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The Relationship of Building Information Modeling (BIM) Capability in Quantity Surveying Practice and Project Performance

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***Abstract*—**The adoption of building information modeling (BIM) is increasing in the construction industry. However, quantity surveyors are slow in adoption compared to other professions due to lack of awareness of the BIM's potential in their profession. It is still unclear on how BIM application can enhance quantity surveyors' work performance and project performance. The aim of this research is to identify the capabilities of BIM in quantity surveying practices and examine the relationship between BIM capabilities and project performance. Questionnaire survey and interviews were adopted for data collection. Literature reviews identified there are eleven BIM capabilities in quantity surveying practice. Questionnaire results showed that there are several BIM capabilities significantly correlated with project performance in time, cost and quality aspects and the results were validated through interviews. These findings show that BIM has the capabilities to enhance quantity surveyors' performances and subsequently improved project performance.

***Keywords*—**Building information modeling (BIM), quantity surveyors, capability, project performance.

I. Introduction

MANY construction projects suffer from time delay, cost overrun and poor quality [1], [2]. The success of a construction project depends on various factors but Cheung et al. [3] mentioned that ability of quantity surveyors was one of the factors which required the effort of quantity surveyors to carry out the project tasks. Quantity surveyor plays a vital role in the construction in managing project cost. They are responsible for the cost management throughout the entire life span of a project from the feasibility and design stages until building completion. One of the major tasks provided by the quantity surveyors is building quantity taking-off and estimation. The tasks are known as very laborious, time-consuming and are always prone to errors. Conventionally, quantity surveyors perform this task manually from paper drawings or using quantity surveying software based on 2D drawings and then, the dimensions are transferred on excel spreadsheet to perform estimation. These conventional working methods are inefficient, time-consuming, and prone to error which has negative impact on project performance. Further, Fortune [4] pointed out that clients are dissatisfied the output of services provided by the quantity surveyors. This is due to around 50-80% of the time needed to create a cost estimate is spent on quantification by the quantity surveyors [5]. Mitchell [6] also commented that quantity surveyors spend 90% of their time calculating building quantities.

However, application of building information modeling (BIM) has the potential to simplify these tedious and time consuming tasks performed. BIM technology provides potential solution for the above problems by automating the tedious tasks [7], [8] which allows the quantity surveyors to devote their time to other value-added services, rather than spending much times on quantity taking-off. Greater demands for more cost-effective, schedule-efficient and better quality projects have led to BIM application in quantity surveying practice. BIM is defined as a modeling technology and associated set of processes to produce, insert, share and manage the information in a single model that accessible by project parties to improve the designs, construction, operations and maintenance processes. In quantity surveying practice, BIM can offer significant benefits over traditional drawing-based manual taking-off process based on 2D drawings. It is a replacement to conventional working methods and can assist quantity surveyors in the generation of accurate quantity take-offs and cost estimates throughout the project lifecycle. Perera et al. [9] addressed that BIM eliminates many tedious tasks of traditional quantity surveying, such as measurement, take-offs, and production of bills of quantity (BQ).

Despite of the benefits, quantity surveyors lagged behind in BIM application [10] compared to architects and engineers. 10% of quantity surveyors were using BIM regularly and further 29% of quantity surveyors have some limited engagement with BIM in Royal Institute of Chartered Surveyors (RICS) 2011 survey [11]. This survey revealed that the reason of low BIM usage among quantity surveyors is due to lack of awareness and being unsure of its potential usability in their practice. Most of the researches have attempted to study the potential of BIM in design perspectives. There are limited of researches focus on the potential of BIM in cost management activities such as cost planning, estimation and quantification [9] which results in low awareness among quantity surveyors. Lack of information regarding BIM capability has caused the quantity surveyors reluctance to implement the new technology. There is an overall lack of knowledge and understanding of BIM among quantity

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surveyors [8] which caused them default back to conventional inefficient working methods. Several authors stressed that it is crucial to create greater awareness of the potential and benefits of BIM in surveying practice [11], [12]. Nagalingam et al. [7] urged that it is vital to understand how BIM can help in performing quantity surveying tasks. Therefore, the purpose of this paper is to identify the capabilities of BIM in quantity surveying practice and to evaluate their relative importance. This is followed by examining the relationship between BIM capabilities and project performances in time, cost and quality aspect.

