass Transportation, Education Resources, Network Construction, Online Service, Enterprise Innovation, Environmental Sustainability, Public Safety,) and smart city construction benefits (public demands). It had been noted that there was an earlier attempt to examine the smart city plans for cities in Taiwan by summarising the initiatives in relation to the dimensions (Lai, 2018).

It can be observed that smart city definitions and assessment seem to go along well with the idea of six dimensions as proposed by Giffinger et. al. (2007). The six (6) dimensions were identified as indicators to indicate the level to which a city is smart. While defining smart city remains unverifiable matter, the six (6) dimensions remain as the key indicators for measurement of smart city.

Methodology

In attempting, to highlight the extent of the smart city initiatives practiced at the identified cities in Taiwan, the alternative framework developed by Adnan et.al. (2016) was adopted. This alternative assessment framework had attempted to overcome the restrictiveness inherent in the assessment of smart city through a heuristic approach. This approach involves a subjective process of reflecting the nature of the phenomenon under investigation. The initiatives that can be identified to make a city smart are examined and then analysed qualitatively. Various sources are gathered to identify and examine the available and developed initiatives. The data can be extracted from official websites, government reports, and government online publications. Validation of the information that has been secured through third party sources were made through visits to the selected cities, which enabled ground observation. From the gathered and verified information of the various initiatives and programmes at the five (5) cities in Taiwan, the extent of the smart city initiatives practiced by each city can be ascertained. The examination of the initiative is compared in relation to the score table that Adnan et.al. (2016) study had developed based on smart city descriptors as shown in Table 2.

The description of the initiatives identified under each dimension are developed by drawing the factors under each dimension from Giffinger's and Adnan et.al models. Table two (Score Table) shows the summary of the descriptors under each of the six dimensions. A comparative review is made on the smart city initiatives from the achievement level identified through the descriptors for the selected cities: Taipei City, New Taipei City, Taoyuan City, Hsinchu City, Taichung City and Kaohsiung City. A heuristic analysis of the initiatives in accordance to achievement levels that were divided into four categories, namely, Basic, High, Advanced and State-of-the Art and fieldwork observation then guided the assignment of levels for each smart dimension for each city.

Table 2. The Descriptors for the level of achievement

Smart city dimension	Scale level	City's level of provision
Smart Economy	Basic (1)	Facilitating local economic activities (infrastructure, facilities, economic support system)
	Medium (2)	Economic growth and value creation
	Advance (3)	Innovative economic growth
	State of the Art (4)	Integrated economic hub
Smart People	Basic (1)	Provision and accessibility to basic level of infrastructure and programmeasas for the training and education towards enhancement of skills and knowledge
	Medium (2)	Provision and creation of elaborate human capital improvement environment with physical and non-physical platforms for the advancement of knowledge, skills and sharing ideals
	Advance (3)	Creation of a conducive ecosystem that attracts and develops human capital through physical and non-physical platform with advanced technological features for the advancement of knowledge, skills and sharing ideals towards a caring and open mind set
	State of the Art (4)	Development and creation of a conducive ecosystem that attracts and develops human capital through the adoption of state-of-the-art ICT and technology driven educational and training towards the cosmopolitanism, caring and open mind set
Smart Governance	Basic (1)	Provision of basic public and social services
	Medium (2)	Public participation in decision-making
	Advance (3)	Public-private partnership
	State of the Art (4)	Fully transparent government with ICT that provides real-time policy conveyance and input
Smart Mobility	Basic (1)	Basic transportation and connectivity to ease movement
	Medium (2)	Full accessibility and some connectivity that further enhanced movement
	Advance (3)	Full accessibility and full connectivity together with an efficient traffic management system
	State of the Art (4)	Full accessibility and full connectivity together with a sustainable traffic management system
Smart Environment	Basic (1)	Provisions for safe and clean environment
	Medium (2)	Protection of the environment
	Advance (3)	Enhancement via green technology in the environmental management system
	State of the Art (4)	Usage of ICT in the sustainable environmental management
Smart Living	Basic (1)	Provision of communal amenities and cohesive social environment

	Medium (2)	Provision of extensive communal amenities and cohesive social environment
	Advance (3)	Availability of varieties and options for global communal amenities with cohesive social and living environment
	State of the Art (4)	Creation of comprehensive global communal amenities with cohesive and integrated social and living environment towards community well-being.

Source: Adnan *et.al*. (2016)

The cities' smartness categories as indicated by Table 2 provides the basis for the examination of the five (5) cities in Taiwan. An analysis of Smart City initiatives between these selected cities was undertaken in the determination of the smart city achievement levels through case study analysis.

Taipei City, New Taipei City, Taoyuan City, Taichung City and Kaohsiung City were selected as case studies based on commonality of several factors including culture, socio-economy, political, geography and city functions. The overview of the smart city initiatives and plans are accessible from the reports and websites of the various cities' authorities (Intelligent Community Forum, Kaohsiung City Government, New Taipei City 2040 vision, Smart Taipei, Taipei City Government (2015), Taichung City Government Information Centre (2018), Taoyuan City Government)

Case 1: Taipei City

Taipei is the capital and largest metropolis of Taiwan. It has a population of an estimated of 2.68 million in 2013. The population of Taipei in 2018 is at 2.67 million. In 2015, the city government announced the city's future vision for 2040 through the 2040 Taipei Metropolis Plan. It presents measures for realising the city's long-term vision, namely, a city urban regeneration station, focusing on the achievement of six major key issues. In terms of the city's spatial development, it involves initiatives involving the programmes overseeing the trees and water management, infrastructure development, people welfare as well as energy management through the intelligence adoption.

The reports generated by Taipei 2050 Vision Institute provided the conceptual underpinnings of Smart Taipei, featuring the use of smart technologies and mobile-web applications to provide citizen-centric services and emphasising the role of technical standards as the precondition for smart city functionality. The current initiatives are mainly implemented and monitored by the Taipei City Government.

The development towards being a smart city for Taipei City is mainly to include smart city initiatives in the city's administrative priorities (We, 2015). The planning and implementation of the initiatives can be observed from the establishment of the Early Smart City Council. This council provides the establishment of the Smart City Project Office that looks into the integration of the work to the handling points of various bureaus. The main task of these organisations is to explore the needs of the public. In the policy-oriented part, for example, about five thousand (5,000) public housing units will be released as smart eldercare homes. The provisions of these homes include from the tables and chairs to the beds to the monitoring of 24-hour elders' vital signs are provided within the smart eldercare health service. Since Taipei is the fastest super aging society among the five cities, the smart eldercare service was one of the first initiative proposed.

Case 2: New Taipei City

New Taipei City is one of Taiwan major municipalities. New Taipei city is a provincial administrative city prior to the upgrade to become a city, which was made in 2010. New Taipei City was once named Taipei County. Its total population was 3.9 million in 2010. It has 3.99 million populations in 2018. Within the Smart City context, the city council has the vision of transforming New Taipei city by harnessing technology to the fullest with the aim of improving the lives of citizen, creating more opportunities, and building stronger communities.

New Taipei City is planned as the top seven (7) intelligent communities from 2014 to 2016. The city practices urban sustainability through one-step solution service and citizen participation. Through the use of the various real-time Apps and other applications, the goal of smart and one government is gradually reached in which the gap between urban and rural is narrowed via the incorporation of technology. The New Taipei City 2040 vision is also to obtain the livable city status.

The development of smart city initiatives in the case of New Taipei City can be described within the following initiatives. Among the initiatives, the public engagement with the government agencies in handling administrative matters could be facilitated. The public could access all administrative procedures at once, as long as they hold the certificate and rely on the identity card number. As the information is open and integrated, there is a possibility of sharing the information. Today, cloud documents cover a wide range of categories and the required information can be fully collected through the connection that is made available.

