Accuracy of estimating techniques for predicting residential construction costs – a case study of an Auckland residential construction company

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ABSTRACT

Estimating is one of the most important functions of a successful project. Accurate estimates optimise good contracting as well as the process of calculating and analysing all the costs that will enter into a particular job to arrive at a set total. The estimator is responsible for these estimates which serve to ensure the project will have a successful financial outcome and these estimates also influence the decisions made for budgeting and assist in clients' decisions for contractor selection.

This research will determine the current practice of a case study company's accuracy in estimation and will also identify the associated issues with the preparation of the estimates which can lead to inaccuracy.

The methodology for this research has been a triangulation from an extensive literature survey review and analysis, then followed by a document analysis of the case study company's project accuracy over the last 5 years and then analysis which is an interpretation of the author's understanding.

The findings have indicated that there are inaccuracies which can be from a range of factors identified in the literature as crucial indicators for deviations from the intended budget. This includes for the selection of provisional sum expenditures, historical data validity, factors affecting the accuracy of the estimate and model house base rate.

The conclusions that have been drawn are that there is only one method of estimation being used in the case study company and when a house becomes an architecturally design house, the model house base rate seems to become invalid completely. The historical data is not being regularly updated with feedback processes and the learning curve of the estimator reviewing each project after completion seems to be limited as the inaccuracies are being carried forward onto the new projects. The estimator's judgement is identified in the literature as one of the most important factors to estimation; however, the data collected indicated that an inexperienced estimator has made decisions that have resulted in ramifications.

Keywords: Estimation, accuracy of estimating, estimating techniques, factors affecting accuracy, historical data, feedback processes, construction costs

CONFIDENTIALITY STATEMENT

The author of this report has agreed that all project names and the case study company's name will be kept confidential. This has been made possible by replacing the project names with Project 1, Project 2, Project 3, etc.

The information gathered during this study is under the sole ownership of the researcher, and access to the information has been limited to the researcher and the supervisor.

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LIST OF ABBREVIATIONS

GFA – Gross Floor Area

QS – Quantity Surveyor

GST – Goods and Services Tax

P & G – Preliminaries and General

1.0 INTRODUCTION

This report looks at the accuracy of estimating techniques used when predicting construction costs in the Auckland region. The report sets a focus on the techniques estimators use to predict costs and how accurate residential construction estimators are with their estimating.

1.1 BACKGROUND

The proposed research will focus on estimation technique accuracy when predicting construction costs in the construction industry.

Estimating is one of the most important functions of a successful project. Accurate estimates optimise good contracting as well as the process of calculating and analysing all the costs that will enter into a particular job to arrive at a set total. In nearly all contract types, the preparation of a realistic cost estimate is a necessary part of any construction project. Estimating is the process of calculated guessing by looking into the future costs of a project before work on it has begun. It occurs before construction has started, and even before tendering for the construction project starts. The estimator or the quantity surveyor is responsible for these estimates which serve to ensure the project will have a successful financial outcome. These estimates also influence the decisions made for budgeting and assist in clients' decisions for contractor selection.

1.2 RATIONALE

There have been previous studies on the accuracy of estimating construction costs in countries such as Australia, Nigeria, Gaza Strip, Pakistan, Germany, Saudi Arabia, and Singapore; however, no such research has been done in New Zealand. The research carried out overseas shows that estimating in many countries follows the same principles that apply in New Zealand; however, some of the methods and construction procurement paths differ. Also, many of the international studies investigate the construction industry as a whole and do not focus on specific components. In this study, the residential construction sector has been selected as the focus of an in-depth investigation of the techniques employed by a case study company in order to check the accuracy of estimating in New Zealand.

This research plans to:

- Undertake a study of the current estimating techniques in an Auckland residential construction company;
- Compare the results of the study with findings in the literature and discuss any similarities or differences; and
- Improve the estimator's ability to calculate construction costs with the best accuracy possible.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provides a literature review which looks at the estimating techniques for predicting residential construction costs and identifies how accurate these techniques are. Supporting literature will be provided for the following research question:

How accurately do estimating techniques used in New Zealand residential construction predict actual construction costs?

Key points have been identified from the literature and will be expanded on in the following sections:

- Definition of estimating
- Definition of accuracy
- Purpose of cost estimating
- Forms of estimating
- Use and/or Value of historical data
- Factors affecting the accuracy of estimating
- Feedback and review of accuracy

2.2 DEFINITION OF ESTIMATING

The estimated cost of a work is a close forecast of what the actual cost should be. The difference between the estimated cost and the actual costs will depend on accurate use of estimating methods. The forecast accuracy varies with each type; it can range from a detailed estimate, which needs to be very close, to a conceptual estimate which is a 'ballpark figure' from which budgets are formed.

Estimating has been interpreted differently by various industry professionals. Akintoye (2000, p 77) describes estimating as a process of predicting costs that are required for the completion of the work. "Cost estimating can be described as the technical process or function undertaken to assess and predict the total cost of executing an item(s) of work in a given time using all available project information and resources."

Morrison (1984, p 58) defines a quantity surveyor's estimate as the deviation from the lowest acceptable tender received in competition for the project. However, he then proceeds to describe estimates for scheme plans prepared in the early design stage that go unaltered before the invitations for tenders are sent out. In this case, the lowest tender bid cannot be realistically compared with the estimate as the tender is for a different (updated) plan. This makes the decisions — made by the quantity surveyor's ability to measure estimated performance against lowest tenders — reliant on the variability of the lowest tenders.

Enshassi, Mohamed, and Madi (2007, p 4) explain that estimating is an important step in the construction process as the reliability of its estimate accuracy — from conceptual to detailed stages — determines the success or failure of a project. Similarly, Odusami and Onukwube (2008, p 1) explain that estimating cannot be a precise technical and analytical process, but to an extent, is a subjective process where estimators consider factors relevant to the successful completion of a project. Therefore, estimating in this sense is not based on the science of construction forecasting, but on the experience and decisions the estimator makes regarding factors that may influence the estimate when areas of uncertainty are evident. Furthermore, Odusami and Onukwube (2008, p 1) also describe estimating for construction projects as an estimate of the market price that is made up of quantities that may exist previously, currently, or even after the event under consideration.

However, Aibinu and Pasco (2008, p 1257) do not describe the estimating process as a single process, but as a cost-predicting exercise during the preliminary stage that comprises two aspects: *bias* and *consistency.* The first aspect, *bias*, can be described as the mean difference between actual tender price and the predicted one; whereas the second aspect, *consistency*, is described as the degree of variation around the mean (the average).

Subsequently, all of the above definitions similarly describe cost estimating as being the process of calculated guessing based on a look into the future costs of a project or product prior to its commencement. Estimates are an approximation, and judging by the theories discussed in the literature, will include uncertainty regardless of their form.

2.3 Definition of accuracy

The accuracy of an estimate can be assessed in different ways depending on whether the figure for comparison is the tender, end product, or budgeted item. It is the degree to which a measurement or calculation deviates from its actual price; therefore, estimating accuracy is an indication of the degree to which the final price outcome of a project may vary from the single point value used as the estimated cost of the project (Dysert, 2006, p 2). This level of accuracy is influenced by factors which may be direct or indirect, and it is crucial to compare the estimate with other projects of a similar magnitude and type for comparison of value in order to set parameters of possible influences.

General accuracy is always important as figures outside of the range of estimated prices can be deemed useless and dangerous. Early stage forecasts for engineering and construction projects are extremely important to the client, contractor, and project team (Oberlender & Trost, 2003, p 199). Early stage estimates are vital for business unit decisions that include strategies for asset development, potential project filtering, and labour and plant commitment for future projects. For the project team, the performance and overall success will most likely be measured and assessed on the capability of actual costs to compare with the early cost estimate. Inaccuracies in early estimates can point to lost opportunities, inefficient development effort, and dropped expectation of returns.