II. BIM Capabilities in Quantity Surveying Practice

BIM capability is defined as the ability of BIM to perform tasks in quantity surveying practice that enhance the job performance of quantity surveyors. After reviewing the literatures, there are eleven BIM capabilities in quantity surveying practice during pre-construction stage that have been identified. Gibson and Hamiltion [13] criticized that pre-construction stage has performed bad in the construction industry as many design and cost decisions are made at this early stage which have a greater effect on later project stages. Hence, the scope of this research is focused on identifying BIM capabilities during pre-construction stage. The eleven BIM capabilities obtained along with their identification numbers (C1,C2,C3,…,C11) are displayed in Table I.

TABLE I
BIM Capabilities in Quantity Surveying Practice

Tag	Capability
C1	Cost appraisal can be prepared quickly at the feasibility stage
C2	Preliminary cost plan can be prepared by extracting quantities directly from the model
C3	Easily update cost plans with more detail as design is developed
C4	Easily generate accurate cost estimates for various design alternatives
C5	Design changes reflected consistently in all drawing views
C6	Cost implication of design changes can be generated easily without manually re-measurement
C7	Clash detection reduces design errors and cost estimate revisions
C8	Cost checking performs quickly to ensure all items are captured.
C9	Improved visualization for better understanding of designs
C10	Automatically quantification for BQ preparation
C11	Intelligent information management system allows data to be stored in a central coordinated model.

The first BIM capability identified is cost appraisal can be prepared quickly at the feasibility stage (C1). Feasibility is a crucial decisive stage at which the client will decide whether to proceed with the project based on the professional advice from the quantity surveyor. Information is limited at the beginning stage which consists of simple sketches and other relevant information. Despite of that, project price at this feasibility stage can be calculated instantly using BIM [14]. BIM allows the quantity surveyors to prepare the initial concept estimates in a faster and accurate way [6] based on available information. The second BIM capability is the preliminary cost plan can be prepared by extracting quantities directly from the model (C2). Preliminary cost plan is prepared to show cost allocation of various group elements that make up a project. BIM has the capability to extract more geometric data depending on the level of data available in the model to generate preliminary cost estimates [7], [15], [16].

The third capability of BIM is easily update cost plans with more detail as design is developed (C3). Design progressively develops as more detailed information becomes available. Conventionally, quantity surveyors tend to face difficulties in updating cost plans as designs are updated and changed frequently. Thurairajah and Goucher [8] highlighted that detailed cost plans can be generated through 5D function by linking the model to costing database. By using BIM, quantity surveyors can extract the quantities directly from the model, thus they can easily update cost plans as design develops.

Easily generate accurate cost estimates for various design alternatives (C4) is the next capability identified. Clients require various design solutions for evaluation and comparison to identify the optimal design and avoid costly construction methods. BIM enables a fast and accurate comparative evaluation of multiple design options at an early stage [6], [17], [18]. Client is satisfied as they are able to receive earlier cost feedback on the design alternatives [19] and gain improved understanding of the likely cost influences of design [20].

Another capability of BIM found is the design changes reflected consistently in all drawing views (C5). One of the problems arised during manual quantification is the risk of using obsolete drawings as changes frequently happens. It requires quantity surveyors' attention to capture all the changes in the drawing. However by using BIM, changes will be automatically depicted in the model and will also be propagated throughout all drawing views [21]. All floor plans, sections and elevations will be accurate and consistent.

Cost implication of the design changes can be generated easily without manually re-measurement (C6) is one of the BIM capabilities identified. Design changes require quantity surveyors to track all changes manually which is time consuming to find out what's changed, what's new, what's been omitted or which specifications are different from the previous design. These often results in risk of overlooking of items due to difficulty to capture everything especially in complex building projects. Using BIM, dynamic links are generated with the model assemblies (architectural, structural, civil, mechanical, engineering and plumbing), elemental areas and the rate library which establish relationships among these elements [6]. Autodesk [22] explained that the relationships are automatically built into the model which results in components within the model will respond and interact with each other when design changes.