Case 3: Taoyuan City

Taoyuan city is the gateway of Taiwan in which it was planned to connect Taiwan to the world through Taoyuan International Airport. Due the advantage of convenient transportation, the city has successfully integrated sea and air logistics, perfected urban infrastructures through active policies and services. Along with the essence of local culture, the industry hub of Taoyuan is growing prosperously. It has a population of 2.15 million. Taoyuan is the newest city of the six special municipalities.

The Taoyuan government uses the innovative technologies in public transport, education, medical care, and sustainable environment. In addition, Taoyuan city government has implemented a plan called i358 New Taoyuan Smart City Elite Project (herein referred to as i358) that uses information communication technologies to transform Taoyuan into a livable, convenient, and more attractive smart city. The i358 project covers three directions, including Smart Governance, Smart Living and Smart Industries. It also covers governance, sustainable environment, disaster prevention, life education, culture tourism, transportation, medical & healthcare and industry development. All aspects that are planned intend to improve Taoyuan by using ICT technologies and resources from both the government and private sectors and aim to achieve efficient, mobile, livable, joyful, and sustainable life for the people in Taoyuan.

The development of smart city in Taoyuan City mainly emphasises the orientation of smart life and smart governance and focuses on the development of smart industry. Some of the initiatives include the "air box" of the sensor to the communication layer "LoRa" (long-distance, low-power transmission technology), and wireless charging from mobile phones to wireless charging for cars and locomotives in which all of these initiatives are driven by innovation.

Case 4: Taichung City

Taichung City is one of Taiwan major municipalities. Following the merger of Taichung city and county in 2010, Taichung city became the second largest municipality among Taiwan's six municipalities. It has a population of 2.72 million.

In order to ensure sustainable development, environmental conservation is essential. Thus, Taichung city government has set up a "Low Carbon City Promotion Team" to develop Taichung into a green garden city. A substantial number of parkways, parks, squares, children's parks, and greenery along waterways and roads have been implemented. Taichung City is inspired by the vision of “Smart, Low Carbon and Innovation”, featuring smart electricity meter, traffic control, healthcare, shared pole streetlight etc. in the future.

Case 5: Kaohsiung City

Kaohsiung City has merged with Kaohsiung County to be Kaohsiung city in 2010. The total population is approximately 2.77 million. Kaohsiung City is an important international hub for Taiwan. It has a complete air/marine transportation network port and the industries of logistics, financial insurance, and services as the center of talent incubation and technology R&D. The smart services promoted by Kaohsiung City Government won high acclaim from different sectors. For example, it topped the rankings in the Commonwealth Magazine in 2016 and the Wealth Magazine in 2017-2018 in the category of smart cities; national ranking also climbed to No.3 from No. 10 on Global Views Monthly in 2017. For instance, the “Love PASS Cloud Service Platform” in the culture category won the Innovative Award in Cloud IoT in 2016. The “Ambulance 12 Leads ECG” in the firefighting category won the 8th Taiwan Healthy City, Senior Citizens Friendly City Award in 2016 and the outstanding award in 2017 Emergency Medicine Annual Conference.

The development of smart city initiatives in Kaohsiung City is mainly aimed at utilising science and technology as well as the legal infrastructure with immediate citizen demand mechanism. Some of the initiatives include air quality indicators, traffic dynamics query and active traffic notification function. The development of smart city in Kaohsiung City is mainly related to traffic management. It is this main aspect for Kaohsiung City's development of smart city whereby instant information is obtained to protect the safety of urban residents. A deep understanding of "safety" is the main key to building a city as the citizens in Kaohsiung City have experienced gas explosions. For the safety aspect, monitoring systems are put in place ranging from industrial area chimney monitoring, water quality monitoring, to traffic monitoring systems. In order to detect petrochemical pipeline leaks early, the Office of Pipeline Safety (OPS) established by the Economic Development Bureau has procedures that have been endorsed by the OPS as well as the organization that are involved to ensure that citizens are ensured of safe living.

Results and Discussion

According to the idea, the six smart city dimensions are smart economy, smart people, smart governance, smart mobility, smart environment and smart living. To develop the instrument to gauge the smartness of a city, Giffinger proceeded to construct criteria and indicators based on these six dimensions These assessment indicators are used to assess the five (5) cities in Taiwan based on the framework. As the assessment is created by calculating a composite score from four scale levels, the composite score for different level is analysed at the interval measurement scale. There are 4 levels which include: Basic (1), Medium (2), Advance (3), and State of the Art (4)). From the data that is collected from urban planning web site, government reports, and other sources, the indicators of the initiatives are determined. From the score of one point for each indicator, the total score is 74 points, 19 points or less represents the Basic level, 19 points to 37 points represents the Medium level, 37 points to 55 points represents the Advance level, more than 55 points represents the State of the Art level.

The cities chosen in the study are those cities that are under the main municipalities that represent more than 1.25 million people and have certain socio-economic conditions and have the conditions for the development of smart cities. Table 3 provides the summary of the development of smart city initiatives at major cities in Taiwan in accordance with major international comparison projects.

The development of smart cities in Taipei mainly incorporates smart cities initiatives into the government's administrative priorities. From the early establishment of the Smart City Committee, as well as the establishment of a smart city project office, current integration of smart city work into the work of different administrative bureaus is organised. In New Taipei City & Taichung city, taking public consultations as an example, in order to facilitate the public to work in government agencies, the public can complete all administrative procedures at one time with the ID card number. This initiative portrays the open and integrated information that has been developed, and there is the possibility of information sharing. Taoyuan City’s mainly emphasises smart life and smart governance and focuses on the development of smart industries. The initiatives that have been developed include the sensor's "air box" to the communication layer "LoRa" (long-distance, low-power transmission technology), and mobile phone wireless charging to wireless charging applied to cars and locomotives. All these initiatives are driven by innovation.

In Kaohsiung, the main focus is on the construction of technological infrastructure and statutory infrastructure. Other initiatives include the real-time citizen demand mechanism, such as: air quality indicators, traffic and transportation dynamic query, active traffic notification function. The city has experienced gas explosion disasters. Therefore, a deep understanding of "safety" is the main key in managing and developing the initiatives for the city.

Table 3: Comparison of the development of initiatives at selected cities in Taiwan

Dimension	Evaluation index	Taipei City	New Taipei City	Taoyuan City	Taichung City	Kaohsiung City
Smart Energy	LED traffic signs, streetlamp energy saving demonstration project	✓	✓	✓	✓	✓
	Environmental inspection electric fleet	✓	✓	✓	✓	
	Energy Savings Demonstration Project	✓	✓	✓	✓	✓
Smart Environment	Epidemic prevention work network	✓	✓	✓	✓	
	Omni-directional urban disaster prevention system	✓	✓	✓	✓	
	Earth and Rock Flow Disaster Prevention Information System	✓	✓	✓	✓	✓
Smart Citizen/People	Improvement of employee information literacy	✓	✓	✓		
	Enrichment of school information facilities and educational resources	✓	✓	✓		✓
	Action library	✓		✓	✓	✓
	Digital Knowledge Center					✓
	App design competition	✓	✓	✓	✓	✓
	Corporate online training					✓
	Student digital learning	✓				
	Distance learning network education platform	✓			✓	✓
Smart Governance	Construction of public security protection e-system	✓		✓		✓
	Disaster scene image transmission monitoring	✓	✓	✓	✓	✓
	Notification service for fines and penalties					✓
	Internet tax payment system	✓	✓	✓	✓	✓
	Action long service	✓	✓	✓		✓
	Government and citizen exchange platform	✓		✓	✓	✓