Liu and Zhu (2007, p 94) state that the accuracy level of cost estimates at the pre-tender stage is one of the most crucial indicators of effective estimation. In the case of underestimating, the client may get an unpleasant shock when the tenders are drastically modified upwards. If the estimate is an overestimation, then the estimator may lose the job or lose the client's confidence. In theory, this statement demonstrates that the fine line between the overestimate and underestimate is what the estimator is aiming for.

Morrison argues that it is impossible to measure performance at any stage of the design process other than the tender stage. Therefore, accuracy is deemed to be the variation of the initial estimate from the lowest acceptable tender bid. "Accuracy of an estimate is measured by deviation from the lowest acceptable tender received in competition for the project" (Morrison, 1984, p 58). This is not the lowest tender bid, but the lowest acceptable one; as with tenders, there are notes, exclusions, inclusions, and conditions which can alter the decision for acceptance.

Oberlender and Trost (2003) state that the accuracy of an estimate is dependant on the following:

1. Who was involved in preparing the estimate,
2. How the estimate was prepared,
3. What was known about the project, and
4. Other factors considered while preparing the estimate.

2.4 PURPOSE OF COST ESTIMATING

Ashworth (2004, p 264) states that the purpose of estimating is to indicate probable construction costs. This is an important factor that clients consider when deciding to build; it determines the feasibility of a project, or even provides the basis for budget control during tendering and construction. Estimating is used to encourage the client to push forward with the scheme design of a project, and to get detailed working drawings drawn up; however, if the estimate is excessive, it can steer the client away from the opportunity. Alternatively, if the estimated costs are too low, it can result in an aborted design, losses, or even litigation from the client.

Estimates are an excellent basis for negotiation as they set the benchmark for the costs that are expected. "Over-estimating or over-provision of funds for one project means fewer funds are available for other business opportunities. Estimates form the basis for tender comparison or negotiation" (Odusami and Onukwube, 2008, p 1). If the negotiation for a trade is taking place and no estimate has been made, the certainty that comes with defending an estimator's negotiation is lost.

As an estimate is an indicator of construction costs, the client can use it as an indicator of probable costs from the early stages of construction in order to monitor costs and the project's budget. It can also serve as a tool to enable the client to evaluate the tender process and determine the most competitive bid.

Essentially, the estimate is intended to look into the future and create a cost which will continue to be feasible and adequate at the time the project is completed. "The aim of construction price forecasting is to provide an estimate of the market price of construction contracts. The estimates may be for an individual or for groups of past, present, or future projects entering the contract market" (Skitmore, 1990).

In summary, the purpose of cost estimation is to produce an accurate and reliable cost estimate of a construction project. To achieve this, the estimator must keep in mind all the factors affecting the estimate and be careful to neither over- nor under-estimate.

2.5 FORMS OF COST ESTIMATING

The types of estimates are varied by several factors imposed on the estimate: its purpose, how much detail is known about the project, and how much time and effort is to be spent in preparation of the estimate.

Ashworth (2004, p 265) lists and classifies these different types of estimating as:

- Preliminary: an initial estimate to establish a benchmark for the project
- Feasibility: to decide whether the project should proceed
- Viability: similar to feasibility, an investigation of the project
- Authorisation: a final cost plan which includes construction detailing
- Final budget: a form of cost-checking the initial budget intended for the project
- Control: during the construction stage, during the execution of work to check progress.

Clough (1986, p 37) classifies construction estimating into two major types according to their functions:

- Conceptual (Preliminary) Estimates
- Detailed (Definitive) Estimates

2.5.1 CONCEPTUAL (PRELIMINARY) ESTIMATE

A conceptual or preliminary estimate is the first significant form of estimating made to attempt to predict the future costs of the project. Also known as "top-down, order of magnitude, ballpark, feasibility, quickie, analogous, pre-design estimate, or preliminary estimate" (Clough, 1986, p 38), a conceptual estimate is usually performed as part of the feasibility analysis at the start of a project. At this time, the estimate is created with minimal data on the project scope, and is usually made without detailed design and specifications.

Therefore, the accuracy of the estimate has a higher fluctuation (lower accuracy) than of a detailed estimation (Choon, 2008, p 69).

Hendrickson (2000, p 148) states, "a preliminary estimate or conceptual estimate is based on the conceptual design of the facility at the state when the basic technologies for the design are known." A conceptual estimate is intended to provide the client with an indicative cost of the project before making the decision to take the project to the next stage. The preparation of the conceptual estimate requires a clear understanding of the client's requirements in order to make sure that the client is expecting the costs.

2.5.2 DETAILED (DEFINITIVE) ESTIMATES

A detailed estimate, also known as a bid estimate or a quantity takeoff, needs to have substantial detail in order to get the quantities which are otherwise not available in a preliminary or conceptual estimate. These quantities are used against costs; indirect costs such as plant, equipment, overheads, profit, escalation, and contingency are then added.

Choon (2008, p 69) describes detailed estimating as an "analysis of the method of construction to be used, the quantities of work, the production rate of resources, and the factors that affect each sub-item. The key to the quantity take-off is a structured work breakdown with a proper code of accounts for all work items." Dysert (2003, p 28) expresses the same point of view — that a detailed estimate is made up of components of a project scope that is quantified and priced using the most realistic unit prices available. Furthermore, detailed estimates are ideally formed to facilitate the final budget authorisation, bid tenders, and cost control during the project construction. Also, detailed design is critically dependant upon the completeness of the design. If engineering plans or other important information is missing, the scope of the items covered will not be included in the estimate, and this will result in going back to the use of a conceptual estimate.

Hendrickson (2000, p 156) states that "a detailed estimate is created when the scope of work is clearly stated and a more detailed design is in progress so that the essential features of the building are visible," Essentially, this says that a detailed estimate is carried out after the conceptual design has been approved and approximate quantities are supplemented by detailed estimates.

2.6 USE / VALUE OF HISTORICAL DATA

The accuracy of construction costs are extremely dependant upon the source of quality historical data and the amount of expertise possessed by the estimator. The limited information available at the early stage of the project may indicate that the quantity surveyor/estimator must make assumptions about design details of the dwelling which may not eventuate as the design, planning, and construction progress (Liu and Zhu, 2007, p 98).

"The accuracy of pre-tender building cost estimates are not improving over time" (Aibinu and Pasco, 2008, p 1265). This can be based upon the estimates of new projects being created from historical data from previous projects. Therefore, over time, the inaccuracies of the past projects are transferred to the new estimates.

Conceptual estimation methods are dependant upon having historical cost information on which the estimates are based (Dysert, 2005, p 5). Dysert explains that for estimation historical information is encompassed by the following methods:

- Capacity factors
- Parametric estimating models
- End product unit costs
- Analogy

Conceptual estimating methods are characterised as requiring considerable effort in data collection, data analysis, and estimating methods before the preparation of the estimate even begins. The preparation of the estimate takes very little time, but the collation of historical data is a lengthy process and is only useful if updated and monitored regularly. Dysert goes on to explain that historical information is only useful to some extent and where new technology, construction methods, or an unknown factor is encountered, the reliability of the historical data becomes void. In these cases, the expertise of the estimator should determine the best alternative way to find a cost.

Typically, historical data is very useful and seems to be used for a number of estimating methods. However, the viability of the historical data is only useful to some extent, and can only be used for repetitions of work already done. New items which have not been previously encountered stand outside the reach of the historical data.

2.7 FACTORS AFFECTING THE ACCURACY OF ESTIMATING

Factors that affect accuracy of estimating come from a large range of categories where sometimes are very difficult to counter. Liu and Zhu (2007, p 99) categorise the factors that influence the cost of a project as control factors and idiosyncratic. Control factors are those that can be determined by the estimators to increase the performance of the estimation. Idiosyncratic factors are factors that affect estimation but are outside the control of the estimator; this includes the following:

- Market conditions,
- Project complexity,
- Weather,
- Size of contract,
- Type of client,
- Site constraints,
- Resource availability, etc.

