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Preliminary Study of Changes in Work Practices of Quantity Surveyors in Building Information Modelling (BIM) Projects

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Abstract: Building Information Modelling (BIM) has been a game changer for the construction industry in transforming how design and construction is delivered. While its introduction aims to increase efficiency in construction, it is unclear what practical changes are affected in the individual work practices of construction players. Many studies have explored the changes in design related work practices, but limited studies have explored the practical changes for quantity surveying (QS) work practices when working in BIM projects. This paper aims to examine the changes in QS work practices according to the RIBA plan of work. The objectives of this paper include i) to identify the positive changes in QS work practices and, ii) to identify the negative changes in QS work practices. Qualitative data were analyzed from the interviews of five Quantity Surveyors with BIM work experience. The analysis revealed that there are six positive changes and four negative changes in QS work practices when involved in BIM projects. The findings from this research can be used to understand the implications of BIM on QS work practices at a practical level and to elucidate the adjustments needed to cope with BIM-related changes.

Keywords: Quantity surveyors, building information modeling, construction, work practices, construction management, cost engineers, cost management

1. Introduction

The adoption of BIM in projects is highly encouraged to increase productivity in the construction industry for its various advantages to improvements in accuracy, cost efficiency, quality and performance, documentation of design and planning, and its ability to aid decision-making through better visualization (Babatunde et al., 2018; Boon & Prigg, 2012; Georgiadou, 2019; Hong et al., 2019; Ismail et al., 2019; Saka & Chan, 2020; Soon, Lam Tatt, Leong, Boon Tik and Ang, 2013).

BIM is a collaborative tool that helps construction players to better facilitate the design, implementation and management of construction activities (Latiffi et al., 2013). The use of BIM is known to transform construction work practices by encouraging collaborative relationships and enabling a common environment for information sharing. By utilizing BIM, project team members are able to swiftly communicate and quickly access important updates on key documents such as architectural drawings and specification schedules (Jabatan Kerja Raya, 2014a). However, the reality in practice is that there is a reluctance to share drawings and documents on the BIM system leading to challenges for the Quantity Surveyor to extract accurate cost information (Mayouf et al., 2019; P. Smith, 2016; Haron et al., 2015). There is also the issue of interoperability between different BIM software used by different construction players, which cause some data to be lost when files are transferred or integrated (Smith et al., 2015; Omar, Nursal,

Nawi, Haron, & Goh, 2014). This is because some file formats are incompatible and thus, cannot properly exchange data within a BIM model using two or more different BIM software (Kim & Park, 2017). The problem is particularly common among Quantity Surveyors who must manually insert cost information to BIM models as the costing software is usually incompatible with the design software. This can be a time-consuming process to ensure the BIM model is kept updated. Several scholars reported that in some cases, costing is still completed conventionally without the aid of any BIM software even when the project utilizes BIM for design (Crowley, 2013; R Stanley & Thurnell, 2013; Turk et al., 2014; Smith et al., 2015). In addition, BIM is very rarely used for contract administration purposes and almost never used beyond the construction phase (Abinu et al., 2014). This was verified by the RICS report in 2011 which found BIM use among QSs to be primarily limited to the design and construction phase. In Malaysia, BIM has been a national agenda for its construction industry since 2007. The Department of Works Malaysia introduced a BIM manual guideline in 2014 intended to clarify the work processes of BIM projects (Jabatan Kerja Raya, 2014). However, this has not improved BIM implementation in the industry and many issues still prevail as cited in various aforementioned studies. There appears to be significant gap between the theoretical benefits of BIM and the reality of its implementation in practice. As the construction industry strives to move towards a digital future, it is imperative that we close this gap by investigating how BIM is impacting the work practices of QSs.

While BIM is meant to increase project efficiency, the practical implications of its use on work practices is yet to be fully understood. More specifically, it is not clear what adjustments are needed in the QS work practice when using BIM. The paper aims to explore the changes associated with BIM in QS work practices according to the RIBA plan of work. The objectives are to identify the positive changes in QS work practices in BIM projects, and to identify the negative changes in QS work practices in BIM projects. The study is significant in that it tries to reveal the practical ramifications of BIM use from the QS perspective and provides valuable information to construction industry stakeholders planning to implement BIM in projects.

2.0 Literature Review

2.1 Impact of BIM on Traditional Quantity Survey Work Practices according to RIBA Plan of Work

The normal scope of work for QSs in the construction industry is easily understood through the RIBA Plan of Work. This typically includes five phases which are the preparation stage, design stage, pre-construction stage, construction stage, and the operational stage (RIBA, 2020). It is important to understand the traditional work scope of QSs in order to appreciate how the use of BIM is impacting their work practice in project delivery. QSs manage costs throughout all stages of a development, thus it is crucial that they are able to do so effectively. The introduction of new systems can have significant ramifications to this effect. The following sections explain how BIM affects the QS work practices within the project stages established by the RIBA Plan of Work.

