Exploring Accuracy Factors in Cost Estimating Practice towards Implementing Building Information Modelling (BIM)

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Abstract

Cost estimating has been acknowledged as a crucial component of construction projects. Depending on available information and project requirements, cost estimates evolve in tandem with project lifecycle stages; conceptualisation, design development, execution and facility management. The premium placed on the accuracy of cost estimates is crucial to producing project tenders and eventually in budget management. Notwithstanding the initial slow pace of its adoption, Building Information Modelling (BIM) has successfully addressed a number of challenges previously characteristic of traditional approaches in the AEC, including poor communication, the prevalence of islands of information and frequent reworks. Therefore, it is conceivable that BIM can be leveraged to address specific shortcomings of cost estimation. The impetus for leveraging BIM models for accurate cost estimation is to align budgeted and actual cost. This paper hypothesises that the accuracy of BIM-based estimation, as more efficient, process-mirrors of traditional cost estimation methods, can be enhanced by simulating traditional cost estimation factors variables. Through literature reviews and preliminary expert interviews, this paper explores the factors that could potentially lead to more accurate cost estimates for construction projects.The findings show numerous factors that affect the cost estimates ranging from project information and its characteristic, project team, clients, contractual matters, and other external influences. This paper will make a particular contribution to the early phase of BIM-based project estimation.

Keywords: accuracy, accuracy factors, Building Information Modelling (BIM), cost estimates, cost estimating practice.

Introduction

Cost estimating is crucial to the successful execution of construction projects (Barzandeh, 2011; Samphaongoen, 2010; Meerveld, Hartmann, & Vermeij, 2009; Butcher, 2003; Akintoye & Fitzgerald, 2000). The practice normally includes defining scope of work, determining project basis and deciding the suitable estimating methods to be used. Cost estimates are developed through the project stages incorporating conceptual, design development and execution, depending on project-specific details. The traditional cost

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estimating process described by Peurifoy & Oberlender (2002) starts with the kick-off meeting, followed by work plan establishment, estimates preparation and estimates documentation. After some reviews and adjustments, the estimates are ready for project execution. In this cyclic process, feedback from completed projects provides input for the improvement of subsequently implemented projects.

Accuracy is a very common term used in describing the primary attribute required in construction cost estimates. Irrespective of the estimated cost, the proximity of estimates to the actual value is indicative of their accuracy levels (Ashworth, 2013). The project cost is a priority area for clients in managing allocated budgetary amounts. Hence, producing an accurate cost estimate is critical to ensuring client satisfaction. An accurate cost estimate is one devoid errors or mistakes (Azman et al., 2013; Flanagan & Norman, 2006; Serpell, 2004), while the estimating error is defined as the difference in the value-range obtained between estimated and actual cost (Serpell, 2004). Thus, the smaller the error, the higher the accuracy (Flanagan & Norman, 1983). Theoretically, in a range of cost estimates, the most accurate value is the one which most reflects the actual or tendered price of a construction project (Azman et al., 2013; Serpell, 2004; Barzandeh, 2011).

According to Skitmore (1988) the underpinning idea that information accuracy is a function of the correctness of input data. Thus there is a positive correlation between cost estimation accuracy and supplied project information and the spread of errors lessens over time. This idea is corroborated by Greenhalgh (2013) who submits that the level of accuracy in cost estimates increases with progressive information detailing from inception to the design development phases. Butcher (2003) on the other hand asserts that although the accuracy of an estimate can be positively influenced by many factors, it is commonly predicted to be (±5%) of the average bid. Therefore, it can be deduced that, in determining the accuracy of cost estimates, the source of the cost information must be taken into account. However, these factors vary from the inception to the final stages of construction projects.

BIM-based estimating undergoes the processes of analysis, quantities extraction, pricing and estimate finalisation; which mirror traditional methods of estimating (Meerveld et al., 2009); the difference being the use of information derived from 3D modelling environments instead of through non-objective interpretation of traditional 2D drawings. The value in this approach to estimating is the adoption of BIM, which itself relies on – as well as generates – accurate information (Sylvester & Dietrich, 2010). BIM furnishes great potentials for estimators to make efficient and accurate cost predictions for construction projects over and above the limitations posed by more traditional methods. Effectively, automated, BIM-based processes allow estimators to extract quantities from 3D models to estimate construction costs quickly and accurately (Meerveld et al., 2009). Nevertheless, it is worth noting that a different kind of attention to details is required to ensure that object selection within digital models is accurate (CRC Construction Innovation, 2009).

