

Bond University
Research Repository



Drivers of the accuracy of developers' early stage cost estimates in residential construction

Lim, Brendon; Nepal, Madhav P.; Skitmore, Martin; Xiong, Bo

Published in:
Journal of Financial Management of Property and Construction

DOI:
[10.1108/JFMPC-01-2015-0002](https://doi.org/10.1108/JFMPC-01-2015-0002)

Licence:
Other

[Link to output in Bond University research repository.](#)

Recommended citation(APA):
Lim, B., Nepal, M. P., Skitmore, M., & Xiong, B. (2016). Drivers of the accuracy of developers' early stage cost estimates in residential construction. *Journal of Financial Management of Property and Construction*, 21(1), 4-20. <https://doi.org/10.1108/JFMPC-01-2015-0002>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

For more information, or if you believe that this document breaches copyright, please contact the Bond University research repository coordinator.

DRIVERS OF THE ACCURACY OF DEVELOPERS' EARLY STAGE COST ESTIMATES IN RESIDENTIAL CONSTRUCTION

Abstract

Preliminary cost estimates for construction projects are often the basis of financial feasibility and budgeting decisions at the early stages of planning. The accuracy of these types of cost estimates is crucial in determining whether or not a project is undertaken or infeasible. Many studies have been undertaken to determine the key factors affecting construction cost and explore significant variance between the actual and estimated cost. However, research on the accuracy of developers' cost estimates in small scale residential building construction projects is limited. This paper provides a literature review to determine the drivers that affect the accuracy of developers' early stage cost estimates and the factors influencing the construction costs of residential construction projects. In order to measure the relevance of the identified issues in the local context and analyse the estimating accuracy, cost variance data and other supporting documentation collected from two case study projects in South East Queensland, Australia, along with semi-structured interviews with the practitioners involved in the studied projects are conducted. The results suggest that many cost drivers or factors of cost uncertainty identified in the literature for large scale projects are not as apparent and relevant for developer's small scale residential construction projects. More specifically, the certainty and completeness of project-specific information, the suitability of historical cost data, contingency allowances, methods of estimating, and the estimator's level of experience play significant roles in the accuracy of cost estimates. Developers of small scale residential projects use pre-established and suitably priced bills of quantities as the prime estimating method, which is considered to be the most efficient and accurate method for standard house designs. However, this method needs to be utilized and backed with the expertise and experience of the estimator.

Keywords: Cost estimate accuracy; developers; residential construction industry; preliminaries; project uncertainties; historical cost data.

Introduction

Reliable and accurate cost estimates of construction projects are very important for clients, contractors and other stakeholders of a project. However, it is common for final project costs to greatly exceed estimated costs (Williams et al., 2005). Flyvbjerg et al.'s (2003) analysis of data for 258 transportation infrastructure projects worth US\$90 billion, for example, found that nine out of ten cost-overrun projects were caused by inaccurate estimation in the early stages (Flyvbjerg et al., 2003). Although the accuracy of cost estimates is expected to improve with more information release as the design progresses (Skitmore, 1987a), accuracy is much more important in the early stages (Lowe et al., 2006; Skitmore et al., 1990).

The production of cost estimates is critical for client decision making in the early planning stages of construction projects (Serpell, 2004). For organisations such as governmental authorities or real estate developers, inaccurate early estimates result in the inefficient use of money, missing development opportunities and unsuccessful project management (Oberlender and Trost, 2001). This heavy task is often undertaken by Quantity Surveyors (Morrison, 1984). However due to the level of uncertainties associated with proposed projects in the early stages of design and that these estimates are often prepared within short time frames based on limited design documentation and project scope, they are susceptible to a wide array of inaccuracies with Barnes (1974), for example, indicating the accuracy of early stage estimate to be in the order of -40% to +20%.

There has been a significant amount of research conducted in the past identifying the factors related to cost estimating inaccuracy (e.g. Skitmore, 1985; Trost and Oberlender, 2003; Aibinu and Pasco, 2008; Ahiaga-Dagbui and Smith, 2014) and developing methods aiming to minimize errors in forecasting cost estimates at the very early stage (e.g. Yeung and Skitmore, 2012). There seems to have been less effort to investigate the accuracy of cost estimates in a systematic way by analysing the cost variation between the estimated and *actual* cost. Furthermore, much of the relevant research has been focused on commercial construction and larger scale projects and there is limited research on the accuracy of developers' cost estimates in small-scale residential building projects. Since many factors including function, scope of work and contract type are quite different in nature for residential building work compared to commercial construction, this paper aims to identify the major factors affecting developers' cost estimating errors. Cost variance data and other supporting documentation collected from two case study projects in South East Queensland, Australia along with interviews conducted with the practitioners involved in the studied projects are used to analyse the estimating accuracy.

Literature Review

Estimates are most inaccurate in the early stage due to limited design and construction-specific information. Trost and Oberlender (2003) conclude that lack of necessary information is the most important factor influencing estimate accuracy at the planning stage. As the design evolves and the scope of the project becomes more well defined, the level of detail and certainty of the information increases, thereby increasing the accuracy of the estimate. It is reported that the inaccuracy of early estimates in Germany, for instance, is around 30% and this inaccuracy is mainly caused by the way the estimate is derived, for example by simply multiplying the floor area with some factor or indicator, which is inaccurately measured or determined for a myriad of uncertain cost drivers that are applicable to a project (Stoy and Schalcher, 2007). However, there are also the possibilities of strategic misrepresentation, deception and bias as reasons for inaccuracy. Flyvbjerg et al. (2002) have noted that underestimation observed in transportation projects cannot simply be explained by error and is better to be explained by strategic misrepresentation. Despite its inaccuracy, an inexpensive, quick, and comparatively accurate pre-design or early stage estimation is nevertheless important for making important project decisions and feasibility studies (Li et al., 2005). A brief review of previous studies on building cost relevant drivers at the early stage and the impacts of these drivers on building cost formation is provided next.