2.2 Preparation Stage

The work scope of a Quantity Surveyor in the first stage are pre-design estimate and to provide advice on cost project.

2.2.1 Pre-Design Estimate and Provide Advice on Cost Project

To ensure a promising return on investment, it is important that the initial cost be established based on the Client's requirements (Gee, 2010). In the first instance, Quantity Surveyors undertake a feasibility study to determine the initial building cost (Raphael & Priyanka, 2014). The accuracy of the Quantity Surveyor's early cost advice is critical to project success as it has a significant impact on the potential for time and money (Fung et al., 2014). At the initial stages of the project, it is acknowledged that information is often limited to simple sketches and assumptions on height, area and capacity of the building structure (Perera et al., 2019). On this basis, the Quantity Surveyor produces a cost estimate using preliminary cost estimation techniques such as cost per gross floor area, cost per unit (i.e. cost per bed for hospital, cost per pupil for school), and cost per volume (Nuwan, 2018). There is no standard document of references for these types of data that is publicly available for QS consultant companies. However, big organisations such as Public Works Department Malaysia (PWD) and the Board of Quantity Surveyors Malaysia (JUBM) do provide these historical building data in cost per area based on their past projects. These building cost data are usually archived in PDF format and uploaded on their company website for internal use (Arcadis, 2020; PWD, 2020). This information is available via a manual search through the archive of building cost data within each company.

With the aid of BIM, building cost data within the system can be extracted easily and various analysis of the data can automated at speed (Boon & Prigg, 2012; Perera et al., 2019; Zhou, Perera, Udejaja, & Paul, 2012). The automated quantities help to generate a reasonably accurate cost estimation by which the Quantity Surveyor can assess the potential risk of cost overrun in their cost advice (Nagalingam, Jayasena, & Ranadewa, 2013). Nevertheless, it is unlikely that the BIM model contains all essential information at the early stage (Turk, Wu, Wood, Ginige, & Jong, 2014). The accuracy and quality of BIM based estimates rely upon the extent that the project has been defined to the

Quantity Surveyors, the adequacy of information included, and the details of the construction methods presented in the plans and specifications by the designer (Mayouf, Gerges, & Cox, 2019; P. Smith, 2016). Poor detail and missing information within BIM models results in design errors and inaccurate estimates (R Stanley & Thurnell, 2013). In some cases the BIM model does not meet the information needs of the Quantity Surveyor to develop cost estimates due to difficulties in managing and searching for the appropriate information within the model (Matipa, Cunningham, & Naik, 2010; D. Smith et al., 2015; P. Smith, 2016). The level of information available for the Quantity Surveyor to extract from a BIM project file is unknown. It is also not known to what extent does the application of BIM software aid the Quantity Surveyor to prepare the pre-design estimate.

2.3 Design Stage

Under the design stage, the work scope of a Quantity Surveyor is to advice on design proposal and to develop cost plan and cash flow forecast.

2.3.1 Advice on Design Proposal

At this stage a detailed cost estimate based on the complete design information received from the architect and engineer will be calculated (Fung, Salleh, & Mohd Rahim, 2014). If employers disagree with the cost estimate based on the detailed design, Quantity Surveyors need to advise on alternatives design solution with design consultants to maintain project within budget. Quantity Surveyors also advise on the alternative procurement methods and construction techniques to ensure cost efficiency is optimized (Essays, 2018a; Guidance, 2016; Nuwan, 2018). Nevertheless, these design options given are often in 2D drawings where visualization is limited. (Rajendran, Seow, & Goh, 2014) agreed that 2D drawings could not demonstrate clear visualization for Quantity Surveyors, and this has led to massed misunderstanding in the design stage. Furthermore, the analysis of the cost breakdown of the project must be extracted manually from the quantified items of the 2D drawings (AllPlan, 2019).

With the aid of BIM software, to provide advice on the alternative design solution together with its cost can be further enhanced where a model of the building in 3D view is able to be visualized (Fung et al., 2014; Mayouf et al., 2019; Thurairajah & Goucher, 2013; Wong, Salleh, & Rahim, 2015). Instead of having to review hundreds of 2D drawings to visualize the complete building, the 3D model view provided by the BIM eases the visualization process quickly (Thurairajah & Goucher, 2013). Visualisation assists Quantity Surveyors to better understand with the construction through 3D model views in which the visualisation function not only represent building detailed properties, but also simulate their interaction (Zakaria, Mohamed Ali, Haron, Ponting, & Abd. Hamid, 2014). Multiple design options can be given to the client so that the client can make the best decision. However, by having multiple options it may confuse the client in decision making and scenario planning (Thurairajah & Goucher, 2013).