	Urban Management Central Control Center	✓	✓	✓		
	Environmental Police Station - Online Inspection Information System	✓	✓			
	Palm-type government	✓	✓	✓	✓	✓
	Cadastral Query Service System	✓	✓	✓		✓
	Social service wireless inquiry system					
	Convenience service cross-platform system	✓	✓	✓	✓	✓
	Precious old tree park and street tree query management system	✓	✓		✓	✓
	Resource recycling exclusive website	✓	✓	✓	✓	✓
	Wireless security protection network			✓	✓	
	Security electronic city wall	✓	✓		✓	✓
	Email voting system					
	Police e-system	✓		✓	✓	✓
	Babysitter Human Bank				✓	✓
	Basic broadband construction	✓	✓	✓	✓	✓
	E generation mobile phone charging station	✓	✓	✓	✓	✓
Smart Traffic/Mobility	Mobile parking lot enquiry and guided parking service	✓	✓		✓	✓
	Instant traffic information guidance system	✓	✓	✓	✓	✓
	Bus dynamic location and arrival inquiry service	✓	✓	✓	✓	✓
	Urban Demand-Oriented Shared Transport Service (DRTS)	✓			✓	✓
	Bus Dynamic Information System Smart Station Building Plan	✓	✓	✓	✓	✓
Smart Living	Remote E-Health and Care	✓	✓	✓		✓
	Remote security monitoring system		✓			
	3D virtual city electronic map	✓			✓	✓
	International village construction					
	Accessible cyberspace service	✓	✓	✓	✓	✓
Smart Economy	Establishment of industry-university cooperative research center			✓	✓	

	Introduction of digital cultural creativity	✓	✓			✓
	The establishment of RFID payment mechanism	✓	✓	✓	✓	✓
	E-commerce network shop platform	✓			✓	
	Business analysis website					
	SME e-service	✓	✓		✓	✓
Smart Tourism	Multi-cloud service network platform					
	Construction of tourism information database	✓	✓	✓	✓	✓

By reviewing the documents and observations of various city initiatives and the official reports of various departments overseeing the smart city movement, these sources provide information describing current urban development in the cities within six (6) dimensions. Thus, the level of achievement under each dimension is determined as shown in Table 4.

Table 4: Level of Initiatives Provision

CITIES	Smart Governance	Smart Economy	Smart Mobility	Smart Living	Smart People	Smart Environment
Taipei City	Advanced	Medium	Advanced	Advanced	Advanced	Advanced
New Taipei City	Advanced	Medium	Medium	Medium	Basic	Advanced
Taoyuan City	Advanced	Medium	Medium	Basic	Medium	Medium
Taichung City	Advanced	Basic	Medium	Basic	Basic	Medium
Kaohsiung City	Advanced	Basic	Medium	Medium	Medium	Medium

Generally, all five (5) cities showed varying achievement of the smart city dimensions. However, all the cities achieved advanced level for smart governance provision. This means that all the cities surpassed the basic provision of smart cities initiatives. In terms of Smart Economy, Taipei City, New Taipei city and Taoyuan City has achieved the indicated Medium level of achievement whereas Taichung and Kaohsiung cities showed Basic level of provision. In terms of Smart Mobility, Taipei city has achieved the Advanced level of achievement in comparison to the other cities that have achieved Medium level. For Smart Living, Smart People and Smart Environment, Taipei city surpass the rest of other cities by achieving Advanced level. In terms of Smart People, Taoyuan City and Kaohsiung City showed 'Medium' level of achievement compared to New Taipei city and Taichung city that have achieved Medium level. As for Smart Environment, Taipei city and New Taipei cities have achieved Advanced level whilst the other cities have achieved Medium level. It is believed that these cities took a long time to develop the smart initiatives. The respective governments established the various smart city projects to realise the vision of Smart City for the cities as well as to try implement the various plans. They hope to integrate private and public resources and improve municipal construction or related services through proposal, matchmaking, and field evidence, so the cities government can take the lead in smart services.

It is found that Taipei city leads when it comes to the provision of Smart City initiatives in three (3) smart city dimensions though shares similar achievement with other cities for Smart Economy and Smart Environment. It is evident that Taipei city outperforms all other cities in this respect considering that Taipei city is an international city. It attracts foreigners to come to work and live there reflecting the achievement of the Smart Living among the Taipei residents.

As indicated in Adnan et.al. (2016), the above assessment provides an overview of the achievement of smart city initiatives at the selected cities in Taiwan at 'first instance' i.e., without considering the prevalent aspects that may have influenced the cities' development in the past. It is noted that each city was developed according to the visions of the city authorities, which must be shaped by the countries' national agenda.

Conclusion

In the development of smart city, many cities' authorities in Taiwan may not be aware of the planning and implementation of smart city development indicators such as air pollution monitoring, green transportation, and international participation. Most of the focus is on the construction of smart transportation which include ecological transportation. It involves the establishment of a solar transportation system, expansion of solar bus shelters and stop signs. The development of low-carbon green vehicles and the introduction of all-electric vehicle technology gradually reduce the dependence on petrochemical energy for the achievement of a low-carbon city towards the pursuance of urban sustainability.

With the use of a simpler approach (a modification of Giffinger's) based on qualitative assessment of initiatives data and from an earlier assessment framework that was adopted earlier by Adnan et.al (2016), an exercise to compare smart city initiatives performance of five selected cities in Taiwan was made. The outcome shows varying results. All the cities achieved advanced level of achievements for smart governance. From the comparison of the six (6) dimensions, Taipei city leads in three (3) dimensions i.e. smart mobility, living and smart people.

Smart environment involves the testing and maintenance of various environmental indicators. Some cities in Taiwan, such as Kaohsiung City and Taichung Mayor, have serious air pollution. Therefore, actions have to be taken towards the improvement of environmental maintenance and testing. This is particularly important so that the ecological environment indicators meet the needs of the citizens' living environment for the sustainable development of the urban environment.

This paper attempts to assess the smart city initiatives at selected cities in Taiwan through a proposed heuristic framework that enables a simultaneous assessment of many cities at once. The results of the assessment show that achievements of the smart city level for each city that relect the visions of the city authorities and may be shaped by national development agenda. After empirical research, the five major cities in Taiwan have different smart development priorities, mainly because the citizens of these cities have different needs. This is extremely important for the development of smart cities. It is observed that Taipei City, as an international city has portrayed a high level of smart city achievement which is reflected by the composition of the local citizens that generally have smart literacy.

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Blockchain Features to Improve Trust in Construction

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Abstract
The Internet of Thing (IoT), cloud technology and voluminous data analytics had, or are relentlessly reshaping the construction industry. Indeed, the disruptive paradigm brought about by these technologies is inevitable and is predicted to accelerate further. Despite, there were numerous issues which hindered an industry-wide effort to embrace the technologies. Chief among those is collaboration with trust issues, continues to present as one of the stumbling blocks hampering the industry's strive for an improved collaboration. Hence, enticed by the amount and extent of studies conducted elsewhere, we were motivated to explore Blockchain technology in the context of Malaysian construction industry after being exhorted with its possibility to improve trust. Our aim was to present the state of affairs pertaining to Blockchain technology in the Malaysian construction industry focusing exclusively on the prior experience of the respondents we interviewed. Our specific objectives through the narrative recorded from the interviewees are: (1) to explore the current application of Blockchain technology in construction through a desk study; and (2) to identify the useful Blockchain technology features for application in construction. Semi-structured interviews were conducted with six construction personnel known to be interested with Blockchain technology. Interviews transcripts were thematically analysed with an aid of Nvivo in order to invoke features useful that would influence trust in construction. Apart from the useful features which were presented in an integrated concept map, the research also found complacency to conventional payment system as the barrier that somehow impede the deployment of Blockchain technology in construction. This small-scale qualitative study is not intended to provide a complete picture on the state of Blockchain technology in the Malaysian construction industry, yet, it adds to the dearth of literature concerning the topic in Malaysia.

Keywords: Blockchain; Construction industry; NVivo; Qualitative; Technology.