Construction Cost Influencing Factors

Numerous factors affect the construction cost of a building, all of which have to be quantified and priced. Primary cost drivers include the building type, size, complexity and quality, type of client, contractor selection, contractual arrangements, location, and economic, legal environment of project location (Skitmore, 1987b). Gunner and Skitmore (1999) found that floor area, number of storeys above ground and contract period have comparatively high correlations with contract sums. In their study of reinforced concrete and steel office buildings in Hong Kong, Li et al. (2005) found that total floor area, total building height, and average floor area are the most important cost factors. Elhag et al. (2005) ranked six categories of important cost factors. However, the impacts of these variables are not well documented. Moreover, information concerning most of those factors is not available in early design stages.

Specific to estimating accuracy, some selected factors contribute to cost uncertainty. The most important of these in the preliminary stages of planning a construction project include: project size, geographical location, construction time, number of bidders, market conditions, level of information, ability of estimators and project duration (Ogunlana and Thorpe, 1991). Gunner and Skitmore (1999) conducted a thorough review of previous studies and summarised the factors affecting estimating accuracy into categories of: building function, type of contract, conditions of contract, contract sum, price intensity, contract period, number of bidders, good/bad years, and procurement basis. Ling and

Boo (2001) identified four main elements - design data, time availability, estimating technique and cost data - that affected the accuracy of cost estimates. The comparative study of 84 UK contractors, showed that project complexity, technological requirements, project information, project team requirement, contract requirement, project duration and market requirement were the main factors influencing contractors' cost estimating practice (Akintoye, 2000). Ahiaga-Dagbui and Smith (2014) argue that scope changes, managerial and technical difficulties, material and labour price changes and estimating errors are some of the major causes of cost overrun on construction projects. Interestingly, estimating errors are related to the level of uncertainty involved in the design and construction of a building (Serpel, 2004).

Based on the comprehensive analysis of the literature, key factors affecting construction cost and hence the accuracy of early stage estimates can be divided into either external or internal factors. Table I provides examples of the factors for each category. External factors comprise unknowns related to the construction market or factors that are external to the project. Internal factors are project-specific factors. The internal factors may also arise from the uncertainties presented or faced during the project's management and construction (Serpell, 2004).

INSERT TABLE I ABOUT HERE

The Suitability of Historical Cost Data

Estimation at an early stage is highly dependent on the use, relevance and availability of historical cost information (Dysert, 2007). The selection of cost data from previous projects is crucial to the accuracy of the estimate. It is usually necessary to make adjustments to convert selected cost data from one time, location and market situation to the anticipated time, location and market situation surrounding the new project (Morrison, 1984). It is common practice to use cost data from previous lowest tenders when preparing estimates. However, as the lowest tender price of any given project may have been determined by a number of factors, including project-specific and market-related conditions, it is therefore not an entirely accurate measure upon which to base the estimate. Estimates based on the lowest tender prices may lead to underestimation (Ling and Boo, 2001). In order to minimise the effects of factors surrounding the variability of the bid price, Morrison (1984) advises using the mean price level of lowest tenders. Moreover, the historical data on which forecasts are based may be inaccurate because they may be based on tender prices rather than final account prices. Also, the data may have been derived from a sample of buildings that were not perfectly matched to the proposed building (Flanagan and Norman, 1983).

Estimator's Experience Level

Cost estimation is an experience-based process and estimators are generally well aware of the uncertainty and unknown circumstances affecting construction costs (Elhag et al., 2005). As there is limited information available at the time of preparing estimates, especially in the early stages of design, the use of historical data and the estimator's subjective judgement play a critical role (Kim et al., 2012). Estimating expertise or the ability to make good subjective judgements is crucial in producing more accurate estimates (Skitmore, 1985). This expertise is further linked with the experience of an estimator (Skitmore et al., 1990; Serpell, 2004) and is especially important when there is a lack of adequate information (Leung et al., 2005). Experienced estimators are more confident in selecting information for estimating and are more consistent in their reasoning for their choice and use of cost data (Ogunlana and Thorpe, 1991).

Methods of Estimating

The choice of estimating method is also the key to estimating accuracy. Traditional methods for carrying out estimates in the early stage of a project include analogous cost estimating and parametric methods. As a common practice, estimators consider the key parameters such as the price per square metre of floor area of a comparable building as a starting point then adjust it for estimating the cost of a new building (Azman et al., 2013). The application of these methods however requires a good historical database, sufficient domain knowledge and expertise. The multiple regression analysis (MRA) has been regarded as a powerful parametric estimating method and has a great potential for forecasting construction costs (Li et al., 2005; Skitmore and Patchell, 1990). But this technique requires good historical data and the clear understanding of the statistical modelling technique. Probabilistic cost estimating models, usually in the form of Monte Carlo simulation, allows the estimation of project costs under various scenarios. While the applicability and acceptability of probabilistic cost estimating is arguable (Chau, 1997; Fellows, 1996; Li et al., 2005), the method requires a large statistical data set and complex mathematical algorithms (Chou and Tseng, 2011).