Apart from offering multiple design options, the Quantity Surveyor is also able to provide advice on the construction methods of the project due to the better visualization of the project in BIM (AIQS & NZIQS, 2018). Detection of errors in the design and the consequences of the proposed construction method can be identified with the use of BIM (AIQS & NZIQS, 2018; Foster, 2008; Fung et al., 2014; Thurairajah & Goucher, 2013).

2.3.1 Develop Cost Plan, and Cash Flow Forecast

At the design stage where more detailed information can be obtained; the 5D BIM model is able to develop a cost plan with detailed description (Kim & Park, 2017). Hence, client will obtain a good understanding of the cost breakdown of the project. The cost breakdown of the project will enable the Quantity Surveyor to detect in which area does the budget exceeds (Mitchell, 2012). With the use of BIM, although there is addition or omission in the design; the BIM software can still enable to develop a cost plan automatically (Nagalingam et al., 2013). Updates on the cost plan can easily be done even with many design changes without the need to go through laborious manual remeasurement (Fung et al., 2014; P. Smith, 2016; Vigneault, Boton, Chong, & Cooper-Cooke, 2019).

2.4 Pre-Construction Stage

Under the pre-construction stage, the work scope of a QS is to obtain contract drawings, prepare quantity take-off, produce BOQ and develop tender document.

2.4.1 Obtain Contract Drawings

In a conventional project, often drawings are received in 2D hardcopy (Babatunde, Ekundayo, Babalola, & Jimoh, 2018). It is common to receive many different versions of the drawing causing miscommunication and uncertainty on the latest drawing version (R Stanley & Thurnell, 2013). The mass printing of 2D drawings are a waste of resources since the digital era can provide better solutions by having all copies of drawings in softcopy (Thurairajah & Goucher, 2013).

In BIM projects, these drawings are all in softcopy where integration of the drawings will be conducted at a later stage (Mayouf et al., 2019). Often, interoperability issues on the softcopy drawings are experienced by the construction parties (Afsari, Eastman, & Shelden, 2017; CIOB, 2015; Sattler, Lamouri, Pellerin, & Maigne, 2019). Often BIM estimating tools do not support bidirectional data exchange (Turk et al., 2014). The introduction of the International Foundation Class (IFC) is not able to resolve the interoperability issues (Perera et al., 2019; D. Smith et al., 2015). Nevertheless, the IFC feature has improved from time to time to reduce the interoperability issues (Singh, Singh, Singh, & Singh Rai, 2017). The JKR BIM guideline has provided a list of software for all relevant parties involved in the construction to use to minimize the interoperability issues. According to the guideline, the BIM coordinator will ensure that all drawings received will be integrated and information input into the system are complete (Jabatan Kerja Raya, 2014).

Upon receiving the contract drawings, BIM enables easier clash detection of the drawings. Immediate early design error can be detected such as overlapping design from architectural, structural, mechanical, and electrical design (AIQS & NZIQS, 2018; Thurairajah & Goucher, 2013). Therefore, errors reduce in the design phase, fewer issues and variation orders arise during construction stage (Fung et al., 2014). Foster (2008) and Ryan Stanley & Thurnell (2014) supported that the problems and conflicts related to the field were reduced by 70% to 80% due to this usage.

2.4.2 Quantity Take-Off

In conventional project, Quantity Surveyors are required to spend a large amount of time on generating the quantity take-off of the drawing and insert into the excel for Bill of Quantity preparation. In BIM project, the time taken to measure the quantities off the drawings are a lot quicker where quantities are able to be produce in hours or days rather than weeks or months (Zhou et al., 2012). Even with design changes, the time required to remeasure the items are reduced significantly compared to manual take off (Perera et al., 2019). BIM allows the automatic update of the quantities according to the update in drawing changes (Raphael & Priyanka, 2014). However, there will be some quantities that the Quantity Surveyor not able to generate from the model, for example, the overall façade area and the total gross internal area (GIA) (D. Smith et al., 2015). Another example is that the BIM software could not detect overlapping places such as lintels, insulation material and wall surfaces resulting to overestimation of the quantities (Kim & Park, 2017). Hence, inadequate detail and missing information within BIM models results in design errors and inaccurate quantity take-off (R Stanley & Thurnell, 2013).

2.4.3 Bill of Quantities

The production of Bill of Quantities can be automatically produced from the BIM software (Jabatan Kerja Raya, 2014). Updating the Bill of Quantities is claimed to be much easier in bills of materials (BOM) when the Quantity Surveyor receives changes in drawings (Li et al., 2014). In conventional project, often it requires the Quantity Surveyor to manually search the items within the thick Bill of Quantities and then update the specified items. With BIM, there is no need to manually search for the items since the update will be automatic. Furthermore, the BIM software will notify which when the items supersedes the other according to the different versions of the drawings (Perera et al., 2019).