Clash detection (C7) is a key capability of BIM that can reduce the cost estimate revisions [8]. BIM has the ability to integrate and merge multiple design models (architectural, structural, mechanical, engineering and plumbing) to identify clashes and analyze for interferences. This in turn reduces design errors and discrepancies that often occur by using traditional methods which consequently reduces the workloads of quantity surveyors preparing revised cost estimates.

Cost checking and monitoring is crucial to ensure every design element is captured in the costing. It is time and energy consuming to perform manually. Items can be easily overlooked or miscalculated in large complex projects which can cause serious impact on project costs. BIM has the capability for quantity surveyors to have visual on-screen checking on the model to ensure all design items are captured and measured [17]. Hence, cost checking is performed quickly to ensure all items are captured is the BIM capability (C8).

Misinterpretation of design drawings is one of the problems in building projects [23] during quantities generation. It requires a significant amount of time on visualization and interpretation of drawings and specifications. If the design is not fully visualized and understood, it can be misinterpreted in the contract documents and consequently create conflicts during construction. BIM visualization (C9) has been recognized as an effective tool in better understanding a project's design especially complex relationships and complex systems [8], [24]. This capability enhances quantity surveyors' understanding of the design especially complex structures and subsequently provides accurate costing at an early stage of the project.

Automatically quantification for BQ preparation (C10) is the BIM capability highlighted in literatures [18], [20], [24]. Quantification takes up a lot of the quantity surveyor's time, focus and attention to count and measure each item in the drawing. By using BIM, takeoff is generated automatically and quantities can be extracted directly from the model for cost estimation. This capability enhances quantity surveyors' job performance as such work traditionally could have taken days to complete; but now can be done in hours.

Drawings, schedules and detailed specification from designers are important for quantity surveyors to perform detailed cost estimations. The information exchange between project stakeholders still rely on inefficient traditional means which is sending paper documents. Quantity surveyors face difficulty in obtaining information from the design team that is timely and accurate to perform cost estimation. BIM is known as intelligent information management (C11) through a repository of information in a database [15] for easier sharing and obtaining of information, compared to traditional practices. All information is stored in the model to allow quantity surveyor to perform their tasks by accessing the single model for relevant information. The easy access to information offered by BIM allows a better exchange and sharing of ideas among project stakeholders which reduces information errors.

III. Research Methodology

In order to identify BIM capabilities and examine the relationship between BIM capabilities with project performance, mixed method of quantitative and qualitative data collection was adopted. Main data collection was begun with the quantitative approach to examine the relationship between BIM capabilities and project performance through questionnaires. Questionnaire survey is recognized as the appropriate method for testing objective theories by finding the relationship among variables [25]. Questionnaires were distributed to quantity surveying firms in Malaysia, Singapore, New Zealand, Hong Kong and Australia to obtain more responses. Quantity surveying firms that have adopted BIM in practice were the main target respondents. Pilot study was undertaken to pre-test the survey and subsequently modified before the industry-wide survey. 325 questionnaires were delivered and 103 valid questionnaires were received representing a 32% response rate. The responses received were analyzed through Statistical Package for Social Science (SPSS) software. In order to rank the capabilities of BIM, relative importance index (RII) has been applied. Next, Spearman's rho correlation test was used to measure the relationship between BIM capabilities and project performance. After that, semi-structured interview was conducted. Leedy and Ormrod [26] highlighted that interview is a suitable method to serve as a follow up purpose to validate the questionnaire's results by examining interviewees' opinions. Fifteen interviews were carried out with experienced quantity surveyors. The interview results reached saturation after fifteen interviews. All selected respondents have more than 5 years of experience in the construction industry and had used BIM in their practice. Interviews were recorded, transcribed, and analyzed using content analysis.