The use of artificial intelligence-based methods such as Artificial Neural Networks (ANNs) and Case-Based Reasoning (CBR) has received the increased attention of researchers in the last two decades (Chou and Tseng, 2011). ANN simulates the learning process of the human brain by forming thousands of simulated neurons and is widely used for its predictive ability in many fields (Kim et al., 2004; Kim et al., 2005). ANN does not require the relationship (e.g., linear, quadratic) between cost factors and the project cost to be defined prior to running the estimation process (Bode, 2000). The ANN model simply assumes that there is a constant relationship between the influential factors and cost of the project components. Since this model has no inherent functional form, it provides more freedom for fitting data than estimation by regression modelling (Wilmot and Mei, 2005). Thus, ANN usually produces more accurate results than more conventional methods of estimation (e.g., regression analysis or expert judgement) at an early stage when there is lack of information, and complex, nonlinear or unknown relationships between the variables and cost components of the project (Alex et al., 2010; Cheng et al., 2010; Duran et al. 2009). However, standard ANN models cannot handle uncertainty and linguistic variables in cost estimation (Duran et al. 2012). Therefore, other methods (e.g., fuzzy logic) that can address uncertainties and qualitative data can be used to improve the precision level of cost estimation by ANN (Wang et al., 2013; Cheng et al., 2010). While ANNs provide a feasible alternative for early cost estimates, their use in cost estimating practice is limited.

CBR is another form of artificial intelligence-based method to solve a new case by using similar cases and previous knowledge/experience. Typically, CBR is a cyclical procedure comprising of four sub-phases of retrieving, reusing, revising and retention (Aamodt and Plaza, 1994; Xu, 1994). It has the flexibility of understanding numerous scenarios based on the type of attributes of any case. CBR can present the verified data as references where other models, such as ANN and MRA, cannot confirm the data on which different outcomes depend (Hong et al., 2011). Unlike ANN, a CBR-based model can work with both quantitative and qualitative data in cost estimation thereby representing the real life problems (Koo et al., 2010). Therefore, the predictive accuracy of CBR models has been found to be superior to ANN and MRA (Hong et al., 2011; Arditi and Tokdemir, 1999). It can also provide a solution in absence of exactness in certain data (Chou, 2009). However, CBR particularly depends on case similarity. If the data cannot represent sufficient similar cases, the result will be inaccurate when predicting the cost of new cases (Ji et al., 2010). CBR is an appropriate tool for conceptual stage estimating, but requires a series of systematic procedures to create the knowledge base (Chou and Tseng, 2011).

Contingencies

Contingencies are additional allowances made in the estimate as a buffer for dealing with unknown (or unforeseen) and uncertain project elements or costs that can affect a project. If contingencies are overestimated, the use of capital may be inefficient; if they are underestimated, the project may fail

(Tseng et al., 2009). Therefore, an exaggerated contingency is common in many project estimates (Mak and Picken, 2000). The level of accuracy of an estimate is largely determined by the design documents provided and the amount of contingency, which is allocated for undocumented scope of work. One method of improving the estimate accuracy is to assign different percentage amounts to various parts of the budget. A higher percentage can be applied to the parts with high levels of risk (Tseng, Zhao & Fu, 2009). However, one of the issues with using percentage figures is that they are most likely arbitrarily obtained and not appropriate for the project at hand (Mak et al., 1998). Interestingly, the Hong Kong Government implemented a technique called Estimating using Risk Analysis (ERA) by identifying and costing risk events associated with a project to determine the appropriate amount of contingencies (Mak et al., 1998). Estimators in the South East Queensland residential market generally benchmark the estimate for preliminaries and margin for a new project based on the experience of similar, previous projects and using key project parameters, and with adjustments made to reflect changing market conditions.

Contingencies are high in the early phases of a project's life cycle to reflect the 'unknowns', usually as high as 30-40% during the schematic design phase, 10% at the final design stage and are expected to drop significantly at the bidding stage as more detailed and complete information becomes available (Arditi et al., 2002).

Research Method

This research used qualitative and quantitative data/information collected from two case study projects as a sample to study the accuracy of early stage estimates and the underlying cost factors or drivers. These projects consisted of two double storey residential dwellings constructed in the South East Queensland (SEQ) region with a budget of \$250,000 - \$300,000. Table II outlines the characteristics of the studied projects.

INSERT TABLE II ABOUT HERE

The projects were undertaken by the same organisation. As such, it is important to note the operational nature of the organisation and its method of preparing cost estimates. The organisation offers a range of standard designs from which bills of materials for each design are produced for the purpose of establishing a base cost for each individual house design. Any variation or change to the design as requested by the client is incorporated in the estimates by the estimators, who then make necessary adjustments to the base cost price. To ensure an accurate interpretation of the collected data, the analysis of construction cost factors for each of the projects was conducted by breaking them down into individual building elemental categories.

The case study involved the collection and analysis of the organisational and project documentation of the two building projects undertaken by the organisation involved. These documents included: job/bill of materials comparison reports, job profit/margin reports and relevant tender documents. Data from these documents were used to conduct a comparison of the deviation between the provisional sales quote estimate and the final total project construction cost for each project. From the analyses of data from these documents, it was possible to identify the factors that had the greatest influence in construction cost variation.

The research also conducted semi-structured interviews with 10 practitioners who were working for the selected organisation and all involved in the case study projects in some way. They were

interviewed in relation to the projects with questions based on the cost drivers and factors as discussed in the literature review. The interviewed practitioners had various roles, including sales estimators, production estimators and site supervisors with varying degrees of experience and expertise. One respondent had less than five years' experience, five respondents had five to 10 years of experience, and remaining four respondents had more than 10 years of experience. The interviews helped to collect qualitative information in relation to the developer's estimating accuracy and cost drivers. They also provided an opportunity to obtain specific, contextual information about the project and any problems/issues that were encountered during its execution. This helped in the comparative analysis of the two case study projects and to verify the collected cost information.