There are also beliefs where the BIM software is claimed to be incompatible with the Standard Methods of Measurement 2 (Ryan Stanley & Thurnell, 2014). The SMM2 is more suitable for manual measurement from 2 D drawings (Ryan Stanley & Thurnell, 2014). A very accurate quantity take-off is hard to achieve due to the absence of standard rules for BIM measurement (Olatunji, 2011). Nevertheless, software have been advancing and this feature has been incorporated such as in the Glodon software version of 2019 (Glodon, 2019).

2.4.4 Tender Document

In conventional project, the tender documentation include the drawings, specifications, BOQ, pricing document, form of tender and other special documents in hardcopies (Cunningham, 2015). The Quantity Surveyors are required to provide the tender document to the Client and Contractor and collect back the tender document for tender purpose (Essays, 2018b). It is well-knew as time consuming and complicated process.

In BIM project, E-tender is carry out in the form of web-based platforms (Seah, 2008). The different of the tender process is from manually execution change to online execution. The tender document is prepared according to Construction Industry Trading Electronically (CITE) format for collaborative electronic information exchange between Quantity Surveyor and Contractor (Hadi & Anim, 2015; Tan Jia Ren et al., 2016). The Contractors just need to download and pay for the tender document in electronic form and then submit the BOQ with pricing back for the Quantity Surveyor to evaluate. Paper usage in E-tender system can reduce up to 90% and benefits to reduce the administrative and transaction cost (Hadi & Anim, 2015).

BIM is the potential solution for the problem of time-consuming as it includes the e-tender processing where it is expected to save more time (Fung et al., 2014). For example, the Contractor able to upload the BOQ with complete pricing to the tendering platform in about 20 minutes. However, P. Smith (2016) stated in fundamental the way to

produce the tender documentation has nothing changed in the electronic environment. The Quantity Surveyor still need to check the documentation errors and inconsistencies.

2.5 Construction Stage

Under the pre-construction stage, the work scope of a QS is to visit the site to assess the project's progress, prepare interim payment, valuation of variation and advice on the variations.

2.5.1 Site Assessment

Monitoring of construction progress is an essential process for the success of any project. However, the current traditional assessment of progress on-site is time consuming where the QS need to visit the site every month and walk around to check the actual work progress compared to planned schedule (Essays, 2018b). The introduction of Unmanned Aerial System (UAS) was potential to collect the on-site data in the construction industry (Bognot, Candido, Blanco, & Montelibano, 2018; Dupont, Chua, Tashrif, & Abbott, 2017). UAS helps to inspect the on-site progress and data collection by capture the pictures or videos with the advancement of camera, photography in only few hours (Gallagher, 2017). With UAS, the on-site situation can be viewed from any angle. According to Bognot et al. (2018), UAS has the capability to improve the efficiency and accuracy of the 3D building modelling. Moeini et al. (2017) stated the integration of BIM and UAS can establish the function of real-time automatic visualization of project progress. BIM contains the information and data of the tender model, while UAS collect the data on-site and represent as the as-built model. The merged of BIM and UAS was used to compare the compare the different between tender model and as-built model visually (Dupont et al., 2017).

Besides, 4D model can show better visualization of the activities, indicate the schedule of each activity and provide a better communication among construction parties how to deliver the project (Politi, Aktaş, & İlal, 2018). Hence, the activities can process by follow the schedule and the activities can be more effectively monitor and control to deliver the project on time. However, this expectation is difficult to achieve due to the constantly change of the on-site situation and nature of the model (Oracle, 2018). Umar et al. (2015) elaborated that 4D model is neither intelligent nor automated, the schedule will not be able to automatically change if there are any issue occur because it cannot detect errors by itself. Nevertheless, the application of BIM is highly recommended to reduce fragmentations throughout the construction process (Nawi, Haron, Hamid, Kamar, & Baharuddin, 2014).

2.5.2 Valuation of Variations

During construction phase, QS are often deal with the variations of the project and provide Client with the cost implications of such variations (RICS, n.d.). They are required to process with the comparison of updated drawings and tender drawings to provide immediate measurement of the variations. Cost report is developed in relation to the cost of the proposed variations (The Hong Kong Institute of Surveyors, 2015). They need to identify any potential claims may arise due to such variations as it could affect the final contract sum (Mbachu, 2016).

With BIM, the variations would not be eliminate totally but it can be reduced to avoid rework on-site (Hall, 2018). BIM promotes the visibility of potential design problem and error via the tool of clash detection in the system (Babatunde et al., 2018). With the advanced clash detection at the design phase, the frequency of unexpected variations can be reduced on-site and therefore reduce the costly rework process (National Institute of Building Technology Nashik, 2018; Raphael & Priyanka, 2014). Hence, with the design errors reduce in the design phase, fewer variation orders arise during the construction stage (Fung et al., 2014; Thurairajah & Goucher, 2013).