IV. Research Findings and Discussions

A. Ranking for the Relative Importance of BIM Capabilities

Table II displays the results from the analysis by outlining the relative important index and ranking. Automatically quantification for BQ preparation (C10) was observed as a top capability of BIM that ranked by the respondents with RII of 0.813. Majority of the interviewees highlighted that clients are dissatisfied with the performance of quantity surveyors in producing BQ. Hence, the interviewees agreed that the C10 was the top capability that can enhance the quantity surveyors' performance by taking away the tedious taking-off tasks.

Cost appraisal can be prepared quickly at feasibility stage (C1) which is ranked second with RII of 0.792. At the early stage, information is limited and it is difficult for the quantity surveyors to prepare an accurate cost appraisal at the beginning stage. Majority of the interviewees addressed that quantity surveyors are able to prepare cost appraisal faster and accurately by using BIM. Hence, it facilitates the clients in decision making process which increase their level of cost awareness in the early design stage.

The third rank of BIM capability is easily generates accurate cost estimates for various design alternatives (C4) with RII of 0.703. Clients tend to request for more cost alternatives for different design options for evaluation and comparison. Interviewees mentioned doing manually is time consuming and does not satisfy the clients. Therefore, all interviewees agreed that this capability is top capability of BIM for quantity surveyors to produce cost estimates faster and accurate for clients. Quantity surveyors can compare, analyze, and evaluate different alternatives simultaneously by providing clients immediate feedback on design alternatives early.

TABLE II
RANKING FOR THE RELATIVE IMPORTANCE OF BIM CAPABILITIES

Tag	RII	Rank
C1	0.792	2
C2	0.636	9
C3	0.674	7
C4	0.703	3
C5	0.665	8
C6	0.680	6
C7	0.684	5
C8	0.686	4
C9	0.619	10
C10	0.813	1
C11	0.610	11

B. Relationship between BIM Capabilities and Project Performance

The relationship between BIM capabilities and project performance in time, cost and quality aspect was identified and tabulated in Table III.

Findings revealed that C1 is correlated with the time and quality project performance. By using BIM, quantity surveyors are able to prepare cost appraisal faster which allow the client to make important decisions at the beginning of the project as explained by interviewees. As a result, it has an impact on time performance as clients are able to receive the cost appraisal earlier and make informed decision. Clients are satisfied and it is hence quality performance is ensured.

The findings indicated that C2 is correlated with time, cost and quality performance. BIM allows the preliminary cost plan to be prepared accurately by extracting quantities directly from the model. It reduces human error and ensures accuracy. The interviewees also pointed out that quantity surveyors would extract the information contained in the model in a shorter time. It subsequently presented to the client the initial cost breakdown for major building elements. Time, cost and quality performances are enhanced.

The C3 is correlated with time, cost and quality performance as shown in the results. Manual practice is prone to errors as the quantity surveyors need to detect many changes and updates in quantities and costing. BIM has the capability to allow them to update the cost plan automatically when design changes as pointed out by interviewees. Interviewees also highlighted that the project performance is enhanced as the work can be preformed quicker and accurately compared to conventional methods.

C4 is identified as correlated with the time, cost and quality performance. BIM capability allows the quantity surveyors to generate accurate cost estimate for various design alternatives. This will provides the quantity surveyor to explore various design alternatives and what-if scenarios to help to optimize the building performance before construction as pointed out by interviewees. Client will be able to consider for different design alternatives by evaluating the time and cost related to the alternatives. Subsequently it eliminates costly and timely traditional construction design or methods.

TABLE III
CORRELATION BETWEEN CAPABILITIES OF BIM AND PROJECT PERFORMANCE

Tag	Correlation Coefficient		
	Time	Cost	Quality
C1	**.252****	.173	**.339****
C2	**.400****	**.236***	**.386****
C3	**.284****	**.192***	**.271****
C4	**.394****	**.294****	**.295****
C5	.101	**.249****	.149
C6	.187	**.283****	**.243***
C7	**.275****	**.240***	**.262****
C8	**.296****	.138	**.313****
C9	**.342****	**.272****	**.358****
C10	**.275****	**.288***	**.450****
C11	**.275****	.176	.183

** Correlation is significant at the 0.05 level (2-tailed)*
*** Correlation is significant at the 0.01 level (2-tailed)*

The analysis findings also displayed that C5 is correlated with the cost performance. Manual revision is tedious as many drawings view affected by the changes made. Interviewees explained that changes made in any representation are propagated to all views and thus, all the representations were coordinated. Information stays consistent throughout the project as changes can be readily accommodated. With this capability, it ensures accuracy for the latest iteration of the design and avoids quantity surveyors using obsolete drawings for cost estimating that may affect the cost performance.