Results and Findings

The literature review identified a wide array of factors potentially causing estimating errors, thereby affecting the level of accuracy of cost estimates prepared at the early stages of project design for large scale construction projects. The following section provides the results and discussion of the applicability and relevance of these factors and the extent to which they impact the accuracy of cost estimates for small residential building projects.

Accuracy of the Cost Estimate and Influencing Factors on Project A

An analysis of the accuracy of the estimate for Project A was carried out. A comparison between the initial pre-tender estimate and the actual total project cost was conducted by extracting data from the bill of quantities for this particular house design, a breakdown of the initial pre-tender estimate and the final project cost report. Table III shows the percentage deviation of the total project costs from the initial cost estimate for each element of the project.

INSERT TABLE III ABOUT HERE

The cost figures for Project A (Table III), indicate a very accurate estimate overall with less than 1% deviation under the total project cost, however, the percentage differences between individual elements suggest that there may have been factors of uncertainty in the project during estimating, or even discrepancies within the information provided, that have consequently led to cost overruns in some areas. The greatest cost deviation in terms of percentage difference for this project lies in the Internal Joinery and External Drainage & Water Supply and the Provisional Sums components. The Provisional Sums allowance was overly overestimated. The amount of Provisional Sums used on this project was 32.38% less than the amount allowed in the estimate. An overestimation of Provisional Sums is regarded as the better outcome as opposed to an underestimation, as the client will be credited back the remaining balance not used on the job. The allowance for provisional sums was included to cover anticipated rock excavation as the engineer's soil report identified the presence of underground rock.

The element of Internal Joinery for this project reflects the greatest percentage of underestimation when compared to the other elements. This suggests that there may have been discrepancies within the bill of materials on which the estimate was based. The amount allocated for internal joinery in the standard bill of materials may have been outdated. There may have been changes to the kitchen layout from the standard design which had not been correctly adjusted in the estimate. Similar to the element

of frames and trusses, internal joinery is also subcontracted to the lowest tenderer, in which case, market conditions and the level of competition in the market at the time of tender may have also contributed to its large variation. In this instance, the level of underestimation may have been minimised or avoided by obtaining a quote for the work in the initial cost estimate.

External Drainage & Water Supply also reflects a relatively high level of percentage deviation from their actual project costs. The local council requirement for the Gold Coast area requires additional measures for drainage work. It was discovered that these extra measures were not factored into the estimate and which therefore led to their underestimation.

The interviewees were asked questions relating specifically to the level of accuracy achieved in the initial cost estimate of Project A. Their responses indicate that the accuracy of the initial estimate for this project was better than average and within an acceptable accuracy threshold. The interviewees were also asked for their opinion on which factors had the greatest level of uncertainty at the stage of tender preparation. Based on the level of information provided at the time of the estimate, it was believed that one of the most significant factors of uncertainty in terms of construction costs was site conditions. The possibility of underground rock excavation had been identified in the soil report. As this was identified early in the process, a provisional sum allowance was made to cover this work.. The geographic location of the project was not considered to be a factor of cost uncertainty as the organisation had delivered many projects in that area and was quite familiar with the requirements of the location. It was also mentioned that the project type and size were not factors of significant concern because there was sufficient design information to determine a reasonably accurate cost of each element of the building. Due to the organisation using its own standard designs with bills of quantities as a tool for estimating costs, the project type and size were well established very early in the estimating process.

On this project, there had been an increase in the ground floor area, where the estimators were able to cost the changes using square metre rates. Based on the experience of the interviewees, the elements of frames and trusses experience some amount of cost fluctuation which is highly dependent on current market conditions. As this element of work is typically subcontracted to the lowest tenderer, the level of construction activity in the industry and the level of competition have a considerable bearing on the cost.

Accuracy of the Cost Estimate and Influencing Factors on Project B

Similar to Project A, the accuracy of the initial cost estimate for Project B was analysed by comparing the initial pre- tender estimate and the total project cost. This data was taken from the bill of quantities for this particular house design, a breakdown of the initial pretender estimate and the final project cost report.

The total project cost for Project B was 7.9 percent less than the initial pretender cost estimate. This translates to a better job profit margin. The estimate, however, has clearly been overestimated in some areas of work as seen in the breakdown of building elements shown in Table IV. The greatest percentage deviation on this project is in the category of Provisional Sums. This allowance was included in the estimate to account for the possibility of additional site handling costs. As evident from project A, the uncertainty of site conditions in the early stages of a project makes provisional sum allowances difficult to determine. As seen in this instance, the Provisional Sums have been overestimated. However, the percentage difference shown in IV is by no means an indication of the impact of the overestimation in relation to the overall cost estimate. The dollar value of the overestimation was not considered a major cost in relation to the overall cost estimate.

INSERT TABLE IV ABOUT HERE

There were no major building variations for this project, and no structural changes to the standard design. Only minor adjustments had to be made to the standard bill of materials for internal finishes. The project scope had been well established early in the design stage and a sufficient amount of design information was available at the time of tender preparation for the basis of the cost estimate. The geographic location of the project did not pose any concern in relation to cost, as the organisation has built many projects in the area previously and is familiar with its local requirements. The interviewees did not identify any other factors which they believed to be of high uncertainty.

The driveways and paths element is another component which has been significantly overestimated. This element of work is not an item that is included in the standard bill of materials, as the area of driveway will vary for each individual project. Therefore, this element is estimated using a square metre rate. From the above, it suggests that either the square metre rate is incorrect and needs to be adjusted, or the area of driveway had been miscalculated. In such instances of overestimation, it may even be the case that the square metre rate includes a buffer to avoid the risk of underestimating. Although a higher margin has been achieved by overestimating the project costs, there is a risk that the tenders for jobs may be lost in other situations where this occurs. Aside from the provisional sums and driveway elements, there is no significant degree of deviation in the other elements.