2.6 Operational Stage

Under the operational stage, the work scope of a QS is to release the retention funds, prepare final account and financial statement (Essays, 2018b). At the operational stage, the information and data in the BIM model is used for maintenance purpose later (Kuckartz, Shakhramanyan, & Yaremenko, 2014). For example the location for maintenance of piling or pump works can be easily identify, develop the maintenance plan and efficiently schedule the maintenance activities (Koelewijn, 2018; Shilton & Collins, 2017). However, there is not much literature reported on the impact of BIM at this stage especially on QS work scope.

3 Research Methodology

The research aimed to identify the potential benefits and challenges experienced by QSs as a result of using BIM and to explore strategies for increasing the effectiveness of the QS role when operating in BIM projects. This is achieved by evaluating how the practical changes instigated by BIM impact upon the work practices of the QS in a project. Due to the exploratory research design and limited amount of empirical evidence available, a semi-structured interview strategy was considered the most appropriate for data collection. The focus of the interviews was to gain an understanding of the QS work experience in relation to BIM in order to appreciate the benefits and challenges of BIM

to the QS role. To achieve this, open-ended questions were used to encourage dialogue on the respondents' narratives and to prompt elaborate responses. The interview data were analysed using thematic coding where passages of text showing a common theme were indexed into categories in a meaningful and systematic way. As the research was concerned with addressing specific research questions, a deductive coding approach was applied which tried to observe patterns from the data set and develop empirical generalisations that was relevant to the research question (Merriam, 2009). This was achieved using open-coding conducted by the second author and then verified by the first author.

Table 1 - Respondents data profile

	Respondent A	Respondent B	Respondent C	Respondent D	Respondent E
Current position	Senior Quantity Surveyor	Quantity Surveyor Assistant	Quantity Surveyor Assistant	Quantity Surveyor Assistant	Assistant Technical Consultant
Working Experience (years)	9	4	5	7	2
BIM software used	Golden	CostX	CostX	CostX	Revit

A total of 10 individuals from QS companies in Penang, Malaysia were invited to participate in the study. To ensure reliability, respondents were selected based on their knowledge of BIM which was assessed by meeting three selection criteria: 1) Working in a Quantity Surveying role; 2) Possessing more than one year of industry experience; 3) Having hands-on experience of using BIM software. However, only five invitations were accepted and proceeded to the interview phase. As shown in Table 1, the respondents carried a combined total of 27 years of experience and have been involved in various BIM software within their practice. Their combined industry experience and practical knowledge of BIM form a strong knowledge base from which valid qualitative data related to the research question could be drawn. Given the narrow research scope, data saturation point was reached in the fourth interview and confirmed in the fifth interview. Each interview was audio-taped and lasted an average of 40 minutes.

4. Results and Discussion

The respondents were asked to describe their experience of utilising BIM in quantity surveying practices and the relevant RIBA stages where this applied. The results are categorised into positive changes (those that bring some benefit to the normal QS work) and negative changes (those that present new challenges to the normal QS work). It was found that the majority of respondents used BIM for 3D visualisation, taking-off quantities, updating the cost plan and preparing the final account. In addition, the more experienced Qs also used BIM for clash detection and evaluating site progress. The changes associated with this use are explained next.

4.1 Positive Changes in QS Work Practices

Positive changes in the context of this paper refers to the ability of the quantity surveyor to increase work efficiency with no additional work required.

4.1.1 Reduced Time in Taking off Building Elements

Respondent B and Respondent E highlighted that BIM allows to visualize the 3D model together with the technical specification which allows the Quantity Surveyor to provide a more accurate estimation as opposed to manually measuring the quantities from the 2D drawings which are prone to human error. Respondent B said that *'when the designer come out with the first draft of the visualize, at least there is a model over there in order for the Quantity Surveyor to extract the initial estimate, so it will be more accurate compare to the meter square.'* Respondent E supported the statement where he said *'after the Architect and the Client develop a conceptual or schematic design, all the Engineer will work together to input their design in a BIM platform, the Quantity Surveyor can easily grab and take the related information they want to produce a total cost estimation faster.'*

The findings in this research indicate that the Quantity Surveyors in Malaysia faces similar experience with construction professionals in other countries such as in New Zealand by Kim & Park (2017), Sri Lanka by Nagalingam et al. (2013) and India by Raphael & Priyanka (2014) where there is a high potential for the quantities measured to be more accurate and makes the process of measurement much more easier as opposed to the conventional method.

Nevertheless, the construction professionals in Malaysia pointed out several issues in achieving an accurate estimation through BIM related software.