Elhag, Boussabaine, and Ballal (2005, p 541) state "the most significant factors affecting project costs are qualitative such as client priority on construction time, procurement methods, and market conditions including the level of construction activity." This shows that the most significant and considerable influences are indeed the idiosyncratic factors as described by Liu and Zhu (2007), as these are out of the control of the estimator.

Dysert (2006, p 5) mentioned that there are many factors which influence the estimate accuracy; i.e. the level of project scope, quality of the data, quality of the assumptions, the experience and expertise of the estimator, techniques used, effort put into the preparation of the estimate, and the market conditions. Other factors that are indirectly related to the estimate but still have an influence are the ability to control the project and the ability to make changes in the estimate for progression in the scope. The biggest factor that influences project cost estimating practice is complexity of design; this is followed closely by the scale and scope of construction (Akintoye, 2000, p 78).

Odusami and Onukwube (2008, p 34) identified and studied the influences that affect the accuracy of pre-tender cost estimation. These included:

- Expertise of the estimator
- Quality of information
- Project teams experience
- Tender period
- Market conditions
- Design detail
- Complexity of design
- Availability of labour and materials

Table 1 has been constructed from an analysis of the literature to show the similarity in discussion for the factors that affect the accuracy of estimating.

Table 1: Distributing the factors according to the references

No	Factors	Odusami and Onukwube (2008)	Dysert (2006)	Elhag (2005)	Liu and Zhu (2007)	Enhassi and Mohamed and Madi (2007)	Akintoye (2000)	Trost and Oberlender (2003)	Shash and Ibrahim (2005)	Azhar and Farooqui and Ahmed (2008)	Sum
	Factors related to consultants, design parameters and information										
1	Experience of the consultant / estimator	√	√			√	√	√	√	√	7
2	Construction team's experience in construction type	√	√		√	√	√	√		√	7
3	Number of estimating staff	√	√				√			√	4
4	Construction team's ability to control the project		√							√	2
5	Impact of team integration and alignment				√			√			2
6	Amount of involvement by the project manager				√			√		√	3
7	Database of historical data		√		√			√		√	4
8	Completeness of cost information and details	√	√				√	√	√	√	6
9	Accuracy and reliability of cost information							√		√	2
10	Applicability of cost information							√			1
11	Procedure for updating cost information (feedback systems)							√			1
12	Use of checklists to ensure completeness and technical basis							√			1
13	Quality of the assumptions used in preparing the estimate							√			1
14	Estimating method/techniques used		√		√			√		√	4
15	Consultant's/estimator's workload during estimation		√					√			2
16	Time allowed for preparing the cost estimate							√		√	2
17	Buildability of design	√		√			√	√		√	5
18	Inspection, testing, and approval of completed works (type and number)			√							1
19	Frequency of construction variations	√					√			√	3
20	Relationship with client/contractors/other design team consultants (previous / present)			√							1
21	Submission of early proposals for costing / cost planning			√							1

No	Factors	Odusami and Onukwube (2008)	Dysert (2006)	Elhag (2005)	Liu and Zhu (2007)	Enhassi and Mohamed and Madi (2007)	Akintoye (2000)	Trost and Oberlender (2003)	Shash and Ibrahim (2005)	Azhar and Farooqui and Ahmed (2008)	Sum
22	Absence of alterations and late changes to design			√							1
	Factors related to client's characteristics										
23	Type of client	√	√	√	√	√	√	√	√		8
24	Client experience and expertise							√			1
25	Client's ability/payment record			√		√					2
26	Client's financial situation and budget	√				√	√	√			4
27	Project finance method/appropriate funding in place on time			√							1
28	Partnering arrangements			√							1
29	Priority on construction time / deadline requirements			√						√	2
30	Experience of procuring construction			√						√	2
31	Client requirements and expectations on quality			√	√					√	3
32	Previous relationship and communication level with the partners				√						1
	Factors related to project characteristics										
33	Type of project (residential, commercial, industrial, etc.)			√				√	√		3
34	Type of structure (concrete, steel, masonry, etc.)	√					√			√	3
35	Scale and scope of construction	√	√		√	√	√			√	6
36	Expected project organisation	√					√			√	3
37	Project size	√		√	√		√		√	√	6
38	Project programme duration	√					√		√	√	4
39	Location of project	√		√		√	√	√		√	6
40	Site conditions and topography of the site			√						√	2
41	Site constraints	√		√	√		√			√	5
42	Site requirements			√						√	2
43	Project complexity	√		√	√		√			√	5
44	Construction method / technology / construction techniques	√		√			√		√	√	5
45	Impact of project schedule							√		√	2

No	Factors	Odusami and Onukwube (2008)	Dysert (2006)	Elhag (2005)	Liu and Zhu (2007)	Enhassi and Mohamed and Madi (2007)	Akintoye (2000)	Trost and Oberlender (2003)	Shash and Ibrahim (2005)	Azhar and Farooqui and Ahmed (2008)	Sum
	Factors related to contract requirements and procurement methods										
46	Type of contract	√		√	√		√	√			5
47	Tender selection method (open, selected, negotiation, etc.)			√							1
48	Method of procurement (traditional, design and build, etc.)			√	√						2
49	Form of procurement	√					√				2
50	Amount of specialist work	√					√			√	3
51	Tax and insurance							√		√	2
	External factors and market conditions										
52	Material (price/availability/supply/quality/ imports)	√	√	√	√	√		√		√	7
53	Labour (cost/availability/performance/ productivity)	√		√	√	√				√	5
54	Equipment (cost/availability/supply/condition/ performance)	√	√	√	√	√		√		√	7
55	Availability and supplies of labour and materials	√					√			√	3
56	Weather conditions			√	√					√	3
57	Impact of government regulation requirements (policy)			√				√		√	3
58	Number of competitors in the market			√		√			√		3
59	Classification and level of competitors in the tendering			√		√		√			3
60	Economic situation				√						1
61	Stability of market conditions	√	√	√	√		√	√		√	7
62	Bidding climate comprising of competitiveness							√		√	2

Further to Table 1, Table 2 has been created to reduce the number of factors to the most commonly mentioned (5 or more in total) in the literature, a total of 19 factors.

Table 2: Short-listed factors

No	Factors	Odusami and Onukwube (2008)	Dysert (2006)	Elhag (2005)	Liu and Zhu (2007)	Enhassi and Mohamed and Madi (2007)	Akintoye (2000)	Trost and Oberlender (2003)	Shash and Ibrahim (2005)	Azhar and Farooqui and Ahmed (2008)	Sum
1	Experience of the consultant / estimator	√	√			√	√	√	√	√	7
2	Construction team's experience in construction type	√	√		√	√	√	√		√	7
8	Completeness of cost information and details	√	√				√	√	√	√	6
17	Buildability of design	√		√			√	√		√	5
23	Type of client	√	√	√	√	√	√	√	√		8
35	Scale and scope of construction	√	√		√	√	√			√	6
37	Project size	√		√	√		√		√	√	6
39	Location of project	√		√		√	√	√		√	6
41	Site constraints	√		√	√		√			√	5
43	Project complexity	√		√	√		√			√	5
44	Construction method / technology / construction techniques	√		√			√		√	√	5
46	Type of contract	√		√	√		√	√			5
52	Material (price/availability/supply/quality/ imports)	√	√	√	√	√		√		√	7
53	Labour (cost/availability/performance/ productivity)	√		√	√	√				√	5
54	Equipment (cost/availability/supply/condition/ performance)	√	√	√	√	√		√		√	7
61	Stability of market conditions	√	√	√	√		√	√		√	7

From here, a ranking of the literature has been made by determining the rating of importance the authors of the literature give to the factors. The following table gives each factor a rating of 1 to 16; the total score is then divided by the number of authors (the average) who included the factor in their research. This refines the factors into an order of significance.