Responses from the interviews in relation to Project B indicate that the level of accuracy achieved in the initial cost estimate was also within an acceptable accuracy threshold. When the interviewees were asked for their opinion on which factors had the greatest level of uncertainty during tender preparation, the most common response was site conditions. Due to the building being situated on a narrow site, there was a possibility of additional costs for site/material handling issues. A provisional sum allowance was included in the initial cost estimate to address this potential issue. Another point that was raised during the interview was the effects of weather on the cost of the project. Rainy and stormy weather conditions were expected during the construction period of Project B. As such, a notable amount of extra cost was anticipated for the slab pour in order to accommodate the wet conditions.

Methods of Estimating

The literature review identified various methods used in early stage price forecasting. It is common practice for cost consultants to take the overall price per square metre of floor area of a comparable building as a starting point then adjust it to suit the anticipated value. However, this is dependent on the availability of suitable historical cost data. Responses from the interviews suggested that historical cost data is readily available and was used in the preparation of the pretender estimate.

As mentioned previously, the method of estimating adopted by the developer in this study involves the use of bill of quantities to establish a base cost for standard house designs. Variations and design changes are adjusted and added to the base cost. Variations may include: structural alterations, upgrades to internal or external finishes, and/or necessary site requirements. The interviewees suggest that this method is accurate and efficient (Table V). Also noted by the interviewees was that their organisation offered only standard house designs and construction, there was little room left for making design errors and dealing with uncertainty in terms of project size and scope. As such, the developer uses an established bill of quantities for each standard house design and not just the overall

square metre rate. However, any significant increase in floor area to a standard house design is estimated by using the square metre rate of the relevant bill of quantities for that design.

INSERT TABLE V ABOUT HERE

Estimator's Experience Level

The literature review stated that cost estimation is an experience-based process and the experience of the estimator preparing the estimate has a significant influence on accuracy. The primary data used for evaluating this proposition was obtained solely from the interview responses. These consisted of opinions from estimators with experience ranging from two to seven years. The majority of the estimators suggested that the level of accuracy achieved was high and that the amount of experience in their current role had a substantial bearing on the outcome. The ability to extrapolate information based on limited design data was suggested as a skill that had been developed over the years in their current role. A number of interviewees indicated that their trade background experience in their previous roles had provided them with the skill of anticipating potential on-site construction issues that may have an effect on the total project cost. The ability to estimate provisional sum allowances was also noted as a valuable skill that had been developed with experience.

The estimator's experience grows with diverse range of experiences gained from working on multiple projects. It was mentioned that one could be a great quantity surveyor or estimator after about 15 years of experience. However, as estimators acquire more experience, it is likely that they would tend to become more adamant with their knowhow and less likely to adopt new and innovative measurement programs and cost estimating techniques.

Contingencies

The literature review identified a problem of exaggeration of the contingency factor of a project. The results from the two case studies shed light on the level of contingency typically used for smaller scale residential projects in a local context and the extent of the exaggeration involved.

A provisional sum allowance was included in the contract price of *Project A* for rock excavation and additional earthworks. This allowance has been determined by the estimator upon the engineer's soil report which indicated underground rock that could have potentially required excavation. In this case, historical data was extremely valuable. The estimator was able to refer to a previous project with similar soil conditions as an indication of the extra costs required. Typically, the value of the provisional sums for rock excavation is determined by taking into account the depth of the rock identified on the engineer's soil report. However, as evident on project A, even for an experienced estimator, the provisional sums allocation proves difficult to estimate. Due to the extent of the issue being unknown, the estimated value of the rock excavation was overestimated by approximately 49.58% as seen in Table IV.

In the case of *Project B*, the provisional sums allowance included in the estimate was for the potential site and material handling costs due to the narrow block on which the proposed house was to be built. The estimate was based on previous experience on which additional costs were incurred to hire a crane to handle materials and the need for additional concrete pump hire for pouring non-integral concrete slabs at the rear end of the property where access is narrow. Although most of the provisional sum was not used, it was a necessary 'just in case' inclusion in the estimate. There is often ambiguity surrounding the decision of provisional sums allowances in such instances as each project varies in nature and the nature and extent of site conditions are often not fully known until the project is well

past the initial estimate stage. It is often the subcontractor who dictates the extent of the costs incurred, which can vary dramatically from project to project.

Conclusions

This research aimed, with information collected from two small scale residential building projects in South East Queensland, to explore some specific factors affecting the accuracy of developers' cost estimates in the early stage. The study showed that many of the factors mentioned in the literature were not as apparent or applicable on the studied projects. This may have been partly due to the operational nature of the organisation and its method of estimating, which rules out many of the factors simply due to the level of design information that is available at the time of estimating – a situation rarely encountered on larger scale projects. That the organisation specialises in project homes also removes many factors of uncertainty that are often experienced with architecturally designed custom-built homes. The only factor that was consistent in both of the case studies was the uncertainty of site conditions. As seen from the analysis, provisional sums had been included for both projects, and in each case, they were both overestimated substantially in terms of percentage deviation.