Introduction

The digital world has evolved so rapidly and consequently helped to transform many of the world's indigenous industries. The Internet of Thing (IoT), cloud technology, mobile, social media and voluminous data analytics had, or are currently reshaping the industries that we know through effective use of the current inventions (Ahram et al., 2017, Zafira et al., 2018). The disruptive paradigm brought about by these technologies is inevitable and had been predicted to accelerate further in the 21st century (Zhao et al., 2016). The disruptive technological paradigm experienced by major industries across the globe thus explained the economic and social transformation triggered by the digital technology in the wake of the Industrial Revolution 4.0 (IR 4.0) (Khan et al., 2015).

The construction industry, though has not incorporated and yet to completely experienced the potential of digital transformation (Mathews et al., 2017), has been receptive and gradually accommodating to technological change. This despite numerous issues which hindered an industry-wide effort to promulgate change globally, where collaboration is still perceived as the stumbling block hampering the industry's strive for efficiency (Abdul Razak et al., 2010, Ozorhon et al., 2015, Yusof, 2017). Trust, in this regard continues to present as one of the major obstacle to collaboration, which is hard to be secluded especially in the hyper connected world (Khan et al., 2015, Islam, 2011). With the increased complexity, connectivity of current ICT systems, the data volume and the diversity involved, trust has become a keystone, notably to ensure robustness and information security of the related systems (Alguliyev et al., 2018, Oliver et al., 2011).

Labib et al. (2018) defined digital trust as “the confidence placed in an organization to collect, store, and use the digital information of others in a manner that benefits and protects those to whom the information pertains”. Digital trust however, is much laden with issues of protection, security and jurisdiction (Duranti and Rogers, 2012), while evaluating the exact trustworthiness value of an entity remains a consistent challenge (Pranata et al., 2012). It comes to the industry’s realisation that in order for collaboration to improve, a significant effort to boost trust should first be put in place.

Penzes (2018), the author of ICE’s “Blockchain Technology in the Construction Industry” stated that one of the most valuable and intangible business assets is trust. Despite, on a fast-paced global economy, the general approach of trust, which is enabled by third parties has become seemingly too complex. This complexity is attributed by the volume of interaction which suppress and often hide critical information. To avoid the vulnerability, Penzes (2018) had promoted Blockchain as an alternative solution for a transparent distribution of information across participants in a network. Through Blockchain, no party holds overall control of the data while information is shared in a pre-defined, unchangeable and simultaneous way (Penzes, 2018). The alternative solution shed a critical moment in the construction industry where technology is no longer seen as a distinct entity to modernise but a tool to harmonise the industry as well.

Researchers in the develop and developing worlds had expediently explored on the potential of Blockhain technology for construction. A preliminary review of these works suggest a varying theme but ‘trust’ appear to be the most mentioned theme of the reviewed works. For instance, a study by Mathews et al. (2017) insisted that BIM + Blockchain could possibly the way to overcome the trust issues in a collaborative environment where the present technologies seem lacking while Heiskanen (2017) argued that productivity could possibly be improved with a better level of trust through Blockchain. Hultgren and Pajala (2018) and Li et al. (2018) appeared on the same tone despite focusing on transparency as a substitute of trust.

Enticed by the amount and extent of studies conducted elsewhere, we are motivated to explore Blockchain technology in the context of Malaysian construction industry after being exhorted with the amount of literature available from the local researchers. Our aim is to present the state of affairs pertaining to Blockchain technology in the Malaysian construction industry focusing exclusively on the prior experience of the respondents we interviewed. Our specific objectives through the narrative recorded from the interviewees are: (1) to explore the current application of Blockchain technology in construction through a desk study; and (2) to identify the useful Blockchain technology features for application in construction. This small scale qualitative study is not intended to provide a complete picture on the state of Blockchain technology in the Malaysian construction industry, yet, it adds to the dearth of literature concerning the topic in Malaysia. This paper is structured to firstly explain on the Blockchain technology before presenting the findings from the interviews. The papers ends by reinstating the thoughts which have culminated the study and the significance contribution that the study bring in the current discussion of Blockchain, particularly in the construction's digital environment.

What is Blockchain?

Blockchain technology is one of the disruptive innovations for decentralized information technology (Abeyratne and Monfared, 2016). Hultgren and Pajala (2018) said that the blockchain technology has been strongly linked to Bitcoin and it was invented as a part of the Bitcoin's underpinning infrastructure. Laurence (2017) recognised Blockchain as the "Fifth Evolution" in computing. This followed as the internet is lacks of confidence layer but Blockchain can provides trustworthy in a digital information (Laurence, 2017). Blockchain contains a sequence of records and each block is hashed and connected to the previous block cryptographically as shown in Figure 1 (Sultan et al., 2018, Nakamoto, 2008).

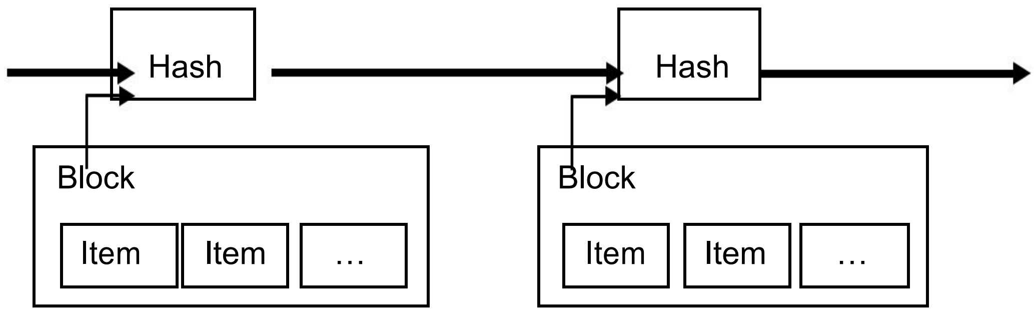

Figure 1. Nakamoto's Blockchain Proposal. ***Source: (Nakamoto, 2008)***

A transaction performed in a Blockchain network is carried out in a transparent manner. The theories behind the technology said that if all transactions are valid, new transactions will be transmitted to all nodes in the accepted blocks. The nodes then expressed their acceptance by using the hash of the accepted block as the previous hash to create the next block of chain (Turk and Klinc, 2017). As more and more transactions being added to the network, the entire history of the immutable network activities is recorded and can be viewed by all participants in the system (Hultgren and Pajala, 2018).

The recent years have seen multitude industries proactively assessing the technology in hope to leverage the potential of Blockchain. Construction researchers in particular have reported numerous application of Blockchain which potentially could improve trust. For instance, Turk and Klinc (2017) and Mathews et al. (2017) concluded that Blockchain could potentially solve the problems that refrain the industry from using BIM such as confidentiality, provenance tracking, disintermediation, change tracing, data ownership and many others. Shou et al. (2017) on the other hands, had proposed three Blockchain-enabled applications that would endorse immutable data record for contract management, supply chain management and equipment leasing respectively.

Application in construction

Two of the areas in which Blockchain is currently known to provide advantages to the construction industry is explained in the following section.

Smart contract

Smart contract is an important extension of Blockchain technology. It is a digital contract, which can execute its terms automatically when the preset conditions are achieved (Graham, 2019). Norul Suhaliana et al. (2018) defined smart contract as an auto-executing scripts which has its database kept on specific address on a blockchain platform which allows automatic generation of certain processes. It also brings the meaning of “a computerized transaction protocol that executes the terms of a contract”. Its target is to minimize the need for trustworthy intermediaries in transacting nodes and preventing eventful and risky transactions (Norul Suhaliana et al., 2018).

As the input data conditions that originated from Blockchain is immutable, codes are secured with inputs being sourced from permanent unchanging data which correspondingly act as a valid digitally binding contracts (Penzes, 2018). Despite Blockchain and smart contract had proliferated many sectors including the financial services, the construction industry appear to be lagging in this aspect, especially in its join capability with BIM (Mathews et al., 2017). The collaboration between Blockchain technology and BIM is slated to invent an independent platform where construction process tracking, quality supervision, design monitoring and investments through smart contracts are enabled (Ablyazov and Petrov, 2019).