Table 3: Ranked factors of significance

No	Factors	Odusami and Onukwube (2008)	Dysert (2006)	Elhag (2005)	Liu and Zhu (2007)	Enhassi and Mohamed and Madi (2007)	Akintoye (2000)	Trost and Oberlender (2003)	Shash and Ibrahim (2005)	Azhar and Farooqui and Ahmed (2008)	Sum
1	Experience of the consultant / estimator	1	1	X		10	16	5	2	14	6.9
2	Construction team's experience in construction type	3	2	X	7	3	13	7	X	16	7.2
8	Completeness of cost information and details	5	1	X	X	X	16	5	4	8	6.5
17	Buildability of design	16	X	10	X	X	8	7	X	6	9.4
23	Type of client	14	3	4	3	6	7	3	1	10	5.6
35	Scale and scope of construction	11	6	X	1	1	2	X	X	1	3.6
37	Project size	12	X	1	1	X	16	X	6	14	8.3
39	Location of project	8	X	1	X	7	9	10	X	12	7.8
41	Site constraints	13	X	1	1	X	5	X	X	15	7.0
43	Project complexity	6	X	1	1	X	1	X	X	16	5.0
44	Construction method / technology / construction techniques	10	X	12	X	X	3	X	9	16	10.0
46	Type of contract	9	X	11	3	X	16	10	X	X	9.8
52	Material (price/availability/supply/quality /imports)	7	9	5	9	12	X	7	X	1	7.1
53	Labour (cost/availability/performance/ productivity)	7	X	5	9	12	X	X	X	13	9.2
54	Equipment (cost/availability/supply/ condition/performance)	7	10	5	9	11	X	7	X	5	7.7
61	Stability of market conditions	4	15	3	10	1	4	8	n/a	14	7.3

From Table 3: Ranked factors of significance. The following ranked order of factor importance has been established from the literature:

1. Scale and scope of construction
2. Project complexity
3. Type of client
4. Completeness of cost information and details
5. Experience of the consultant and/or estimator
6. Site constraints
7. Material (price/availability/supply/quality/imports)
8. Construction team's experience in construction type
9. Stability of market conditions
10. Equipment (cost/availability/supply/condition/performance)
11. Location of project
12. Project size
13. Labour (cost/availability/performance/productivity)
14. Buildability of design
15. Type of contract
16. Construction method/technology/construction techniques

2.8 FEEDBACK AND REVIEW OF ACCURACY

Feedback from a project is intended to assess the forecasting performance, and should have a number of characteristics (Flanagan and Norman, 1983, p 18). Effective feedback has three simple requirements:

- Simple to use and capable of giving early indications of error
- Capable of identifying any consistent bias in forecasts
- Capable of highlighting situations in which there is not consistent bias

With this information gathered, a trend analysis can be carried out over the last few projects to find where errors are occurring, and what the percentage of error is.

Research in pre-tender estimating practice shows that the knowledge of the estimator is a major factor in identifying their expertise. This, therefore, affects the accuracy of the estimate (Lowe, 1994, p 423). The application of feedback systems is there to improve the accuracy of pre-tender estimates. The usefulness of reviewing the accuracy of previously completed projects reflects a learning cycle that can benefit future improvement to estimating accuracy. The following are considered to be prime examples of good methods of reflection to provide records for future reference (Lowe, 1994, p 423):

- Portfolios that keep track of important learning experiences (errors made)
- Diary for self-reflection of own work carried out

- Review of point-of-view of peers
- Structured reflection and peer appraisal from
- Collaboration to check for errors
- Checklists and self assessments

Feedback and review of accuracy has a significant problem: the biggest barrier to learning from experience is that too often the experience of the estimator will block them from future learning. The impression received from estimators is that in many cases they are too confident in their estimates to continue learning.

"Previous research on building pre-tender cost estimating stresses the importance of giving accurate estimates and minimizing estimating errors" (Cheung, Wong, Skitmore, 2008, p 349). When it comes to estimating, there are two types of errors: overestimates and underestimates. Both have ramifications, but estimators seem to be risk adverse and tend to overestimate — and in the clients eyes, this is more acceptable than underestimating which can lead to under budgeting and losing money. This is where feedback and the review of accuracy are so important; the use of contingencies over the historical data or cost allocated is a risky operation, and refining the data available by review can improve accuracy.

Essentially, feedback systems are used to review, assess, and improve the data available for future use to prevent the inaccuracies in the estimates being carried over onto new projects.

2.9 PROVISIONAL AND PRIME COST SUM EXPENDITURES

Estimates can comprise a provisional sum which is an indicative cost used for items in the contract which hold uncertainty of the actual cost. However, the scope of the provisional sum must be stated in order to validate any cost fluctuations that are on-charged to the client. Morrison (1984, p 59) states that when the effects of a provisional or prime cost sum is ignored, the estimating performance becomes remarkably inconsistent, as fixed price expenditures require sufficient detail in order to be estimated accurately.

The use of a provisional sum is an effective form of cost expenditure; it does not automatically improve the estimator's accuracy, but instead, forms a basis for the estimate being open to cost fluctuation for unknown risks in the project. Kaming, Olomolaiye, Holt, and Harris (1997, p 92) describe the cost fluctuations in projects as a common result of inflation. This is due to the demand exceeding supply, and with unprecedented events such as economic booms, the inflationary effects increase substantially.

2.10 Conclusion

This chapter has provided a complete background for research on the accuracy of the estimating process. The literature review shows that estimating has been recognised as a crucial stage of a construction project. The success or failure of a project is reliant upon the accuracy of the estimates — from conceptual to detail.

Every professional may have a different interpretation of estimating. Estimating cannot be a precise technical and analytical process; but to an extent, it is a subjective process. Estimators consider factors relevant to the successful completion of a project, so essentially, estimating is a process of calculated guessing by looking at the anticipated future costs of a project or product before it actually commences. Estimates are an approximation and will, therefore, include a fair deal of uncertainty.

Accuracy is defined as the degree to which a measurement or calculation deviates from its actual price; therefore, estimating accuracy is indicative of the degree to which the final price outcome of a project may vary from the single point value used as the estimated cost of the project. This, essentially, is what every estimator in the industry is after: accurate estimates which are close to the end result figure. However, from the literature, the accuracy of estimating has not improved over the years as estimates are always influenced by direct or indirect factors which may push them off the targeted budget.

The literature repeatedly mentions that feedback systems are an essential part of reviewing, assessing, and improving the data available so that the new estimates do not have inaccuracies carried forward from previous projects. This is, ideally, a process of learning from mistakes, and seems to be a process neglected by estimators and their companies when it comes to improving the accuracy of the estimating practice.

The literature review can draw conclusions that there are definite factors that affect the accuracy of estimating; however, as these factors are identified, it becomes evident that the practice and improvement of the estimating practice is a must; otherwise, the inconsistencies will continue to be transmitted to new estimates.

This research will investigate whether estimating techniques in an Auckland residential construction company case study accurately predicted actual construction costs, and will attempt to fill in the gap in the existing literature theory of the current practices. The methodology to achieve this is described in the next chapter.

3.0 METHODOLOGY

3.1 INTRODUCTION

This research intends to answer the question *"How accurately do estimating techniques used for residential construction predict actual construction costs?"*

This research aims to determine the factors which affect the accuracy of estimating techniques and identify how these factors influence actual construction costs by using a case study of a residential construction company, and by answering the following questions:

- What factors are seen as being the highest influencers for accurately predicting construction costs?
- What methods are used to predict these construction costs?
- How often is the historical data and pricing structure updated through back-costing or feedback after the completion of a recent project?
- How accurately does the case study company predict construction costs, and what influences the inaccuracies?

To answer these questions, a document analysis of the case study company's construction cost records will comprise a comparative feedback of the estimated costs from pre-construction to the actual construction costs.