From the results of this study, it is evident that there were indeed estimating inaccuracies although, however, the accuracy of the estimates produced are still believed by the involved estimators to be within an acceptable threshold. Project A was underestimated by a small percentage margin and was not deemed significant enough to upset the overall project profit margin. Project B, however, was overestimated, which resulted in greater profit margin. These inaccuracies had stemmed from a combination of factors such as unknown site conditions, experience level of estimators, market conditions, provisional sums allocation and their rationale, and the suitability of historical cost data. Due to the nature of the residential construction projects undertaken by the organisation involved, many of the factors of project uncertainty identified in the literature were not found to be as relevant to residential construction. In comparison to larger scale projects, small scale and less complex standard residential construction have a greater level of certainty and completeness of project information for factors such as design information, project scope/size, construction methods and location/site specific factors.

The body of literature emphasises the importance of having suitable historical data as a basis for the estimate. For most commercial scale projects, the square metre rates of a similar building are often used to create a basis for the estimate in the early stage of a project. This was not applicable to the reported case study projects, as the estimates for both projects were based on historical data generated from standard bills of materials and prepared by a developer. A major problem that is mentioned in the literature is that lowest tenders of previous jobs are commonly used as a benchmark, which may reflect very different market conditions and specific site conditions to the proposed project. This problem is not inherent on developers' smaller scale residential projects where pre-established and suitably priced bills of materials are used and regularly updated to reflect changes in material or labour costs. Due to design and other project-specific information being available to estimators early on, the estimators did not use square metre rates. However, they are still used in situations where projects have a significant increase in floor area from the standard design.

Furthermore, the contingency factor had little relevance to the studied projects. As stated in the literature, a contingency factor is usually included in the estimate to account for potential risks and uncertainties that may be encountered on a project. This is normally the consultants' practice for large scale commercial projects. This is not however usually the case for developers' small scale residential project homes. A contingency amount is included into an estimate when the risk or uncertainty factor is not yet clearly defined, and is used to account for any issues that may incur additional costs which may not be apparent at the early stages of estimating. While many project level uncertainties were clearly addressable in the studied projects, a provisional sum amount was included in the estimate to account for some of the unknown factors or variations. Any remaining or unused provisional sums

after the completion of the project, is credited back to the client. Due to the nature of the studied projects and the level of information available at the early stages of design, contingency amounts were not applicable in these circumstances.

The availability of complete project and design information enabled the organisation involved to use standard bills of quantities as an estimating method on their projects. Such information is not generally available in the early stages of larger scale projects. By using standard bills of quantities for standard house designs as a base rate, any variations to the standard are easily calculated and factored into the estimate. While this may be an effective method of estimating, it is only possible due to the nature of the projects that the organisation undertakes. Larger construction projects and even architecturally designed custom built houses will rarely have the same level of design completion and project specific information available at the time the initial estimate is required.

The standard bills of quantities method is an efficient method for standard house designs. However, it needs to be utilized and supported with the expertise and experience of the estimator, which is seen to have a significant impact on the estimate accuracy. The estimators' experience and expertise is therefore crucial for a successful project. The estimators acknowledged that the skills that they had developed in their current roles, as well as their experience in previous roles, had contributed to the accuracy of their estimates. There is a potential to improve the accuracy of cost estimates, particularly for residential construction projects. Since this study focused on only two projects undertaken by a single organisation operating in the region, it is suggested that further research should be conducted on other projects by different organisations in order to add to the credibility of this study.

References

- Aamodt, A., Plaza, E. (1994), "Case-based reasoning: Foundational issues, methodological variations, and system approaches", *AI communications*, Vol. 7, pp.39-59.
- Ahiaga-Dagbui, D.D. and Smith, S.D. (2014), "Rethinking construction cost overruns: cognition, learning and estimation", *Journal of Financial Management of Property and Construction*, Vol. 19 No. 1, pp. 38-54.
- Aibinu, A.A. and Pasco, T. (2008), "The accuracy of pre-tender building cost estimates in Australia", *Construction Management and Economics*, Vol. 26 No.12, pp. 1257-1269.
- Akintoye, A. (2000), "Analysis of factors influencing project cost estimating practice", *Construction Management & Economics*, Vol. 18 No. 1, pp. 77-89.
- Alex, D.P., Al Hussein, M., Bouferguene, A. and Fernando, S. (2010), "Artificial neural network model for cost estimation: City of Edmonton's water and sewer installation services", *Journal of Construction Engineering and management*, Vol. 136, No.7, pp.745-756.
- Arditi, D. and Tokdemir, O.B. (1999), "Comparison of case-based reasoning and artificial neural networks", *Journal of Computing in Civil Engineering*, Vol. 13, No. 3, pp.162-169.
- Arditi, D., Alnajjar, A. and Vingert, N.. (2002), "Construction cost estimating support system", *Cost Engineering*, Vol. 44 No.10, pp. 17-25.
- Azman, M.A., Abdul-Samad, Z. and Ismail, S. (2013), "The accuracy of preliminary cost estimates in Public Works Department (PWD) of Peninsular Malaysia", *International Journal of Project Management*, Vol. 31 No.12, pp. 994-1005.
- Barnes, N.M.L. (1974), "Financial control of construction" in: S.H.Wearne. (Ed.), *Control of Engineering Projects*. Edward Arnold.