Penzes (2018) provided few illustrations where smart contract would bring advantages to the construction industry. Among other, he illustrated how smart contract can register the total worked hours of every worker on a construction site which make every transaction and interaction more accurate, effective and traceable. Blockchain platform performs in a similar manner, where lists of tasks and particulars are added together into smart contracts, which will initiate payments according to the worked hours. These highly transparent and faster payments would be activated by smart contracts through blockchain application linked to the project bank account where payment could still be made in fiat currency but initiated by the blockchain-enabled smart contract.

Digital payments

Payment is one of the construction industry's biggest issues, especially late payment, unpaid at all or being detained as a result of disputes which often ends with business failure (Penzes, 2018, Li et al., 2019). According to a report published by Euler Hermes Global (2016), late payments percentage rose by 27% in 2015 while the average payment time for construction companies and Small and Medium-sized Enterprises (SMEs) were 82 days. The report showed that such practice intimidates the whole supply chain of a project, especially those SMEs with small capital who cannot tolerate the large upfront costs without continuous payment and a healthy cash flow to support its operation (Graham, 2019).

In the construction industry, one of the most applicable utilization of blockchain is establishing a Blockchain based platform into the execution phase of the project that allows payments to be dealt digitally, through analyzing and validating of work approval, contractual terms and smart contract actions. An example given by Penzes (2018) illustrated that an operational team on site will be registered and assigned with specific tasks where their details are recorded on the blockchain platform together with the hours they spent on construction site. The site personnel will oversee the pre-determined specifications and quality control procedures of the works during and after completion of the construction process. Subsequently, with the approval of the personnel by their digital signature through their smartphone, the smart contract will initiate payments and update the progress of the project on blockchain. It is obvious that improvement in transparency and traceability of payment methods by blockchain in construction industry can be utilized to its full capacity to ensure uninterrupted cash flow in business.

The Respondents, Instrumentation and Analysis of Interview Transcripts

A total of 10 interview invitations were sent to prospective respondents who were identified through contact and personal rapport. We had clearly mentioned the purpose of the interview in our invitation with an excerpt of the proposal included in the emails. Apart from that, the prospective respondents were also given a brief explanation on Blockchain through phone calls and resource materials. We maintained a simple criterion for selecting the respondents throughout the process where personal interest to Blockchain, knowledge, background and experience was thoughtfully emphasised. A reasonable amount of time was spent to evaluate and entice the prospective respondent's interest. The process therefore had focused more on identifying suitable respondents with knowledge which is aptly well-suited in qualitative research.

Due to the technical knowledge required to comprehend Blockchain technology, we found many of the respondents were at first hesitate to be interviewed. This despite they were known to practice certain degree of technology such as BIM. The prospective respondents were consequently briefed before six (6) out of ten (10) finally agreed to be interviewed. The primary objective of the interviews was on gathering first-hand feedback on the useful features of Blockchain technology thus data saturation, although an important measures in qualitative research was not given due emphasis. Table 1 describes the background of the respondents who were interviewed. The interviews had managed to gather respondents with adequate knowledge in Blockchain and construction.

Table 1. Background of respondents interviewed

Respondent ID	Background
R1	Respondent R1 is an architect by training who had over 10 years of working experience in an architectural firm. R1 had earned a Bachelor's of Science in Architecture and a Master degree in civil engineering.
R2	Respondent R2 is a quantity surveyor by training who had over 3 years of working experience in a quantity surveying firm.
R3	Respondent R3 is a project manager who had over 15 years of working experience in Malaysia and Singapore.
R4	Respondent R4 is a civil engineer who had over 10 years of working experience. R4 is currently a principal of an engineering firm.
R5	Respondent R5 is an assistant quantity surveyor who had over 7 years of working experience in a quantity surveying firm.
R6	Respondent R6 is a civil engineer who is also a secretary of a Malaysia based Blockchain association. R10 had involved in several conferences by giving talk in Malaysia and Singapore about revolution of blockchain in the property market.

Questions for the interview were develop based on the understanding of the current application of Blockchain in construction. As we are looking for primary data, semi-structured interview will provide original data which fulfil the research goals (Hox and Boeije, 2005). According to Harrell and Bradley (2009), semi-structured interviews are regularly used when the researcher wants to probe more information into the topic and people tends to understand the topics via the answers provided. In this research, interviews were conducted to identify the useful features of Blockchain derived from the desk study as well as to capture salient points from the respondents.

Analysis of the Transcripts

The first stage of data analysis involved transcribing, listing and interpreting the narrative to accentuate its underlying concept. The purpose of this process was to accumulate as many concept from the narrative with the prospect of manifesting common connotation among the concepts. This will subsequently assist in highlighting the important concepts and help to aggregate any similar concepts indicated by different respondents.

The accentuated concept – depicted in (bracket), helps the research to proceed by disclosing the gist of the concepts and provide a preliminary appreciation on the category of concepts embodied in the narrative (Bryman, 2008). This consequently allows the concepts to be structurally viewed and highlight the general heading of the concepts in preparation for the synthesis needed in this research.

Feedback on smart contract

Table 2 shows the excerpt from the interview transcripts transcribed from the recordings on the features useful for construction in smart contract:

Table 2. Accentuated interview transcript on smart contract

	SMART CONTRACT
R1	It improve the efficiency of trading (EFFECTIVE). But, it might be more dangerous to use it (RISK). This is because third parties are not involved (INDEPENDENT) so it might lead to dispute later (RISK). It must be the third party who justify it (RISK). The contractor and developer cannot justify the contract themselves (VERIFICATION).
R2	Contract in construction industry need to be very clear between each party (RISK). An effective transaction technology able to solve this kind of issue. (SETTLEMENT) (TRANSACTION) (EFFECTIVE)
R3	Smart contract can eliminate the need of trusted parties (INDEPENDENT) because it can increase the efficiency of the process of contract administration later (EFFECTIVE). However, I think that some documents still require a third party to verify (INDEPENDENT). (VERIFICATION) We already familiar to the written documents in black and white.
R4	It may be can be used in tendering stage (TRANSACTION). When the payment is needed and transaction can carry out automatically (AUTOMATISM) throughout the contract administration process. (TRANSACTION) E-tendering enable every parties to look over the tender online which enhance the efficiency. (EFFECTIVE)
R5	It will make the progress smooth in construction industry (SECURE). (EFFECTIVE) We also can monitor (VERIFY) the work as all data has been recorded and stored in the system (TRANSPARENT).
R6	It requires an Oracle to inform what has taken place offline, and the Oracle needs to input the correct information – so there is an element of risk (RISK) there. (TRUST) Large payments can be broken down into smaller amounts which increases the cash flow of the contactors and mitigates the risk of a large unpaid debt. (TRANSACTION) We can include a third party verification into the smart contract. (VERIFICATION) In the future, once we can apply electronic signatures legally to sign digital contracts, we should be able to digitally sign a smart contract (AUTOMATISM) as we would physically sign a paper contract. (SETTLEMENT) I believe there are several projects that is moving in this direction. (EFFECTIVE)

Note: Words in bracket are accentuated to invoke the features/themes. Showing unmodified/original narrative from transcribes.