Methodology

This paper presents early findings on construction cost estimating factors through literature review and expert interviews. The deductions and findings from the review of literature serves as the motivation and rationale for the expert interviews conducted subsequently.

A qualitative approach was used to support information gained from the literature review. Semi structured interviews were chosen to gain more insights on cost estimating factors from industry players. More information was obtained from the interviews although it was time consuming. During the interviews, the respondents were allowed to give as much details as they wanted concerning to the issues. As a result, it gained more valid information

on the respondents' opinions towards the accuracy factors in cost estimating to contextualise the issues in this paper.

As the interviewing process lasted for few hours and due to time limitation, only a small number of interviews could take place. The interviews took place in Selangor, Malaysia, engaging only four quantity surveyors as the respondents. However, it was considered sufficient as the results from these interviews were in-depth, in which the respondents who specialise in construction cost estimating with more than 20 years of working experience, have given a detail explanation towards the issues raised.

Audio-recorded interviews were thus obtained and transcribed using content analysis. To develop the analysis, the interview results were coded based on categories derived from the literature review. The coding process was done by sorting, organising and assigning the raw data quoted by the respondents into codes to fit the categories (refer Table 1). As such, the datasets obtained from the interviews were subsequently elaborated and mapped against previously grouped factors in the literature. For purposes of confidentiality and anonymity, the identities of all participants were encoded and referred to as: QS 1, QS 2, QS 3 and QS 4.

Results and discussion

Literature Review

There are several essential factors that deserve consideration in establishing accurate cost estimates. As such, before conducting any exercise in cost estimation, a thorough assessment of all relevant factors should be carried out at the early stages of planning for construction projects. These factors would provide crucial information that would be useful for obtaining significantly more accurate values than would normally be possible.

Updated project information, the essential element in estimating cost, would considerably empower estimators to produce more reliable cost estimates (Tas & Yaman, 2005; Olatunji & Sher, 2010). In relation to such project information, Aibinu & Pasco (2008) highlighted the influencing factors for obtaining accurate estimates, namely: project value, gross floor area, number of storeys, project location, procurement route, project type, structural material used and price intensity. Through multiple regression analysis, they found that the accuracy of project cost estimates is most influenced by project size, in the sense that the estimates of smaller projects are more biased than those of larger projects. Additionally, Stoy, Pollalis, & Schalcher (2008) integrated the relevant cost drivers for project information in a regression model, with a view to improving the accuracy of cost prediction for residential buildings. The model incorporates variables of compactness of the building, number of elevators, absolute size of the project, construction duration, proportion of openings and region. Some of the factors affecting accuracy are considered part of project information, according to Azman, Abdul-Samad, & Ismail (2013), including: project value & project size, price intensity theory, number of bidders, location (state), type of schools and contract period.

Apart from project information, researchers have also outlined other factors related to project attributes, such as: the clients, contracting matters, estimator and also external influence. A comparative study conducted by Akintoye (2000) identified that the relevant principal factors influencing project cost estimating practice are: project complexity, technological requirements, project information, project team requirement, contract requirements, project duration and market requirement. Similarly, Enshassi et al. (2005) listed these factors as: project complexity, project information, technological requirements, contract efficiency, market requirements, project duration and project risk, while Serpell

(2004) classified the main factors affecting the accuracy of conceptual estimates as scope quality, information quality, uncertainty level, estimator performance and quality of estimating procedure.