- Bode, J. (2000). "Neural networks for cost estimation: Simulations and pilot application". *International Journal of production Research*, Vol 38, pp. 1231–1254.
- Chau, K.W. (1997), "Monte Carlo simulation of construction costs using subjective data: response", *Construction Management and Economics*, Vol. 15 No. 1, pp. 109-115.
- Cheng, M.-Y., Tsai, H.-C. and Sudjono, E. (2010), "Conceptual cost estimates using evolutionary fuzzy hybrid neural network for projects in construction industry", *Expert Systems with Applications*, Vol. 37 No. 6, pp. 4224–4231.
- Chou, J.S. (2009), "Web-based CBR system applied to early cost budgeting for pavement maintenance project", *Expert Systems with Applications*, Vol. 36 No. 2, 2947–2960.
- Chou, J.-S. and Tseng, H.-C. (2011), "Establishing expert system for prediction based on the project-oriented data warehouse", *Expert Systems with Applications*, Vol. 38 No.1, pp. 640-651.
- Dominic D. Ahiaga-Dagbui, D. D. and Smith, S. D. (2014), "Rethinking construction cost overruns: cognition, learning and estimation", *Journal of Financial Management of Property and Construction*, Vol. 19 No. 1, pp. 38-54.
- Duran, O., Rodriguez, N. and Consalter, L.A. (2009), "Neural networks for cost estimation of shell and tube heat exchangers", *Expert Systems with Applications*, Vol. 36 No. 4, pp. 7435–7440.
- Dysert, L. (2007), "Is estimate accuracy an oxymoron?", *Cost Engineering*, Vol. 49 No.1, pp. 32-36.
- Elhag, T.M.S., Boussabaine, A.H. and Ballal, T.M. A. (2005), "Critical determinants of construction tendering costs: Quantity surveyors' standpoint", *International Journal of Project Management*, Vol. 23 No. 7, 538-545.
- Fellows, R. (1996), "Monte Carlo simulation of construction costs using subjective data: comment", *Construction Management and Economics*, Vol. 14 No. 5, pp. 457-460.
- Flanagan, R., & Norman, G. (1983), "The accuracy and monitoring of quantity surveyors' price forecasting for building work", *Construction Management and Economics*, Vol. 1 No. 2, pp. 157-180.
- Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. (2003), *Megaprojects and risk: An anatomy of ambition*. Cambridge University Press.
- Flyvbjerg, B., Holm, M. S. and Buhl, S. (2002), "Underestimating costs in public works projects: Error or lie?", *Journal of the American planning association*, Vol. 68 No. 3, pp. 279-295.
- Gunner, J. and Skitmore, M. (1999), "Comparative analysis of pre-bid forecasting of building prices based on Singapore data", *Construction Management and Economics*, Vol. 17 No. 5, pp. 635-646.
- Hong, T., Hyun, C. and Moon, H. (2011), "CBR-based cost prediction model-II of the design phase for multi-family housing projects", *Expert Systems with Applications*, Vol. 38 No. 3, pp. 2797–2808.
- Ji, C., Hong, T. and Hyun, C. (2010), "CBR revision model for improving cost prediction accuracy in multifamily housing projects", *Journal of Management in Engineering*, Vol. 26 No. 4, pp. 229–236.
- Kim, G.-H., An, S.-H., Kang, K.-I. (2004), "Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning", *Building and Environment*, Vol. 39 No. 10, pp. 1235-1242.

- Kim, H.-J., Seo, Y.-C., & Hyun, C.-T. (2012), "A hybrid conceptual cost estimating model for large building projects", *Automation in Construction*, Vol. 25, pp. 72-81.
- Kim, K.J., Kim, K. (2010), "Preliminary cost estimation model using case-based reasoning and genetic algorithms", *Journal of Computing in Civil Engineering*, Vol. 24 No.6, pp. 499-505.
- Kim, S.-Y., Choi, J.-W., Kim, G.-H. and Kang, K.-I. (2005), "Comparing cost prediction methods for apartment housing projects: CBR versus ANN", *Journal of Asian Architecture and Building Engineering*, Vol. 4 No.1, pp. 113-120.
- Koo, C., Hong, T., Hyun, C. and Koo, K. (2010), "A CBR-based hybrid model for predicting a construction duration and cost based on project characteristics in multi-family housing projects", *Canadian Journal of Civil Engineering*, Vol. 37 No. 5, pp. 739-752.
- Leung, M., Ng, T., & Skitmore, M. (2005). "Critical stressors influencing construction estimators in Hong Kong". *Construction Management and Economics*, Vol. 23, No. 1, pp. 33-43.
- Li, H., Shen, Q. and Love, P.E. (2005), "Cost modelling of office buildings in Hong Kong: an exploratory study", *Facilities*, Vol. 23 pp. 438-452.
- Ling, Y.Y. and Boo, J.H.S. (2001), "Improving the accuracy estimates of building of approximate projects", *Building Research and Information*, Vol 29 No. 4, pp. 312-318.
- Lowe, D.J., Emsley, M.W. and Harding, A. (2006), "Predicting construction cost using multiple regression techniques", *Journal of Construction Engineering and Management*, Vol. 132 No. 7, pp. 750-758.
- Mak, S. and Picken, D. (2000), "Using risk analysis to determine construction project contingencies", *Journal of Construction Engineering and Management*, Vol. 126 No. 2, pp. 130-136.
- Mak, S., Wong, J. and Picken, D. (1998), "The effect on contingency allowances of using risk analysis in capital cost estimating: a Hong Kong case study", *Construction Management and Economics*, Vol. 16 No. 6, pp. 615-619.
- Morrison, N. (1984) "The accuracy of quantity surveyors' cost estimating", *Construction Management and Economics*, Vol. 2 No.1, pp. 57-75.
- Oberlender, G. and Trost, S. (2001). "Predicting accuracy of early cost estimates based on estimate quality", *Journal of Construction Engineering and Management*, Vol. 127 No. 3, pp. 173-182.
- Ogunlana, S., & Thorpe, A. (1991), "The nature of estimating accuracy: Developing correct associations". *Building and Environment*, Vol. 26 No. 2, 77-86.
- Serpell, A. F. (2004), "Towards a knowledge-based assessment of conceptual cost estimates", *Building Research and Information*, Vol. 32 No. 2, pp. 157-164.
- Skitmore, M. (1985), *The influence of professional expertise in construction price forecast*. Salford: University of Salford Department of Civil Engineering.
- Skitmore, M. (1987a), "The effect of project information on the accuracy of building price forecasts", *Building Cost Modelling and Computers*, pp. 327-336.
- Skitmore, M. (1987b), *Construction prices: the market effect*. University of Salford Environmental Resources Unit Salford, United Kingdom.
- Skitmore, M., and Stradling, S., Tuohy, A. and Mkwezalamba, H. (1990), *The accuracy of construction price forecasts*. Technical Report, Department of Surveying, University of Salford.