Feedback on digital payment

Table 3 shows the excerpt from the interview transcripts transcribed from the recordings on the features useful for construction in digital payment:

Table 3. Accentuated interview transcript on digital payment

	DIGITAL PAYMENT
R1	It is applicable if it is legalised and recognised (LEGAL) (CONVENTIONAL). Will not be possible if only some parties using it (not all) (TRUST).
R2	Many parties already accustomed to the digital payment (TRANSACTION) through banks like CIMB clicks and Maybank2u. (CONVENTIONAL)
R3	In construction industry involve of many payment or transaction in money. (TRANSACTION) this system might be still not reaching a perfect system on comprehensive system to being develop. (CONVENTIONAL)
R4	If the technology is legalised, then the parties in construction just dare to apply it. (LEGAL) Again, our parties already accustomed to the online transfer (TRANSACTION) through the banks like CIMB clicks. (CONVENTIONAL)
R5	But as our industry has become accustomed to the online banking as we all has been familiar with their system (TRANSACTION), I think blockchain still have long way to go to beat the current online banking system. (CONVENTIONAL)
R6	Blockchain is based on the internet and all transactions should be done online (SECURE). There is also technology where wallet to wallet transfers are allowed offline but it is later updated to the Blockchain when both the wallet go online. (TRANSACTION) To facilitate a true adoption across all industries under a regulated environment, a sovereign coin is required which will be convertible RM1 to RM1 and this value is fixed by the Central Bank. (LEGAL) The Blockchain does not necessarily need to keep track of payments (IMMUTABLE), in fact, it can also track credit. (TRACEABLE) With smart contract, we can also program stage payments and others. A key benefit of having a transparent and efficient system is that the money flow is accelerated through the economy creating

more multiplier effect. (TRANSPARENT) It also prevents fraud) by ensuring when companies undertake more liabilities than it is capable of bearing, all participants will be aware of it. Dispute resolution will also be faster as the courts or arbitration centre have all the key evidence available. (SETTLEMENT)

Note: Words in bracket are accentuated to invoke the features/themes. Showing unmodified/original narrative from transcribes.

Weightage and focus of the identified concepts

A thematic analysis was performed based on the method espoused by Bryman (2008). In this regard, Bryman (2008) had suggested the counting of frequency with which certain words occur, in order to reveal the predilection that has exaggerated certain number of concepts used in a research. This helps by disclosing the weightage that the concepts have and consequently provide evidence for confirming the categorisation contained within the concepts. For this purpose, dedicated qualitative analysis software – NVivo was used in respect of the analysis. The software helped to minimise any error in the process hence increasing the credibility of the themes that are developed from the concepts.

Subsequent to the analysis, a model representing the frequency of the accentuated concepts was generated from the software as shown in Figure 2. Model A, which represent 'Smart contract' shows that: (1) (*Smart*) contract (ref: 8); (2) Effective (ref: 7); (3) (*Reduce*) risk (ref: 7); (4) (*Expedite*) transaction (ref: 6); (5) (*elimination of*) third parties (ref: 4); and (6) Verification (*improve trust*) (ref: 4) were among the features contained in the narrative. The frequency in which the features were mentioned indicate the usefulness of the features for application in construction.

On the other hand, Model B, which represent 'Digital payment' shows that: (1) System (*of payment*) (ref: 6); (2) (*Expedite*) transaction (ref: 6); (3) Online (*transaction system*) (ref: 5); and (4) (*elimination of*) third parties (ref: 4) were among the features contained in the narrative. Apart from the useful features mentioned by the respondents, the narrative also contained what seemed to us the barriers to the digital payment. This is an interesting point to highlight as future works could expand on exploring the barriers to Blockchain in construction. In this regard, respondents were found to highlight on: (1) Conventional (*payment system*) (ref: 5); and (2) Accustomed (*to conventional payment system*) (ref: 3).

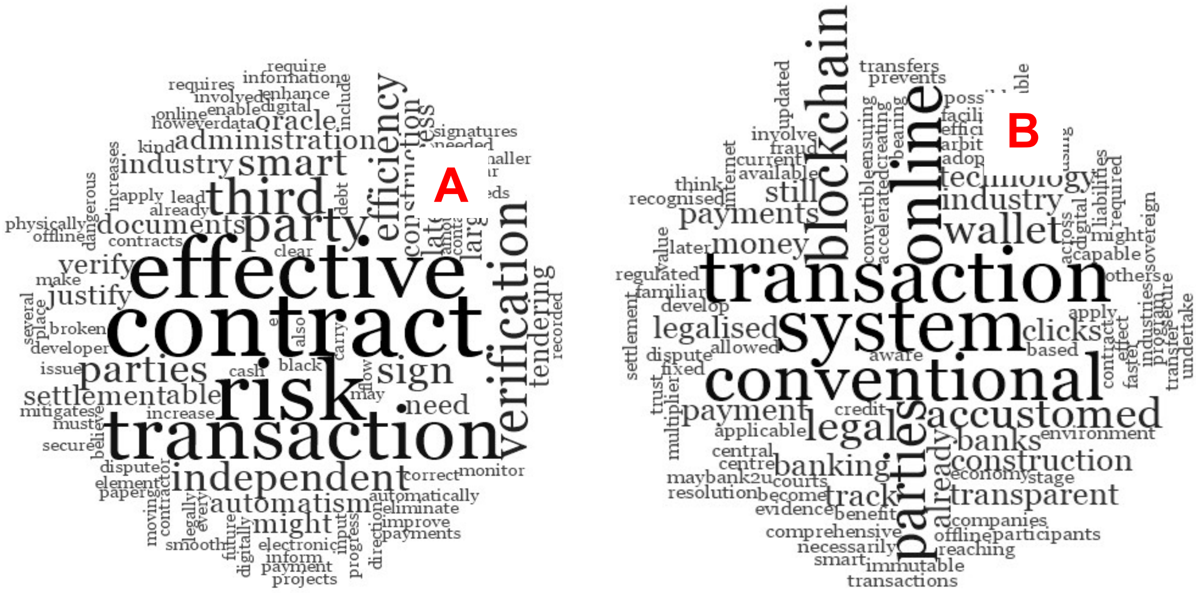

Figure 2. The NVivo models for representing the frequency of concepts from the narrative – (Model A) Smart contract; and (Model B) Digital payment

Development of an Integrated Concept Map and Discussion of The Findings

Generally, the analytical process pursued in this study has managed to restructure the features useful: Model A and Model B and barriers: Model B, in accordance to the latent themes impelled from the narrative. In this regard, a substantial amount of information had been captured in both smart contract and digital payment. It is an interesting finding to note that Model B, contains barriers which we do not anticipate gathering during the interviews process.

In view of the above findings, it was thought that an integrated concept map in respect of the develop concepts would possibly help to further explain the outcome derived in this study. Hypothetically, a concept map would allow detail pattern from the categorisation of the concepts to be induced and contribute farther in espousing points not specifically known in the prior analysis. In this regard, the concept map is posed to offer an additional perspective to the finding, thus allowing relatable conclusion to be made in prospect for a greater understanding. Subsequent to the premise, an integrated concept map was developed by utilising the NVivo's concept map feature and presented in Figure 3.