The C6 revealed as correlated with the cost and quality performance. Interviewees pointed out that clients are dissatisfied as quantity surveyors struggled with the ability to respond to the design and requirement changes and to understand the impact of those changes on the overall project budget. Interviewees stated that cost implications were a concern for the client as it influences the project budget. This capability will generate cost implication automatically when the design changes. Hence, it is important for quantity surveyors to generate cost implications to show the cost differences which allow the clients to see how the changes affect the total cost of a building.

C7 is found to be correlated with the project time, cost and quality performance. Interviewees mentioned that design deficiencies would incur extra costs, time wasted and client complains. With this capability, design errors can be detected earlier and cost estimate revisions can be reduced which subsequently enhance the project performance. It ensures that all the design elements were included so that quantity surveyors would able to perform accurate measurements and costing.

C8 is displayed correlated with the project time and quality performance. Interviewees complained that quantity surveyors spend much time on cost checking which prolong time performance but BIM capability enables time saving on checking. Quantity surveyor can filter what is being counted, which leads to a reduction in errors and times. By visual on screen, it reduces the burden of quantity surveyors to perform such tasks by ensuring all the design items are accounted for. Time is saved and quality performance is ensured.

Analysis results displayed that C9 is correlated with the project time, cost and quality performance. Interviewees agreed that by enhancing the quantity surveyors' understanding on design using this capability; they are able to interpret accurately and captured a precise costing. Moreover, time is saved as quantity surveyor can have clear understanding based on 3D visualization rather than based on their interpretation on paper drawings. Clients are satisfied as quantity surveyors have clear understanding on the design and costing.

The findings demonstrated that C10 is correlated with time, cost and quality performance. One of the interviewees shared the experience of adopting BIM in practice, in which the project achieved time saved by automated the quantification as human error factor was removed and cost savings as quantity take-off was completed accurately which allow the construction team to purchase exact materials needed. Interviewees highlighted that clients are satisfied with the performance of quantity surveyors who spend less time on manual QTO.

Findings indicated that C11 is correlated with the time performance. BIM provides a platform for integrated information exchange through a single model which allows quantity surveyors access information timely. By having timely and promptly information and documents, quantity surveyors can perform their tasks faster and improve project time performance. Interviewees mentioned that it saves time as quantity surveyors don't need to require information from different design consultant.

V. Conclusion

Changing of clients' requirements and dissatisfaction performance of quantity surveyors are the factors pushing the quantity surveyors to seek for higher efficiency methods, as compared to the existing working methods. BIM plays a major role in supporting the quantity surveyors in doing their tasks effectively and efficiently which subsequently improve project performance.

By proving a comprehensive list of BIM capabilities and studying the relationship between these BIM capabilities and project performances, it will gain quantity surveyors' understanding of the potential and impact of BIM technology in their practice and also project performance. It helps to show how the BIM capabilities in quantity surveying practice affect the project performance which in turn promotes adoption of BIM among quantity surveyors as the project performance would improve by using BIM.

Future studies in BIM application in quantity surveying practice can be focused on studying the challenges and problems of adopting BIM specifically faced by quantity surveyors. By identifying the obstacles face by the quantity surveyors, it will enhance adoption by removing the problems. Further, it is recommended to study the obstacles in few aspects such as people, process and technology. It is more systematic to sort all the obstacles to BIM adoption into groupings such as the aforementioned categories. This systematic grouping will result in deeper understanding of the problems faced. Hence, this approach will enhance future research on strategic improvement.

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