Throughout this chapter, the following subsections will further expand on the research methodology used to investigate and answer the research question:

- Research Design
- Data Collection
- Sampling
- Data Management
- Reliability and Validity
- Research Ethics
- Conclusion

3.2 RESEARCH DESIGN

In carrying out the literature review, a number of methods were encountered which contained a mixture of quantitative, qualitative, and mixed methods. However, the most effective and most commonly used method was a mixed approach of both quantitative data collection with a qualitative analysis, or vice versa.

Typical studies would be from Odusami and Onukwube (2008) where a quantitative approach was taken to identify the 21 factors which affect the accuracy of pre-tender estimation in order of ranked influence. This is effective as it provides a statistical remedy for analysis through a number of participants. Similarly, Akintoye (2000) uses the method of obtaining a list of factors affecting the accuracy of the estimating process through an analysis of the literature, and then sends out questionnaires to get a ranked list from the participants on relative importance of the factors. This method of using mail-out surveys is effective on a large scale where there have been case studies in the past with a large number of respondents from whom to get a reasonable result.

Another method was used by Morrison (1984); instead of using the participants' response to the rank the importance of the factors, a total sample of 64 projects was used to compare the effectiveness of the estimating practice (Morrison, 1984). This was first evaluated with a plus-minus percentage outcome and then a deeper (qualitative) analysis of why there were discrepancies and inaccuracies in the estimates made in the early stages of the design. The method used by Morrison compares not one but a large number of case study projects over a range of companies, and is an example of how to create a more accurate and reliable outcome and analysis of the actual estimating practice. As mentioned above and in the literature review, the most commonly used and predominant method is a mixed approach; this has been selected as the most suitable for this research, and will consist of the following data collection method:

- Data back-costing (Document analysis/statistical study)

A case study serves as a connection between the theoretical knowledge found in available literature and the reality that is the current practice in the industry. **Critical case study analysis** will aim to find and organise the problem in a specific case; in this instance, a residential construction company. The critical analysis will be used to evaluate and analyse the presented problem, and to solve it. The purpose of the critical case study is to determine the central issue of the problem, key decision makers, and to find an effective solution — whether it be a recommendation or suggestion or indicate a need for future study (Bell, 2007, p 11).

This case study will focus on one residential construction company; it is identified as a critical case study as the correlation of the literature knowledge and the industry practice needs to be identified in order to answer the question of how accurately the estimating techniques predict the construction costs. This is the first step in analysing the industry's level of accuracy for certain estimating techniques, as an examination of a case study company can provide a benchmark that can contribute to much greater research.

Gillham (2000, p 86) states that “quantitative data has a special place in case study research in so far as it extends the range of evidence on the topics under investigation – and qualifies what we have learnt from other sources.” The statistics can be descriptive or inferential which will bring the outcome to what may lie behind it or what explanations for its outcome are visible. Because statistical significance is heavily dependant on the size of the numbers involved, and this research is primarily for one case study, the best use to be made of the findings will be to establish grounds for further research in the industry.

The literature pointed the way to selecting data collection requirements, as it used smaller case studies to form the basis for larger statistical analyses of the industry’s performance. However, this method is only effective when the first case study is created as a baseline observation; that is the purpose of this research.

Using a mixed method approach in the beginning stage will assist the research by quantifying the range of influential issues seen in the literature, while the last stage will describe and explore the issues by a first-hand statistical analysis of actual data.

3.3 DATA COLLECTION

This case study comprises a data back-costing comparative analysis.

Data back-costing / feedback comparative analysis

The data collection process is the data back-costing / feedback comparative analysis which comprises a three-step process:

- Obtain the estimate used to forecast the construction costs
- Use the estimate as the comparison of the actual construction end cost
- Display the difference of the estimate to the actual construction cost as a plus or minus (+ -) percentage.

The purpose of doing a feedback analysis of each project is to take what has been explained and identified in the literature as measures and factors affecting the estimating process, and then see how they affect the accuracy of the estimates. Moreover, the estimates are not effective if they are done at random for projects of different value, so the projects will need to be grouped according to value of the most commonly encountered ones — from $300,000 to $650,000.

3.4 SAMPLING

Fellow and Liu (2008, P 159) state that "the objective of sampling is to provide a practical means of enabling the data collection and processing components of research to be carried out whilst ensuring that the sample provides a good representation of the population; i.e. the sample is representative." Ideally, the objective of *sampling* the plan is to draw conclusions about populations (in this case it will be a sample of projects). This is achieved by drawing conclusions from a portion rather than the whole; this would be called a census.

The first task was to identify the sample method to use to make selections from the population. By looking into the options of types of samples available, the most effective and suitable choice was made.

To select the most useful sample type, it had to be one that could facilitate a selection process from the population as a whole, and also have a wide diversity in the types of projects that could be studied. For example, random sampling is not ideal as it could end up with a lot of the same types of projects. Therefore, the selected sample method is *purposive sampling*. Purposive sampling is also referred to as judgemental sampling where typical projects are used to represent the population (Fellow, Liu, 2008, p 160). This involves participants (in this case projects) being selected that are standard or otherwise known as typical representations of the population selected. It will be judged for selection through a number of factors:

- Date of project completion (Data will be from the last 5 years)
- Group range by project value ($300,000 - $650,000)
- Mixture of both client-supplied plans and contractor-designed plans
- Time of initial estimate

The next step was to establish the population/sample size (number of projects to be used): as this is a case study, there is only one participant; but a number of projects is critical for an effective analysis.

3.5 DATA MANAGEMENT

There is one type of data being collected: the data back-costing comparative analysis (document analysis).

In terms of the data collected for the document analysis, this will be gathered and the project names will be coded into a cover name to protect its identity (covered in section 3.8 Ethics); the project value will be grouped with no specific project dollar amount indicated.

All data is stored on a private computer of the author, no other persons can access the data unless authorisation is given. A hardcopy of the data collected and analysed is left with Unitec to be stored securely for research purposes.

3.6 RELIABILITY AND VALIDITY

Reliability is generally related to the data that is collected, observed, or analysed as a representation of the entire population, and not a one-off finding. Also, if this research should be repeated in the future by another author, use of the exact methods and tasks should be possible under the same conditions and rules (Denscombe, 2010, p 193). This shows that it is testable at a later date for renewal of information to check if anything has changed.

Validity is concerned with the requirements/methods of the research; it determines if the data collected and analysed has met all the requirements or expectations of the research carried out. This could include the types of projects used, and whether every project is unique enough to represent and cover all aspects of the analysis (Denscombe, 2010, p 193). This will determine whether the methods are the most suitable and accurate.

3.7 RESEARCH ETHICS

"Morals comprise the fundamental beliefs of people over what is right and what is wrong and so, underpin behaviour – human actions and interactions." (Fellows, Liu, 2008, pg 247).The difference between right and wrong is the line which cannot be crossed when the documents being obtained by the provider are being collected. The sensitivity of commercially unavailable data is crucial, and human actions, behaviour, and the form in which the data is expressed needs to be handled with the utmost care.

Prior to the data collection, this research project was evaluated in an ethics review assessment by Unitec to ensure that the participant and the company data's commercial sensitivity were protected with the correct measures of data collection and presentation.

Ethics is there to minimise harm and to ensure that the research participants are not subjected to any risk or exposure due to improper methods of protecting privacy. The issue of privacy was controlled by using the following method of presentation of data:

- Prior consent was obtained from the participant company with all details of the research assignment explained, and leaving no areas of uncertainty.
- The participants' and company's names were not to be published on any public documents.
- Company data would not be expressed in exact dollar values for each project used for analysis; these were grouped into a category of $300,000 - $650,000, and the comparative differences were only expressed as percentage values.
- Project information would not be divulged in the report; projects would be expressed as "Project 1, Project 2, etc..."
- Before submission of the final report to Unitec, a copy was given to the participants to look over and give approval to go ahead; any changes were discussed and agreed to.

The issue of right of access to this research will be only at the discretion of Unitec, as all financial company data from the reviewed projects would be held for up to five years after the report submission for research purposes only. The issue of data storage was controlled by the researcher by storing the data in a confidential manner.