- Skitmore, M., Patchell, B. (1990), "Developments in contract price forecasting and bidding techniques", in Brandon. P. S. (Ed.), *Quantity surveying techniques: New directions*, Blackwell Scientific Publications, pp.75-120.
- Stoy, C., Schalcher, H.-R. (2007) "Residential building projects: building cost indicators and drivers", *Journal of Construction Engineering and Management*, Vol. 133 No. 2, pp. 139-145.
- Trost, S. and Oberlender, G. (2003), "Predicting accuracy of early cost estimates using factor analysis and multivariate regression", *Journal of Construction Engineering and Management*, Vol. 129 No.2, pp. 198-204.
- Tseng, C., Zhao, T. and Fu, C. (2009), "Contingency estimation using a real options approach", *Construction Management and Economics*, Vol. 27 No.11, pp.1073-1087
- Wang, H.S., Wang, Y.N. and Wang, Y.C. (2013), "Cost estimation of plastic injection molding parts through integration of PSO and BP neural network", *Expert Systems with Applications*, Vol. 40 No. 40, pp. 418–428.
- Williams, T., Lakshminarayanan, S. and Sackrowitz, H. (2005), "Analysing bidding statistics to predict completed project cost." In *Proceedings of the International Conference on Computing in Civil Engineering*, Cancun, Mexico, pp. 1-10.
- Wilmot, C.G., Mei, B. (2005), "Neural network modelling of highway construction costs", *Journal of Construction Engineering and management*, Vol 131, No. 7, pp. 765–771.
- Xu, L.D. (1994), "Case based reasoning". *Potentials, IEEE*, Vol. 13 No. 5, pp. 10-13.
- Yeung, D. and Skitmore, M. (2012), "A method for systematically pooling data in very early stage construction price forecasting", *Construction Management and Economics*, Vol. 30 No. 11, pp. 929-939.

Table I. Factors Key to Construction Cost Estimate Accuracy

Environmental Factors	Project Specific Factors
<ul style="list-style-type: none">• Market Conditions• Number of Bidders• Reduction of Supply• Financial Uncertainty• Good/Bad Years• Level of Construction Activity• Weather Conditions	<ul style="list-style-type: none">• Project Type/Size• Project Duration• Type of Contract• Geographic Location• Design Data• Complexity of Project• Site Conditions

Table II. Case Study Projects Profile

Project Characteristics	Case Study Project A	Case Study Project B
Building	Double Storey Residential Dwelling	Single Storey Residential Dwelling
Construction Type	Brick Veneer/Timber Cladding	Brick Veneer/Timber Cladding
Size (GFA)	300m ²	300m ²
Location	Jimboomba, Gold Coast	Underwood, Brisbane
Project Duration	11 months approx.	11 months approx.

Table III. The Deviation of Actual Cost and Estimated Cost on Project A

Project Element	Percentage Difference between the Estimated Cost and Actual Cost
Site Preparation	15.14
External Drainage & Water Supply	28.85
Gas Service	21.13
Scaffold	-7.58
Concrete	4.41
Frame & Trusses	-19.85
Upper Floor	1.40
Roof	6.37
Staircases	11.19
Structural Steel	-16.63
Brickwork	-11.17
External Cladding	-12.87
Windows	5.33
Doors	5.31
Sanitary Plumbing & Fixtures	0.78
Internal Wall & Ceiling Linings	0.62
Internal Joinery	72.47
Internal Fixtures	-7.30
Internal Wall/Floor Finishes	-2.18
Electrical & Lighting	-7.70
Paint	10.93
Waterproofing	5.05
Driveways & Paths	-17.61
Provisional Sums	-32.38
Total Project Cost	0.47

Table IV. The Deviation of Actual Cost and Estimated Cost on Project B

Project Element	Percentage Difference between the Estimated Cost and Actual Cost
Site Preparation	0.34
External Drainage & Water Supply	6.75
Gas Service	0.00
Scaffold	9.42
Concrete	-4.63
Frame & Trusses	-10.51
Upper Floor	-2.13
Roof	3.33
Staircases	0.00
Structural Steel	0.06
Brickwork	-6.31
External Cladding	-7.81
Windows	-6.35
Doors	4.89
Sanitary Plumbing & Fixtures	16.46
Internal Wall & Ceiling Linings	0.90
Internal Joinery	-1.01
Internal Fixtures	-5.29
Internal Wall/Floor Finishes	13.78
Electrical & Lighting	-1.63
Paint	7.17
Waterproofing	-3.10
Driveways & Paths	-27.56
Provisional Sums	-49.58
Total Project Cost	-7.91

Table V: Suitability of Historical Cost Data

Statement	Level of Agreement				
	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Historical cost data was an important factor in the preparation of the pre-tender estimate.	4	6	0	0	0
The cost data used for the preparation of the pre-tender estimate was reliable.	2	5	3	0	0
The method of estimating adopted by the organisation is accurate and efficient	1	6	2	0	0