Respondent A mentioned that *'... we experience cut off the time, we can cut about one and a half week to complete the measurement and it depend on the project.'* Therefore, the finding in this research shows similar experiences with the literature from Perera et al. (2019) and Zhou et al. (2012) where the time to produce quantity take-off can be saved a lot in BIM projects. Besides, the research of Ismail, Drogemuller, Beazley, & Owen (2016) said the Quantity Surveyor can cut off a lot of time to generate the quantities from the drawing one by one, he can speed up the time to prepare the quantity take-off. The finding in this study further explain on how the BIM can contribute to speed up the time in producing quantity take-off. According to Respondent B stated, the Architect shall design the model according to the Quantity Surveyor's Bill of Quantity requirement at the beginning to effectively reduce the time in quantity take off. It will reduce the time to produce and increase the accuracy of the quantity take-off. Respondent E said that *'the Quantity Surveyor do not need to manually calculate each component from each drawing, because he can just search the total number of columns for the project and it will pop out automatically in the software.'*

Nevertheless, the research also reveals a new finding regarding the contribution of BIM to the preparation of tender documents. According to Respondent E stated *'... during the tender stage, after the Quantity Surveyor get the information from the drawing, he can easily extract the BIM information from the BIM model and input into the tender document.'* Respondent B indicated the way to prepare the BQ is completely different with the traditional way. In BIM environment, the Quantity Surveyor can pre-set a template or a benchmark method of working to extract all the objects from the model into the proper BQ. He further explained *'... the time to prepare the BQ or the tender document will be significant lesser because BIM model able to provide at least 90% to 95% of the information, then the time use to complete the whole BQ is significantly drop down about 70%.'*

4.1.2 Quick Identification of Building Elements in the Drawing

Visualising from any perspective is much easier with BIM where respondent B said that *'... the layout or design of a building can be viewed from any perspective in 3D where the Quantity Surveyor can turn around, up and down the BIM model rather than made a visualisation in their mind.'* Respondent A and Respondent C agreed where the model can be viewed in any angle and perspective to increase their understanding on the building design. Therefore, the findings in this research indicate similar experiences with construction professionals in the other countries Thurairajah & Goucher (2013) and Zakaria et al. (2014) where they agreed that the BIM software had increased their understanding of the building design through the 3D model due to the flexibility of viewing the building design in any angle.

In addition to the similar experiences faced by the construction professionals in Malaysia, the findings in this study contributed in the body of knowledge by explaining further on how visualisation feature has helped the profession to increase their understanding on the building design and how it has helped the profession to deliver their services more efficiently. For example, respondents B reported that the search feature in the BIM software significantly helps the Quantity Surveying profession to better deliver their services by the quick identification of building elements in the drawing. Furthermore, the walk-through feature has helped the Quantity Surveying profession reduce time needed to visualise and understand the building design. The further explanation through the examples of the feature identified in this research had extended the findings by Chuang et al., (2011) and Wong et al. (2015) to support how visualisation assist Quantity Surveyors to carry out more effective analysis on the proposed design.

4.1.3 Efficiency in Updating Cost Plan

BIM has the capability for rapid updating quantities in the cost plan and allows the cost plan to be updated automatically without the need to go through laborious manual remeasurement. This finding is in line with the international literature such as Fung et al. (2014); Nagalingam et al. (2013); P. Smith (2016) and Vigneault et al. (2019) where they stated the BIM software enable to develop a cost plan automatically although there is addition or omission of the design updated by the designers. The results in this study extended the findings from the previous studies by further explaining on how the cost plan can be produced easily and how it has helped the Quantity Surveyors to complete their work in shorter time. Respondent B said *'... to update the cost plan is very easy, because all the cost plan and quantity will update accordingly. When the quantity in the model has been updated by the design team, the Quantity Surveyor just need to rerun the template or the extraction whether amend or remove any object in the model, they can reflect to the cost plan, tally back directly and all these can be done just a few minutes of time.'* In addition, Respondent B used the quantity as an example to support its explanation, while Respondent E explained the cost as an example. Respondent E said that *'In BIM, the Quantity Surveyor just need to update the real cost of each project such as the main power, equipment and machinery, the software can directly measure everything in one task and can produce the PDF report of the cost plan.'* In general, the results indicated whatever have change in the model, the cost plan can be update consider immediately as long as the cost plan has connected with the model properly.