There was to be no form of misrepresentation or deception of use of data by the author; the participant was made fully aware of the purpose, methods, and presentation of the research prior to any data collection taking place. To ensure the research ethics codes were not breached, the ethics guidelines were adhered to as stipulated in the information sheet, participant consent form, and the right to request for access to data form.

The application for ethics approval form was also approved by the research supervisor and the course coordinator prior to the research being conducted.

3.8 CONCLUSION

In the literature review, the most frequently used method for a project of this nature is document analysis. Documents required for this project are; initial estimate, variation schedule, and actual cost report.

A purposive sampling method was used, with typical projects used to represent the population. They were judged under a number of criteria to shortlist the best suited projects.

Prior to the data collection, this research project was evaluated in an ethics review assessment by Unitec to ensure that the participant and the company data's commercial sensitivity were protected with the correct measures of data collection and presentation.

4.0 DATA AND DISCUSSION

4.1 INTRODUCTION

This research intends to answer the question: *"How accurately do estimating techniques used for residential construction predict actual construction costs?"*

Section one

The data analysis in the following chapter was collected through document analysis of 10 different projects using the project value bracket of $300,000 to $650,000 over the last five years. These documents were used as a fair representation of the company's portfolio of work. The documents were obtained through permission from the managing director in order for the company's estimating analysis to take place. The findings have been analysed in terms of the research question and as confirmation of theory drawn from the literature.

The purpose of this chapter is to detail the data collection process carried out and describe the data management process to a greater extent as mentioned in the previous chapter. The data will be categorised by the project number and split into a deeper, defined, elemental breakdown for closer analysis.

Section two

This section intends to discuss the data findings by using a linear analysis of the sampled projects accuracy over the last five years of data collected. This chapter will also discuss the following information between the findings:

- Similarities between data findings
- Differences between data findings
- Significant findings
- Actual data compared with literature

From here, the conclusions and recommendations for future research can be made in the next chapter.

4.2 DATA COLLECTION PROCESS

The data collection process has been carried out – as mentioned and described in the previous section 3.3 – with a document analysis. The document analysis comprises a three-stage process which utilises the initial estimate, variation schedule, and actual cost report of a project to transfer the data into a comparative table. The document analysis took place over a four-week period at the discretion of the author after working hours. Before the documents from the case study company were collected, ethics approval and permission granted from the case study company were obtained. The case study company's name and project names were replaced with codes in accordance with the ethics protocol.

4.3 DATA MANAGEMENT PROCESS

The data management process consists of the raw data being summarised into an elemental cost breakdown. This is categorised into the following 17 elements used by the company to group different costs in the project:

1. Foundations, excavations, and retaining wall
2. Floors
3. Fencing and landscaping
4. Decks
5. Driveway, paths, and patio
6. Exterior sheathing
7. Roof
8. Insulation
9. Exterior joinery
10. Interior linings and finishing
11. Electrical
12. Hardware
13. Interior joinery
14. Decorating
15. Plumbing
16. Drainage
17. Additional items including P & G

The elements are split into two areas, the first section being the budget which consists of the variations and initial estimate. The second section is the actual cost which is tabulated from the actual cost report. This data is entered into a spreadsheet where a + - percentage is calculated; however, the costs are then hidden and only the percentage is shown on the report. This enables a more detailed analysis of the project which can be thoroughly discussed later in this chapter in accordance with the differences and similarities of the data to the literature. The data management process has been compiled through a quantitative approach which allows the author to highlight trends through the precise information that has been presented in the data. The data was entered into the spreadsheet for analysis using the following process:

- Enter the initial estimate and variation schedule into the appropriate budget element by:
  - Deducting the New Zealand Goods and Services Tax (GST) to get to the net cost in order for all costs to be of the same representation.
  - Adding the costs cumulatively to arrive at an element total.
  - Some projects which do not show in the budget required manual calculation consisting of a dollar per gross floor area rate for each element
- Enter the cost report into the correct actual cost element by:
  - Taking the summary cost total of each coded item and adding it into the element table.
  - Where conflicting items are seen, judgement of the correct group to apply the cost is made.
- Final calculation of the + - percentage of cost deviation is calculated by dividing the actual cost by the budget and rounding to two decimal places for each element, and then summarising into a total project deviation total.

4.4 ISSUES WITH DATA COLLECTION

Data collection had barriers to a perfect analysis which consisted of the following areas that limited the accuracy (minor) of the data comparison:

- Missing information – some projects did not have budget sheets which required manual calculation of the budget; also, as the projects got older, the variation schedules and cost reports lacked the detail required.
- Conversion of GST from 12.5% to 15.0% when deducting GST from the estimates to get to the net value; some variations were not shown if they were raised and paid before 1 October 2010
- The format and consistency of the variation schedules and cost reports seemed to change with the old projects along with some variations of schedules that were not existent, or if only a summary of the variations was available
- Incorrectly coded items in the cost reports made it difficult to identify which element the cost belonged to; for example, torch on membrane could be for a flat roof or a mid-level deck; however, the cost was not separated out.
- Some projects included the land which required some costs to be removed from the calculation such as solicitor fees, land cost, interest on the land, etc.
- Overlap of overheads in the cost reports when they should be separated into the company overheads such as quantity surveyor fees or company labourer fees.

4.5 DATA MANAGEMENT AND ANALYSIS

4.5.1 PROJECT 1 - 2011

House type: Standard

Project duration: 13 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	-8.00%
2	Floors	15.12%
3	Fencing and landscaping	n/a
4	Decks	n/a
5	Driveway, paths, and patio	n/a
6	Exterior sheathing	8.49%
7	Roof	31.63%
8	Insulation	9.25%
9	Exterior joinery	-32.17%
10	Interior linings and finishing	24.47%
11	Electrical	2.22%
12	Hardware	-5.64%
13	Interior joinery	-48.49%
14	Decorating	-70.95%
15	Plumbing	6.10%
16	Drainage	-3.99%
17	Additional items including P & G	-3.32%
	Total deviation as a percentage	**1.69%**

Table 4: Project 1 – 2011 data analysis

Project 1 was generally very accurate overall, with an estimate that came within 1.69 percent of the actual budget. However, the percentage differences between individual elements suggest that there were changes made or discrepancies with the actual construction cost in the information provided at the estimating stage. This would suggest that there were material price increases and changes in scope during construction, and indicates that historical data may need updating, or possibly, that contingency for price escalation is not being considered. As a whole, the project is within budget, but there are fluctuations throughout the building components which need attention. Also, from the budget vs. actual figures it seems budgets are not being set, or that the budgets are being mixed up over several trade elements. Some invoiced work has been coded incorrectly, which makes it difficult for back-costing and for feedback from projects to be accurately achieved. This may mean that project feedback processes need more time and effort to dissect the information to truly identify the discrepancies and inaccuracies. The biggest discrepancy in this project is the joinery (in terms of value, not percentage). This could be due to the joinery being an architectural range for which the budget for the model house is not sufficient. During the initial stage of the project estimation, it would have been better practice for the estimator to obtain a quote or to make the joinery a provisional sum so that the difference could have been on-charged to the client.

4.5.2 *Project 2 - 2011*

House type: Standard

Project duration: 11 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	8.10%
2	Floors	5.14%
3	Fencing and landscaping	n/a
4	Decks	n/a
5	Driveway, paths, and patio	n/a
6	Exterior sheathing	5.43%
7	Roof	20.68%
8	Insulation	-46.61%
9	Exterior joinery	-27.70%
10	Interior linings and finishing	-19.23%
11	Electrical	-3.60%
12	Hardware	-26.50%
13	Interior joinery	-88.54%
14	Decorating	-10.28%
15	Plumbing	13.14%
16	Drainage	-11.28%
17	Additional items including P & G	50.48%
	Total deviation as a percentage	**6.25%**

Table 5: Project 2 – 2011 data analysis

Project 2 had a significant number of variations to the contract; hence, all budgeted figures become invalid. From the budget, there is a difference of 6.25 percent, which is quite good in terms of additional margin; however, the biggest difference is in the joinery expenditure (in terms of value not percentage). This has clearly been underestimated and there are a number of reasons which could contribute to this.