Elhag, Boussabaine, & Ballal (2005), assessed and ranked cost-influencing factors of construction projects at the pre-tender stage for building projects in the UK. From a possible 67 variables involved, the underpinning factors were categorised into six (6), namely: client characteristics, consultant & design parameters, contractor attributes, project characteristics, contract procedures/procurement methods and external factors/market conditions. Findings from the literature suggest that the activities of architects and consultants have significantly more impact on project costs than those of contractors, suggesting that the extent to which estimates vary from actual costs is determined at the early design stages rather than later during the construction stage. Nevertheless, factors affecting the accuracy of pre-tender cost estimates in some Nigerian projects slightly differ from the norm as suggested by Koleola & Henry (2008), whose research considers factors such as: consultants' expertise, information quality & flow requirements, project team's experience of construction type, tender period & market conditions, extent of completion of pre-contract design and complexity of design & construction.

A framework identifying the controlled critical factors for effective cost estimation by Liu & Zhu (2007) outlines two main factors; control factors and idiosyncratic factors. Control factors are further classified into input, behavioural and output control categories. These are factors which can be controlled by estimators while idiosyncratic factors are those outside the influence of the estimator such as market conditions, weather, and site constraint. Factors influencing construction projects have been consolidated by Cheng (2013) into four categories, namely: environmental & circumstantial influences, contract scope, projects risks and management & technique.

By performing factor analysis and multivariate regression on 45 elements from 67 completed construction projects, Trost & Oberlender (2003) rank the five key factors that have the most significant impact on the accuracy of cost estimates. The factors are: incorporating basic process design, team experience & cost information, the time allowed for preparing estimates, site requirements and bidding/labour climate. Using the principal component technique to construct a predictive project cost model on other trends, Chan & Park (2005) propose three key groups of determinants which influence project cost estimates, namely: project design, complexity & time, as well as the level of professional competency of project team members and contractors.

Based on the underpinning factors in cost estimates determined from the studies so far highlighted. This paper submits that estimating factors can be grouped into six main categories, namely: project information, project characteristic, project team requirement, clients requirement, contract requirement & external influence. The summarised list of the main factors identified from a review of related literature is illustrated in Figure 1.

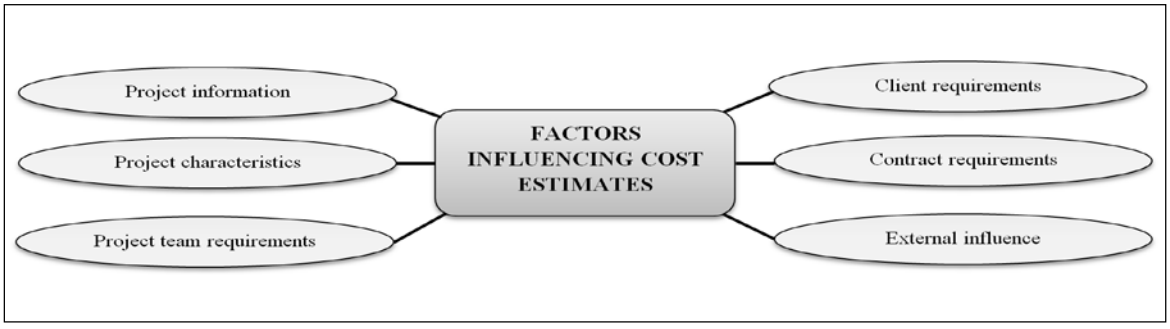

Figure 1. Cost estimating factors from literature

Expert Interviews

Responses from the interviewees are outlined based on the factors grouped in the previous literature. Interviewees comments show evidence that the main influencing cost estimating factors are those related to project information, project characteristics, project team requirements, client requirements, contract requirements and external influences. The details are shown in Table 1 below.