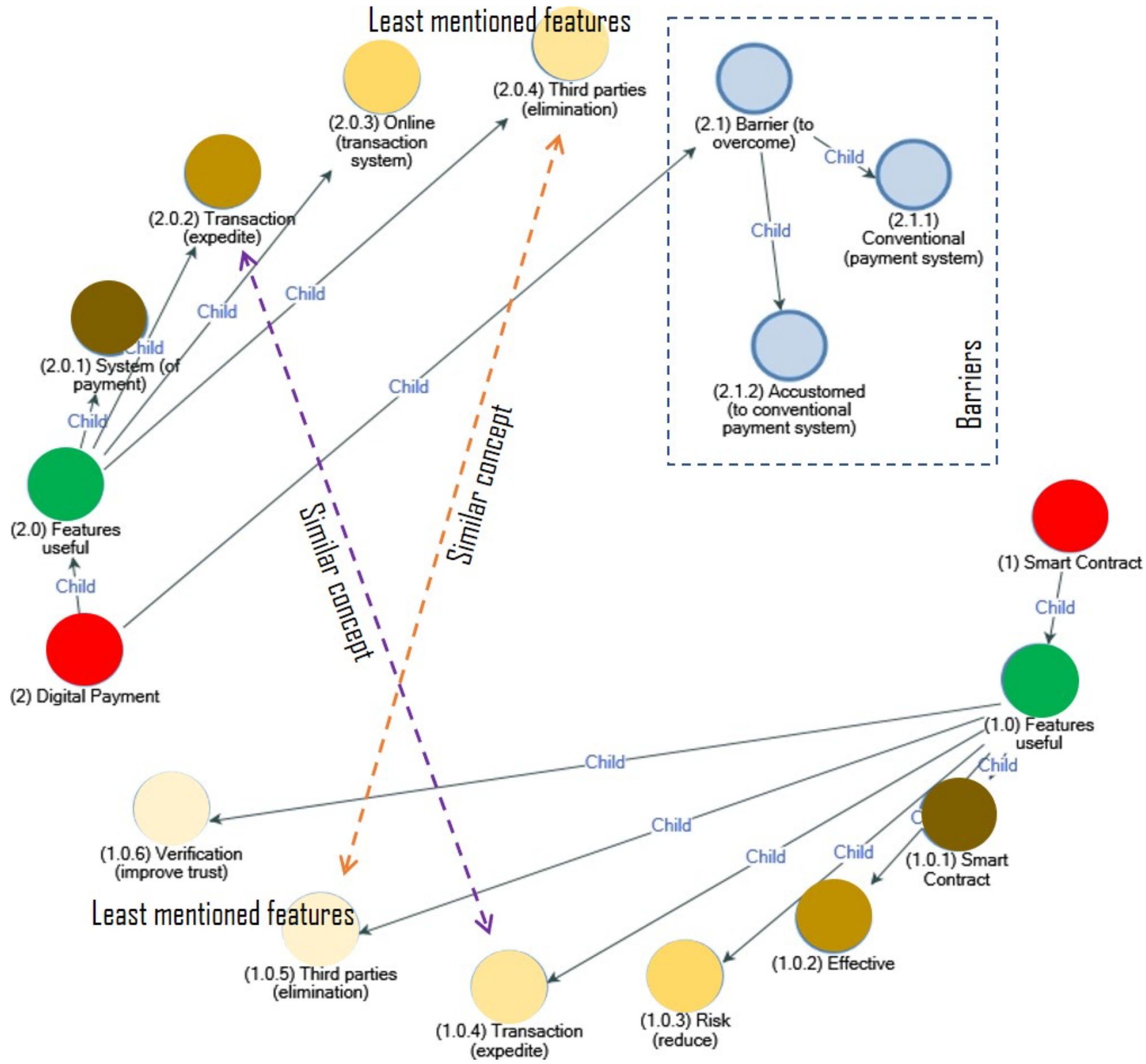

Figure 3. An integrated concept map representing the concepts develop from – (Model A) Smart contract; and (Model B) Digital payment

Features useful in smart contract

In the area of smart contract, the respondents stated that the application of Blockchain will influence trust as the technology was considered effective for contract administration (R3). The remaining respondents considered the online platform created by Blockchain to be effective for trade purposes. As the purpose of contract was to deal with risks, respondents R1, R2 and R6 mentioned that the risks associated with certain clauses in the conventional form of contract might be reduced hence improving trust. The next concept invoked from the analysis is transaction (R2, R4 and R6). Looking closely into the transcribed data, respondents were in the opinion that Blockchain technology could help to avoid late payment or even unpaid cases. This shows that respondents were in the opinion that to improve trust, issues related risks and transaction should be considered as priority. Apart from that, R2, R3 and R6 had also mentioned about verification. This shows the respondent's emphasis on security as a useful feature in construction.

Features useful in digital payment

In the area of digital payment, the respondents stated that the application of Blockchain technology will influence trust as the technology will create a system useful to authorise payment (R3, R5 and R6). As for transaction, R2, R3, R4 and R6 were in the opinion that the construction industry already had a good experience with digital payment platform and therefore saw no issue with Blockchain. An interesting feedback was given by R6 who had given an elaborate insight on digital payment transaction. R6 mentioned that in order for the construction industry to harness the potential of Blockchain, the system must first be regulated with a sovereign currency recognised by the monetary authority. The monetary authortity must be ready to accept an equivalent rate of say, 1 unit of sovereign currency with RM1. Common in both smart contract and digital payment is the elimination of third parties. The elimination of third parties allows a lean and wiry transaction.

Despite the features useful, the interviews had also identified aspects which could be considered as barriers to Blockchain technology deployment in construction. All respondents except R6 had mentioned that the industry is accustomed to the conventional payment systems which are commercially provided by local banks. In this instance, the respondents mentioned that Blockchain proponents must have a strong and valid case to show before the technology is accepted by the industry. Though majority of the respondents seemed complacent with the conventional payment system, R6 is the only respondent who sees the potential of Blockchain. This is understandable as R6 has a considerable understanding with the Blockchain technology.

We also found through the interviews that the features important to Blockchain such as: (1) the elimination of third parties and (2) verification were mentioned albeit less in comparison to the other concepts. This invoked question over the respondent's awareness about the technology particularly involving the features which can improve the trust issues. As our interviews had impelled on this situation inadvertently, we thus bounded with our ability to provide explanation on it. There may be a need to explore on the barriers especially on the application of Blockchain covered in this paper.

Conclusion

This paper presented an inimitable case of Blockchain in construction. It particularly explores on the features useful for construction which smart contract and digital payment had been the focused of the exploration. The interviews outcome reported in this paper had managed to unearth important concepts which reflect the respondents knowledge in relating Blockchain with their experiences in construction. We somehow admitted that the limited number of respondents involved in this research might had impeded further concepts on Blockchain to be derived but considered the findings adequate to reflect the experiences had by the respondents involved. Overall, we would like to suggest that Blockchain has a lot of potential in construction. Based on the interviews we had conducted, respondents were generally positive and bought over by its potential to reduce trust issues in construction. Despite, similar to other technologies making a headway in construction, respondents were discouraged by the learning path and the feasibility to adopt. Further research should take on this heed to provide an encouraging environment similar to the current environment enjoyed by BIM and big data as we all had seen.

Acknowledgement

The findings reported in this paper is part of a much larger study which attempts to establish the potential opportunities and direction of Blockchain technology in construction. The authors wish to thank the Ministry of Higher Education through FRGS (Ref: PYL/2019/02372 - R.J130000.7852.5F195) and Universiti Teknologi Malaysia through GUP (Ref: PYL/2019/01947 - Q.J130000.2652.16J81), the anonymous reviewers for the constructive comments and the editors of The Malaysian Surveyors for the opportunity to publish the findings in this journal.

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Systematic Review on the Perquisite of Building Information Modelling (BIM) Implementation in Construction Industry

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Abstract
The Building Information Modelling (BIM) not new nor to late to discuss. Implementation of BIM in construction industry spread due to the demand by the construction players as the benefits that they may gain from the implementation. The objectives of this study it's to identify the benefits of BIM implementation may offer as prerequisite to the current available benefits has been discuss by previous scholars. There are 20 benefits has been discussing from 35 referred indexed journals between 2004 to 2020. Thus, the outcomes may further contribute to enhance the existing knowledge towards BIM implementation in construction industry.

Keywords: Building Information Modelling (BIM), Perquisite, construction industry

Introduction

The Building Information Modelling (BIM) is a new method introduced in construction projects, which is used to manage project data and building design in digital form throughout a building's life cycle (Ilhan & Yaman, 2013). Moreover, this method also provide a platform to let the stakeholders to exchange and interoperability of information among themselves (Ilhanet al, 2013). Besides that, the powerful benefit of the BIM such as to reduce time and cost and increase the productivity and efficiency not only attract the construction players to adopt it, but also increasingly implement it in various domains (Bui et al., 2016).

Since 1970s, the transformation of construction practice from traditional method to BIM based design had become one of the most discussed topics in the field of construction as a result the Architecture, Engineering and Construction (AEC) industry has been increasingly adopting it (He et al., 2017). Even though the adoption of the BIM will bring a lot of benefit, but the transformation is seen as a challenging process. Since, there are four stages to its transformation, which are: conventional stage (known as level 0); design-based modelling stage (known as level 1); collaboration-based modelling stage (known as level 2) and integration-based modelling stage (known as level 3), all the stages are represented as level of BIM development (Succar, 2009).