From the above, it would suggest that items which have not been affected by variations requested by the client have been within the budget, but items for client changes are significantly different. From the above, it also seems that the items in the contract that are usually provisional sum expenditures exceed the estimates. This is unusual as the provisional sum is an actual cost versus the indicative budgeted expenditure. Any additional costs should have been on-charged to the client; however, the underestimate could also be a result of incorrect coding of the invoiced items.

Although, in this case, a higher margin has been achieved by overestimating the project costs, there is a risk that tenders for jobs may be lost in other situations where this occurs.

4.5.3 *PROJECT 3 - 2010*

House type: Architectural

Project duration: 6 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	n/a
2	Floors	-15.66%
3	Fencing and landscaping	-11.98%
4	Decks	n/a
5	Driveway, paths, and patio	-7.72%
6	Exterior sheathing	4.82%
7	Roof	7.86%
8	Insulation	-39.11%
9	Exterior joinery	-9.46%
10	Interior linings and finishing	-26.41%
11	Electrical	-19.31%
12	Hardware	6.00%
13	Interior joinery	41.48%
14	Decorating	-4.19%
15	Plumbing	-5.55%
16	Drainage	-4.27%
17	Additional items including P & G	-77.19%
	Total deviation as a percentage	**-10.93%**

Table 6: Project 3 – 2010 data analysis

This job shows a significant loss as the actual costs exceeded the budget allowed in the contract. Because the discrepancy has spread across the entire job, it seems the trend could have been the result of several factors. First, the standard model the house is on is the square metre rate, and this could be inefficient. This rate is generic and used as a kick-off point for estimating; if this is inaccurate by either the quantity of the gross floor area or the rate not being at the appropriate amount, it could upset the entire estimate. Also, looking at the date of the estimate, it shows that the contingency for price increases has not been allowed for.

Another influence could have been that at the time the estimate was carried out, work was in short supply and a builder's discount was given in order to obtain the job. In strict terms of the estimating aspect, it is out; however, the underlying factors are construction issues and the client's personality. Construction issues such as remedial work, incorrect application of finishes, or general errors made on-site could also be reasons for the differences in the budget vs. actual figures. The client has a major influence over the project; an easy-going client makes their decisions quickly and keeps the job going. However, a difficult client questions all claims, changes, and progress which eventually slows construction and costs the contractor money. It is apparent from the P & G that the job has gone on for way too long.

4.5.4 *Project 4 - 2010*

House type: Standard

Project duration: 11 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	32.08%
2	Floors	-32.50%
3	Fencing and landscaping	12.52%
4	Decks	81.66%
5	Driveway, paths, and patio	19.87%
6	Exterior sheathing	1.23%
7	Roof	13.39%
8	Insulation	-87.60%
9	Exterior joinery	16.84%
10	Interior linings and finishing	0.29%
11	Electrical	-7.44%
12	Hardware	24.76%
13	Interior joinery	6.62%
14	Decorating	6.60%
15	Plumbing	-24.78%
16	Drainage	-70.32%
17	Additional items including P & G	18.26%
	Total deviation as a percentage	**2.39%**

Table 7: Project 4 – 2010 data analysis

Overall, Project 4 was very accurate with very few overruns. However, looking more closely at the job, two items which stand out are the insulation and drainage. Insulation has been trending from the other jobs as a constant overrun. This indicates that the historical data is not being updated with new building code requirements.

This poses a minor risk with just one item being only a few thousand dollars outside of the budget. However, over a long period of time, this could build up a constant deficit — but one that can easily be fixed by updating the historical data (including the standard model house).

4.5.5 *PROJECT 5 - 2009*

House type: Standard

Project duration: 7 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	39.89%
2	Floors	-2.36%
3	Fencing and landscaping	n/a
4	Decks	60.64%
5	Driveway, paths, and patio	9.59%
6	Exterior sheathing	17.25%
7	Roof	-62.97%
8	Insulation	46.26%
9	Exterior joinery	-7.25%
10	Interior linings and finishing	-0.35%
11	Electrical	17.34%
12	Hardware	-6.02%
13	Interior joinery	31.31%
14	Decorating	6.07%
15	Plumbing	23.18%
16	Drainage	14.74%
17	Additional items including P & G	-10.21%
	Total deviation as a percentage	**7.15%**

Table 8: Project 5 – 2009 data analysis

Project 5 has a difference of 7.15 percent under the intended budget; this is better for the job margin, but is clearly an overestimate in terms of what should have been budgeted for. One item which stands out is the Roofing element; this has had a significant overrun which indicates that the type of roof budgeted for was substantially lower than the required amount. This can be due to a number of reasons such as: the type of roof was not estimated as a sea spray zone type roof; historical data was not updated frequently enough to identify the proper rate; there may have been construction issues with a damaged roof needing replacing; an inexperienced estimator may not have provided for extra allowances for difficult roof construction with high pitch; or the gross roof area was not measured correctly at the initial stage.

Another frequent mistake or discrepancy which seems to be reoccurring is incorrectly coded elements in the invoicing system this company uses. For example, the decking element should consist of the timber, hardware, builders' labour, waterproofing, plumbing, and staining invoices; however, it seems this has been mixed or merged with other elements and creates difficulty when it comes to back-costing to see where improvements can be made. The margin would, in fact, be higher on this job due to the under budget figures; however, this form of estimating proves to be inefficient as the contractor is pricing himself out of the market.

4.5.6 *Project 6 - 2009*

House type: Architectural

Project duration: 14 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	37.38%
2	Floors	-12.08%
3	Fencing and landscaping	71.27%
4	Decks	n/a
5	Driveway, paths, and patio	-105.78%
6	Exterior sheathing	2.50%
7	Roof	61.96%
8	Insulation	50.36%
9	Exterior joinery	-29.20%
10	Interior linings and finishing	15.10%
11	Electrical	26.06%
12	Hardware	35.89%
13	Interior joinery	17.16%
14	Decorating	-74.10%
15	Plumbing	12.99%
16	Drainage	-24.63%
17	Additional items including P & G	-22.76%
	Total deviation as a percentage	**10.81%**

Table 9: Project 6 – 2009 data analysis

Project 6 seems to be overestimated for the majority of the elements at a total difference of 10.81 percent. This project has four significant overruns: driveway paths and patio, exterior joinery, decorating, drainage, and additional items including P & G. Driveway paths and patio have been underestimated from the beginning; no variation could be raised as the contract has not changed, and it is not a provisional sum to on-charge as the budget deviation. This has resulted in the client obtaining a concrete driveway more cheaply without paying anything over the initial estimate. The problem with this is that either the measured area was under the required amount, or the rate used was insufficient. The exterior joinery, as indicated from previous projects, seems to constantly be underestimated; this shows that the rate allowed per $/GFA is insufficient, and when a house deviates from a standard residential series joinery range, it requires trade quoting or a replacement of the fixed cost with a provisional sum. Again, this is an issue with the historical data, and relying on it to be used as a general tool for estimating.

Decorating has been underestimated by approximately -74.10 percent; this is a result of the estimator not allowing enough when it comes to deep base, pastel, or dark-coloured paints. This is a contract exclusion; however, it has not been claimed from the client in a variation, and therefore, it becomes a cost control issue rather than a estimation issue. The drainage has exceeded the budget, but unlike the other projects, this is not a provisional sum; therefore, the difference could not be on charged on to the client. This is a problem for items which have unforeseeable conditions for estimating.