Table 1. Cost estimating factors by interviewees

Raw data (Interviewees' responses)	Codes of factors	Categories of factors
"…when we talk about making the right costing, the information must be correct. It is the most important. You must have the correct information. The information may be various; it is about ***location, drawing, requirement, floor area, how large*** *it is, what the* ***standard*** *is."* **-(QS 2)** *"You can see the criteria in terms of whether the project is a terrace house, is located in* ***Location*** *X,* ***high rise building, type of project****. If it is a high rise building, so you should refer to the cost information of high buildings as well."* **- (QS 1)** *"You need to have the basics. You must have that information. If there is no information, I don't think you can do estimates… It is absolutely necessary. It is related to* ***location, design, specification level, client, target group****..."* **- (QS 1)**	Location; drawing; requirement; floor area; how large; standard; high rise building; type of project; design specification level; client; target group	Project information
"SMM is used as our basis, but it depends on ***the information available****. If SMM states that tiles is calculated in m², so we follow it as m², as well as skirting where it is measured separately…but if there is no information on the skirting, we will assume it probably in percentage…"* **- (QS 4)** *"The first one is the* ***availability of the drawing****. It would be the design. The more complete the drawing; the better the estimate. All QSs can do estimates; it depends on the* ***details of the drawings****. Everything is based on designs & drawings."* **- (QS 3)** *"Whether they are renovation works, hotels and so on, if you never estimate their costs before, what is important is the* ***cost data****. That's all. It doesn't matter if you have done it before…It is important to get information about it."* **- (QS 1)**	Information available; availability of drawing; details of drawing; cost data	Project characteristics
"It is the ***knowledge about cost data****. The similarity in terms of project the estimator have experienced previously. If assumption needs to be made, it should be based on* ***experience****…Without experience; sometimes*	Knowledge about cost data; experience; experience in	Project team requirements

he cannot allow any items as he couldn't see whether it is relevant to be made or not."- **(QS 4)** *"I think the* ***experience in the rates,*** *what the estimators should have is to* ***know about the rates****."*- **(QS 3)** *"Feeling whether it is true or not. That* ***experience****…The feeling also comes with* ***common sense****."*- **(QS 2)** *"…through the* ***research*** *that has been done and so on…He will make his* ***assumptions*** *and also with the help of* ***past projects****."*- **(QS 1)** *"Variations depend on* ***the estimators' competencies****. It will not happen if we do it accurately, regardless of either doing it manually or by software application…It depends on human, wrong assumptions, carelessness. "It is the own* ***character of the estimator*** *as well, whether he is lazy or hardworking, resourceful and so on."*- **(QS 1)**	the rates; know about the rates; common sense; research; assumption; estimator's competencies; character of estimator	
"When the developer ***has fixed their margin****, we cannot simply overestimate or underestimate the cost. We have to redo as it would become wrong report."*- **(QS 4)** *"Sometimes clients have specific requirements. For example, project A's requirement is different…perhaps more to the preliminaries, site management. Such as developers, they are more concerned about* ***profits****. We have to consider the estimates; we need to know the* ***standards of the client****."*- **(QS 4)** *"I experienced twice, where, when we put the price; the client stated that it was expensive and the project couldn't start as the client didn't have enough* ***budget****…"*- **(QS 3)** *"When the client has got the* ***return****, he'll be okay. If the pre-tender estimate deviates from preliminary estimates,* ***the issue*** *will be addressed* ***by the client****."*- **(QS 1)** *"…some of them do estimates in two months, but are still not ready, but time should be shortened to meet* ***client's timeline****."*- **(QS 1)**	Fixed margin; profits; standards by client; budget; return; issues addressed by client; client's timeline	Client requirements
"It is ***standard margin set by the company*** *if nothing is put in contingencies, which will be used for any items missed or there are changes in design."*- **(QS 1)** *"Now we have* ***new standards*** *of green building... you want the building as green building or you want it to be normal."*- **(QS 2)** *"…an estimate never came once. It will come several times,…up to the one that we are very sure the information is complete…As the information kept on*	Standard margin set; new standards; revised several times	Contract requirements

*coming, …**revised** were also being made several times. We are constantly improving the cost estimates after **several times**..."*- **(QS 2)**		
*"If we establish **contingencies** in pre-tender estimates for the BQ, it is for the construction cost in the event of **fluctuation**, **changes in design or design upgrading**..."*- **(QS 1)** *"Sometimes we cannot predict whether it is underestimated or overestimated as **variation orders** (VOs) are issued only during the construction process. Usually, as long as it is not built, we will not know whether the project is underestimated or overestimated."*- **(QS 1)** *"When we got only preliminary information, it is not clear, many **uncertainties**, that's where we need to make one factor to be included in our cost to put all these things…"*- **(QS 2)**	Contingencies; fluctuation; changes in design; design upgrading; variation orders; uncertainties	External influence

From the Table 1, most of the interviewees have emphasised that the information of a project such as type, location, size and others are vital to producing more accurate estimates. The estimator skills and knowledge also becomes a major factor contributing to the estimates accuracy.