However, the implementation of the BIM can conquer the problems which usually occur in a construction project, but the application of it still in infancy (JKR, 2013). The construction players should be aware about the benefit of BIM, to help them improve the implementation rate of BIM in construction processes. Unfortunately, the BIM is still new in Malaysian construction industry, even though it has been proved can provide the solution for construction issue which mentioned above (Latiffi et al., 2013).

Therefore, this paper objective it's to describe a perquisite of BIM implementation on construction industry may be further beneficial to boost the understanding and increase the implementation itself among construction players.

Perquisite of Building Information Modelling (BIM)

In table 1 is showing 23 number of perquisite of implementing the BIM, and such benefits are grabbed from several journal. The highest time referred of BIM's benefit is 'Eliminate clashes in design', which had been referred 14 times. Due to the design model created by structure engineer, architect, environmental engineer, MEP engineer (Mechanical, Electrical and Plumbing) and other professionals are independent to each other, so once all the models are integrated into the BIM modelling process, then all the clashes will be detected thereby achieve the purpose of eliminate.

Besides that, the second most referred benefit of the BIM is 'Improve multi-party communication and maintain synchronize communication' and 'Improved visualization for better understanding of design', both of them had shared the same referred times which is 10. Due to the BIM had the ability to update models in real time, resolve conflicts, examine the variation during the initial design phases and allow the involved parties to interchange critical project data in the project lifespan on it, so this is the reason why the BIM can improve the communication and collaboration between the parties (Georgiadou, 2019). Other than that, the modelling function of the BIM can improve the visualization of the design, therefore not only the client, quantity surveyor and other related parties can observe the building in more detailed but also can let an architect easier to introduce his design to the client (Hasan & Rasheed, 2019).

Besides that, the third most referred benefit of the BIM is 'BIM provides fast, effective and reliable quantity take-off and cost estimation' and 'Rapid identification of design changes', both of them had shared the same referred times which is 9. Due to the BIM is can based on the design and create certain information and quantities of material automatically, so the efficiency and accurate during quantity take-off and cost estimate will be enhanced compare with traditional method (Chan et al., 2019).

Aside from that, in the process of BIM, if someone changed or edited the design, then BIM not only will update it in soonest but also share it to all involved parties at the same time (Wong et al., 2014). On the other hand, the fourth most referred benefit of the BIM is 'Integrate construction scheduling & planning', which had been referred 8 times. The BIM not only will help the construction teams in scheduling and planning but also help to identify the construction issue and also any possible issue in the building assets process, as 4D model allow to demonstrate of scheduling of personnel and machineries, and it also provides visualization of construction process to enhance the understanding of process among the construction teams (Latiffi et al., 2013).

Lastly, the fifth most referred benefit of the BIM is ‘Increase productivity and efficiency’, which had been referred 5 times. As discuss above, the BIM can eliminate the clashed during the design phases, so when the process come to construction phases then can reduce that rework caused by design errors, thereby the productivity and efficiency can be increased.

TABLE 1. The perquisite of Building Information Modelling (BIM)

No.	Benefit / Author	Increase productivity and efficiency	Assess time and cost associated with design change	Eliminate clashes in design	Improve multi-party communication and maintain synchronize communication	Integrate construction scheduling & planning	BIM provides fast, effective and reliable quantity take-off and cost estimation	It updates cost plans with more details as design is developed	It generates accurate cost estimates for various design alternatives	Time saving in the preparation of estimating costs	Reduction of requests for information	Simplify cost checking and update	Improved visualization for better understanding of designs	Data storage in central coordinated model	Improve cost database management which reduces loss of information	Rapid identification of design changes	BIM gives support to design, scheduling, and budgeting of built assets	The speed of design can be increased when using the database provided by BIM tools as less communication with engineers is required	BIM provides an effective way to improve design and documentation quality significantly	Increase the quality of projects	BIM can assist construction players to construct small or high-risk projects successfully
1	Al-Ashmori et al. (2020)	/	/	/	/	/															
2	Miettinen & Paavola (2014)	/																			
3	Bentley (2017)	/																			
4	Bui et al., 2016)	/																			
5	Gardezi et al., 2014)	/																			
6	Migilinskas et al., 2013)		/																		

7	Tarmizi et al., 2015)		/																		
8	Memon et al., 2014)		/																		
9	Hu et al., 2019)			/																	
10	Leite et al.2011)			/																	
11	Branz (2013)				/																
12	Khosrowshahi & Arayici (2012)				/																
13	Scheer et al. (2014)					/															
14	Tirunagari & Kone (2019)					/															
15	Jrade & Lessard (2015)					/															
16	Roh et al., 2011)																				
17	Yarmohammadi & Castro-lacouture (2018)																				
18	Lim et al. (2020)			/	/		/	/	/	/	/	/	/	/	/	/					
19	Zhou, et al. (2012)				/		/						/								
20	Stanley & Thurnell (2014)				/		/														
21	Babatunde et al. (2018)			/	/		/	/	/	/	/	/	/	/	/	/					
22	Chan et al. (2019)						/														
23	Hasan & Rasheed (2019)			/	/		/				/		/								
24	Azhar (2011)						/									/					
25	Deutsch (2011)						/														
26	Thurairajah & Goucher (2013)			/			/														
27	Wong et al. (2014a)			/				/	/			/		/	/	/					
28	Wong et al. (2014b)			/				/	/			/		/		/					
29	Eadie et al. (2013)			/						/											
30	Ghaffarianhoseini et al. (2017)										/										

31	Sylvester & Dietrich (2010)												/								
32	Harrison & Thurnell (2015)												/								
33	Smith (2014)				/																
34	Geogiadou (2019)				/																
35	Arayici et al. (2012)														/						
36	Latiffi et al. (2013)			/		/							/			/	/	/	/	/	/
37	Cho et al. (2011)			/		/							/			/	/	/	/		
38	Furneaux & Kivit (2008)			/		/							/			/	/	/	/	/	/
39	Jabatan Kerja Raya, JKR (2013)			/		/							/			/	/	/	/		
40	Azhar et al. (2012)																				
	Times referred	5	4	14	10	8	9	4	4	3	4	4	10	4	4	9	4	4	4	2	2

Methodology

A literature review can be known as a comprehensive research and interpretation of literature on specific topics (Aveyard, 2010). Aside from that, the used types of literature review for this research is called as systematic review. By according to Walsh and Downe (2005), the systematic review "is a robust way of comparing quantitative research and proceeds according to well-determined steps, which include statistical analysis of the pooled results of studies". Hence, the research work for the chapter 2 will be started by extensive literature review which based on the research objectives, then statistic and ranking the collected data, and the interpretations will be made at the end. Furthermore, the reason why using the systematic review is because it can provide a reliable and accurate results.

Besides that, the gathered data which using systematic review are known as secondary data. For the secondary data, it can be known as the result of analyzed the data which gathered by someone else (Martins et al., 2018). Or in other words, the secondary data is reusing the existing data for a new research question (Vartanian, 2010). Therefore, by referring to table 2 can know that this research had referred total 83 numbers of journals which published years are between 2004 and 2020.

TABLE 2. Journal referred according to the year published

Year of Published Journal	Numbers of Journal Referred
2004	1
2006	1
2008	2
2009	2
2010	3
2011	2
2012	2
2013	2
2014	2
2015	2
2016	3
2017	4
2018	2
2019	3
2020	4
Total	35

Conclusion

Several perquisites of the Building Information Modelling have been discussed in this paper. Back to the square where this perquisite can be further enjoyed by all construction players when all of them are understand the fundamental of BIM itself.

This can be further enhancing when every each of the parties involves in construction industry plays their own roles and ultimate aims to comes as one its support. There are no use to enforce if no empowerment by the relevant parties.

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