4.1.4 Fewer Design Error & Reduction in Variation Due to Clash Detection Done Early

The quantity surveyors in Malaysia in this study acknowledged the many advantages of the BIM software to identify clashes or errors in drawings such during the overlapping design between architectural and mechanical & electrical drawings. This finding is similar to international literature where other construction professionals reported the advantages of the feature especially at the beginning stage of a project (AIQS & NZIQS, 2018; Foster, 2008; Thurairajah & Goucher, 2013). The results in this study extended the findings from the previous studies by further explaining the work practice of the construction professionals in Malaysia. According to respondent B, a cloud platform named 360 is an example used in a BIM construction project in Malaysia. The architects of the project will first upload their building design drawing in the 360 platform. Subsequently, the mechanical and electrical engineers will then download the same file to input their drawings and integrate their design with the building. At this stage, it is common practice that the clash detection process will be conducted. Once the process has been finalized, then the complete drawing will be given to the Quantity Surveyors for their further action. One of the respondents mentioned '*Quantity Surveyor is not going to do the detection one by one or read through all the drawings, he is no longer the platform to do the detection and then make the query.*'

4.1.5 Efficiency in Evaluating On-Site Progress

The respondents from the survey agreed that the use of BIM technologies had assisted quantity surveyors in evaluating on site progress where rich data on the field can be obtained. The respondents mentioned that technologies that have been used in the construction industry in Malaysia for site evaluation are such as Openspace, laser measurement and 3D Environment Scanner. Respondent E stated '*the best part of this software is if there is a problem at that position, we can create a field note and paste on that capture. Therefore, anyone that view the capture can see the note.*' He further indicated, '*Openspace can generate a report, just click generate report and it will automatically produce the construction progress's report including the captions, field note, date and time. It can save time, not need to do the copy from the camera, paste into the Microsoft Word and put the information.*' Respondent B highlighted the technology so calls the laser, pointer or laser measurement can check whether each of the element on-site is the same as the design in the model. He mentioned, '*... already have the technology in the construction industry just the implementation is not that wide, such as the 3D Environment Scanner can scan the 3D environment whether the whole environment is same as the model.*'

4.1.6 Reduce Remeasurement Process and Efficiency in Preparation of Final Account

According to Respondent B, the as-built model created at the end of the construction work significantly aided quantity surveyors to prepare the final account document. Respondent B stated '*... the Quantity Surveyor will use the as built model compare with the tender model and to check whether the final account is tally because they have the information since the construction start.*' The findings extend the study by Dupont et al., (2017) where it further informs on how data from the as built model can be used to aid construction professionals. Furthermore, findings from this research also indicated that the process of remeasurement is significantly reduced with the existence of the as-built model in BIM projects. With the as-built model, Quantity Surveyors no longer need to go through the long process of searching references (i.e. drawings and documents) and confirming which of it are up to date. Respondent D said, '*... it cut short the remeasurement procedure because they got the data in the beginning, so if you keep on track during the construction stage, you can also continue track for the VO and catch up all the changes until the final account stage.*' Respondent E also supported that with the as built model, the Quantity Surveyors will know the cost at the final post-construction stage, the variation or any claim from the Contractor before he processes to final account. He said, '*... not much work at the post-construction stage for the Quantity Surveyors because Quantity Surveyors obtain every information since the beginning.*'

4.2 Negative Changes in QS Work Practices

Negative changes in the context of this paper refer to no changes in the normal QS work practice and changes that introduce some level of difficulty to their existing work.

4.2.1 No Changes in Preliminary Costing

Many past studies indicated the advantages of adopting BIM in the design phase to the QS work practice such as enabling an accurate and reliable cost estimate and generating automated quantities that make cost estimation much easier (Kim & Park, 2017; Nagalingam et al., 2013; Perera et al., 2019). However, not much is known about how Quantity Surveyors develop initial building cost advice for BIM projects if the preliminary design is not yet complete. The research findings show that the QS work practice proceeds in the conventional fashion without the support of BIM tools in the early design stage because there is no information available via BIM to feed the cost estimation. It is only when the BIM model is fully developed can the Quantity Surveyor take advantage of the data for developing a reliable

cost estimate. Respondent A said that ‘... we will use BIM where there is complete design information from the Architect and Engineer in the BIM model. Otherwise we normally fall back to our conventional methods.’ Respondent B stated that ‘... if there is no initial design, you still need to go back to the good old-fashioned way which is estimating based on cost per meter square.’ Moreover, Respondent D said that ‘I do not think we use BIM to produce the cost estimate. It is just a normal software like Excel that helps to collate cost information and then calculate an estimate based on the previous similar projects.’ In addition, Respondent E said that ‘there must still be a conceptual or schematic design developed by the Architect and the Engineer, then only can the Quantity Surveyor get the information they need.’ The respondents all agreed that even in BIM projects, Quantity Surveyors still need to use preliminary cost estimating techniques such as cost per gross floor area, cost per unit and cost per volume with information based on similar past projects in order to produce the initial cost estimate (Nuwan, 2018).

4.2.2 Frequent Information Checking

Three of the respondents stressed the importance of the data quality and quantity keyed in the BIM system and the accessibility of those data that will greatly influence the accuracy of the cost estimate. The findings concur with previous studies that emphasise the interdependency of BIM based estimates with the supply of information, specifications and detail of construction method fed into the model (AIQS & NZIQS, 2018; Mayouf et al., 2019; P. Smith, 2016). As explained by Respondent B, the accuracy of the preliminary cost estimate depended on the how developed the BIM model and the level of information available at that stage (i.e. Level 1, Level 2, Level 3). The higher the level, the richer the data available and thus, the more accurate and reliable the cost estimate.