Based on a review of literature and expert interviews, the influencing cost estimating factors have been grouped into six primary factors namely project information, project characteristic, project team requirement, clients requirement, contract requirement & external influence. The summarised list of those primary factors and their sub-components are depicted in Table 2 below.

Table 2. Summary of cost estimating factors

Authors (Year) / ***Main factors***	Akintoye (2000)	Trost &	Serpell (2004)	Enshassi et al. (2005)	Chan & Park (2005)	Elhag et al. (2005)	Liu & Zhu (2007)	Aibinu & Pasco	Stoy et al. (2008)	Koleola & Henry	Cheng (2013)	Azman et al. (2013)	**Expert interviews**
Project information													
Project value								√				√	
Project size/floor area						√		√	√			√	√
Price intensity								√				√	
Project location	√			√		√		√	√			√	√
Project type						√		√				√	√
Project duration	√				√				√				
Storey/compactness/volume/ Opening						√		√	√				√
Project characteristics													
Design/construction (drawing/scope/process)		√	√	√	√	√	√			√	√		√

Information (flow/availability/quality)	√	√	√	√		√	√			√			
Project complexity (design/construction)	√		√		√	√							
Project team requirements													
Experience/expertise/ professional level	√	√	√	√	√		√			√	√		√
Team alignment/capacity/ communication	√	√					√						
Personal characteristic/performance													√
Estimation design/ process/procedure		√	√				√						
Management & technique (time/cost control)		√					√				√		
Client requirements													
Client's budget/financial status	√	√		√									
Return profit /money issues		√											√
Client characteristic/type	√					√							
Time/quality requirements						√							√
Contract requirements													
Scope of contract											√		√
Tender/contract period	√									√		√	
Tender selection method						√							
Procurement route/contractual arrangement	√					√		√			√		
Type of contract/standard						√							√
Pre-contract (design/construction)	√									√			
External influences													
Site requirements		√											
Bidding/contractor attributes		√		√	√	√						√	
Market conditions (rates/inflation/fluctuation)	√		√	√		√				√	√		√
Technology requirements	√	√	√		√								
Uncertainties (contingencies/variations)	√	√	√			√							√
Political situation				√							√		
Environmental (climate/geology/disaster)											√		
Disputes (contract/regulations/payment)											√		

Table 2 shows that the key influencing factors between the opinions of experts in practice and those of the 12 authors are due to: 1) the concentration of the experts in one geographical region, hence a convergence of their opinions, and 2) the impact of organisational policies and work culture in practice within the same nationality.

By mapping information quantities taken off digital models to the six factors highlighted in this paper, cost estimators can provide more accurate estimates beneficial for decision making of BIM stakeholders. Consequently the six factors may serve as the minimum criteria for improving cost estimate accuracy. Thus they will determine whether or not BIM object parameters meet the minimum requirement specified by those factors.

Conclusions

The factors that are crucial to attaining accuracy in cost estimation have been investigated within the context of this paper. These factors have been condensed into six main categories, namely: project information, project characteristics, project team requirements, client requirements, contract requirements & external influences. On the basis of these categories therefore, this paper rationalizes that professionals within the AEC can leverage the functionalities embedded in BIM authoring tools to ensure the accuracy of cost estimates derived from digital models on the basis of the identified categories.

This paper concludes that BIM-based cost estimation should be approached from the standpoint of ensuring that information provided for BIM repositories address the six cost estimate categories presented in this paper. Although the developed categories are non-definitive, they serve the purpose of ensuring a uniform, albeit minimum, level of quality is attained in deriving cost estimates that are accurate.

This paper is based on preliminary research on the information of cost estimation on BIM. Therefore, recommendations for future research are:

1) A testing of the outcomes of this paper on the accuracy of BIM-derived cost estimates against traditional estimates.
2) It will be worth carrying out further investigation on other factors that affect the accuracy of cost estimates. Thereafter, the extent to which they approximate the factors highlighted in this paper can be determined.

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