The problem of incomplete data in BIM models at the early design stage is unique to Malaysia and is commonly experienced by even advanced construction industries in the United Kingdom and New Zealand (Smith et al., 2015; Stanley & Thurnell, 2013). It is understood that BIM is only a tool that allows project information to be systematically stored and transferred. However, Respondent A cautioned that it would be unreasonable for Quantity Surveyors to fully rely on the system for cost estimation because it is only as good as the data input. To ensure a reliable cost estimate, Respondent E said that it was crucial for Quantity Surveyors to take extra steps of checking whether the BIM model contained sufficient data. This included frequent checks for information updates on the BIM model to avoid working on the basis of outdated information when completing the quantity take off and cost estimation.

4.2.3 Manually Remeasure Items to Confirm the Computerised Measured Quantities

The respondents reported that manual remeasurement of the items was usually necessary to confirm the computerised measured quantities. Respondent A explained that this was because of errors in the extraction of quantities directly from the BIM model. When the system automates quantity take-off, there are gaps in measurements left out by the system as it is not capable of detecting concealed items. For example, Respondent C and D informed that the system was unable to detect and measure reinforcement bars in concrete structures. In another example, Respondent B described that the wall quantity would exclude lintels in BIM models. However, according to the measurement rules set out in SMM2, the lintels’ quantities should not be excluded from the wall. The issue demonstrates the need for learned knowledge and competencies in measurement ahead of computerised systems. Respondent B was quoted, ‘...no matter how good the model is, the Quantity Surveyor still needs to refer to the 2D drawings. The BIM model may be able to help the Quantity Surveyor up to 95% of the time but the remaining 5% must be based on conventional 2D drawings.’ While BIM systems offer an excellent modern function that allow quantities to be computed automatically from the BIM model (Jabatan Kerja Raya, 2014), Quantity Surveyors must be careful and wary of the limitations of this function in producing an inclusive cost estimate. Therefore, the manual remeasurement of items is an indispensable step in cost estimation to overcome these limitations (Kim & Park, 2017).

In addition, the use of SMM2 as the standard rule of measurement in Malaysia presents several issues. Respondent B expressed the difficulty of using BIM software for measuring quantities due to the complexities of the SMM2 rules. Olatunji (2011) and Ryan, Stanley & Thurnell (2014) believe that current BIM software are incompatible with the SMM2 as the SMM2 was designed for manual measurement of 2D drawings. A renewed version of measurement rules was needed for BIM models in order to ensure accurate quantity take-off.

4.2.4 Physical Monitoring Progress

One of the main highlights of BIM is the ability to visualise a live work schedule at Level 4D. The model visualises the project progress and estimates the time for project completion. However, the model is formed based on ideal non-disruptive conditions and does not take into account any environmental or human-related challenges that may slow the project progress. For example, Respondent A shared that in a previous project, the BIM model showed that the project could be completed in two years. However, the reality was that the project experienced about 10% delay after only one and half years into the schedule. Respondent B further advised that it was crucial for the Quantity Surveyor to still go to site and physically monitor site progress because the BIM model is often not a true representation of the actual site performance. In addition, there are always issues to be addressed on site which may require adjustments to

the schedule. The findings emulate the problems in the United States where the existence of 4D BIM models did not provide leverage over site monitoring functions (Oracle, 2018). Conventional strategies were still prevalent and necessary for the Quantity Surveyor to perform its role.

5 Conclusion

The research identified a total of six positive and four negative changes in the work practices of quantity surveyors. The findings show how the use of BIM in projects affects changes in the quantity surveyor's work practice across the project stages. It was concluded that although the use of BIM enabled better efficiency in some areas of the QS work practice, other areas required additional work for the Quantity Surveyor to prepare in order to carry out its role. These include ensuring sufficient data input to update the BIM model and remeasuring computerised quantities of building elements. There appears to be a disconnect between the hypothetical ambitions of BIM technology and the work practice realities of Quantity Surveyors. While the introduction of BIM is meant to "ease" project functions, the study found that many of these opportunities are missed due to technical limitations and practical inconsistencies. There is a need to better understand the work practices of Quantity Surveyors at an operational level so that BIM models can be effectively aimed at enhancing specific functions. Currently, BIM provides a mixed bag of impacts on the QS work practice with some creating positive changes and some negative changes. The study provides a preliminary view of the challenges experienced by Quantity Surveyors in adapting work practices to accommodate BIM. Future studies are encouraged to explore the experiences of other construction players such as the Contractor in using BIM to improve their work practices.

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