Underground work like foundations, excavation, and retaining wall — and in this case, drainage — is reliant on the site condition. Drainage is also as-built; therefore, the plan pipe work and fittings positioning becomes invalid. Lastly, the additional items including P & G have been underestimated for a number of reasons; the overheads are being mixed up with the job costs, and construction has taken too long so that the temporary services such as portaloos, scaffolding, power, water, etc. have exceeded their budgets.

4.5.7 Project 7 - 2008

House type: Standard

Project duration: 6 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	-2.15%
2	Floors	-14.56%
3	Fencing and landscaping	32.71%
4	Decks	28.54%
5	Driveway, paths, and patio	29.15%
6	Exterior sheathing	-22.70%
7	Roof	63.21%
8	Insulation	58.59%
9	Exterior joinery	7.14%
10	Interior linings and finishing	16.12%
11	Electrical	22.11%
12	Hardware	11.08%
13	Interior joinery	-5.65%
14	Decorating	-13.92%
15	Plumbing	12.91%
16	Drainage	-359.92%
17	Additional items including P & G	-83.40%
	Total deviation as a percentage	**0.49%**

Table 10: Project 7 – 2008 data analysis

Project 7 is very accurate overall; however, this has a deviation of 0.49 percent with major overruns in the drainage and additional items including the P & G element. The underestimate caused by the drainage is a result of a fixed cost item in the contract locking in the contractor with no choice but to absorb the difference. Trends seen from the other projects are that the drainage is usually a provisional sum as it is *as-built,* and highly dependant on the site topography and council conditions.

The floors have been severely underestimated due to the fact that the model house or "standard" per gross floor area budget may not have been updated regularly. With a house that is outside the scope of a standard midfloor, the rate allowed is not sufficient and becomes invalid. Other overruns seem to trend from over-long construction increasing the temporary costs; this can result from a number of reasons; i.e. insufficient budget from initial estimate, construction programming not tight enough, or delays caused by the client's constant changes in project scope delaying construction. Unlike the previous jobs, this one did not have an overrun in the joinery element which may be due to the fact that double-glazing was not required at this stage.

4.5.8 *Project 8 - 2008*

House type: Standard

Project duration: 12 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	34.95%
2	Floors	-0.65%
3	Fencing and landscaping	2.65%
4	Decks	41.43%
5	Driveway, paths, and patio	n/a
6	Exterior sheathing	-16.07%
7	Roof	14.67%
8	Insulation	42.43%
9	Exterior joinery	25.39%
10	Interior linings and finishing	19.63%
11	Electrical	-16.73%
12	Hardware	137.22%
13	Interior joinery	0.16%
14	Decorating	-20.42%
15	Plumbing	-22.03%
16	Drainage	-261.81%
17	Additional items including P & G	-12.23%
	Total deviation as a percentage	**2.84%**

Table 11: Project 8 – 2008 data analysis

Project 8 is close to being on target with only a deviation of 2.84 percent. A few discrepancies in the job that stand out are the drainage, hardware, decorating, and plumbing. The biggest discrepancy is the drainage cost created as a fixed sum in the contract; while in the other projects, it is almost always a provisional sum. This seems to be a commonly made mistake when estimating a job in the initial stage when the underground work poses a great risk. Being ground conditions, council requirements and as the drainage is as-built then this initial plan becomes invalid.

Next, the hardware element seems to be coded incorrectly; it is hard to tell if it was accurate at all or if the client has supplied all the gear without the contractor raising a credit variation. The next two inaccurate items are the decorating and plumbing elements; these did not have a budget established, and several remedial costs are apparent without back charges to the responsible trade. This is, however, not an estimation problem, but a site manager and/or cost control problem reflecting a lack of attention to the site's daily activities.

Finally, the most recurring inaccuracy — and one that seems to be underestimated constantly — is in the additional items including P & G; this can be a result of slow construction, budgets not being set, underestimation, and mixing overheads in the job cost when they should be separated into the company overheads.

4.5.9 PROJECT 9 - 2007

House type: Standard

Project duration: 7 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	1.41%
2	Floors	-159.45%
3	Fencing and landscaping	n/a
4	Decks	91.35%
5	Driveway, paths, and patio	-14.15%
6	Exterior sheathing	-33.64%
7	Roof	73.56%
8	Insulation	16.53%
9	Exterior joinery	-11.16%
10	Interior linings and finishing	-13.08%
11	Electrical	-0.45%
12	Hardware	7.24%
13	Interior joinery	-3.57%
14	Decorating	-31.21%
15	Plumbing	-13.65%
16	Drainage	17.97%
17	Additional items including P & G	33.44%
	Total deviation as a percentage	**0.44%**

Table 12: Project 9 – 2007 data analysis

Project 9 is very accurate overall, but appears to have major overruns in the specific elements when looked at more closely. The elements of concern are in the floors and decks; it is difficult to identify if they are actual overruns as they contain several different trades which have not been coded correctly. This poses the risk of not following the budget which defeats the purpose of even setting one. The job is accurate overall, but the discrepancies within the entire job show that the project is not being carried out correctly.

One key aspect which has changed from previous projects is that the additional items, including P & G, are not an overrun, but under the budget. This is apparent from more budgets being set at the early stage, and the pre-tender estimate being more accurate than the previous projects. This project dates back nearly five years, but the budget setting in the invoicing system seems to be more accurate in terms of not mixing up overheads and allowing for detailed breakdowns. This being said, the project does show discrepancies throughout; although. as a whole, it has come out on target.

4.5.10 Project 10 - 2007

House type: Architectural

Project duration: 15 months

Ref	Item Description	% Difference
1	Foundations, excavations, and retaining wall	-41.96%
2	Floors	-36.02%
3	Fencing and landscaping	n/a
4	Decks	21.16%
5	Driveway, paths, and patio	-32.08%
6	Exterior sheathing	-2.22%
7	Roof	64.83%
8	Insulation	1.06%
9	Exterior joinery	-32.23%
10	Interior linings and finishing	-28.36%
11	Electrical	21.40%
12	Hardware	-275.35%
13	Interior joinery	-220.67%
14	Decorating	-58.06%
15	Plumbing	-6.58%
16	Drainage	1.16%
17	Additional items including P & G	-20.51%
	Total deviation as a percentage	**-13.71%**

Table 13: Project 10 – 2007 data analysis

Project 10 has the highest deviation overall with an accuracy of -13.71 percent which has nearly all elements in the negative bracket. Clearly, it has been underestimated in all aspects which could be caused by a number of factors. The first of these is "time": the time lapse between when the estimate was made and the time of construction. Another factor is the effectiveness of the $/m^2 of GFA budget established. The estimates are first based on a m^2 rate established from the model house; however, the effectiveness of the rate drops when the house complexity changes. Also, the gross floor area of the house passes the maximum allowance. The model house only has one version, so there could be an additional allowance or a contingency for architecturally designed houses, or provision of a new system of pricing houses when it exceeds a certain GFA.

The biggest discrepancies are the hardware and interior joinery; the interior joinery seems to be a result of the painter's invoice for a deep-based paint. This is an extra cost to a standard paint colour which has not been on charged to the client in a variation that has resulted in a loss in that element. The hardware variance seems to be from an underestimate in the early stages of the initial estimate. An element which does not often seem to be off the target is the electrical trade; this element is always on target with the standard per GFA m^2 rate, and with any additional changes charged on to the client. Alternatively, the drainage in this case is a provisional sum which results in the actual cost replacing the budgeted cost and has put the specific element in a very accurate estimating range.

4.6 SIMILARITIES BETWEEN DATA FINDINGS

When the budget and the actual costs are compared to one another there are similarities which seem to reoccur through the projects. The drainage element is a prime example of the use of provisional sums being so important to a project's level of accuracy. Morrison (1984, p 59) describes how provisional sums, when ignored, have an influence on the estimator's performance, as fixed price expenditures require sufficient detail in order to be estimated accurately.

The following shows how the accuracy of a project alters when an element is subject to uncertainties such as ground, local authority, and building code conditions.

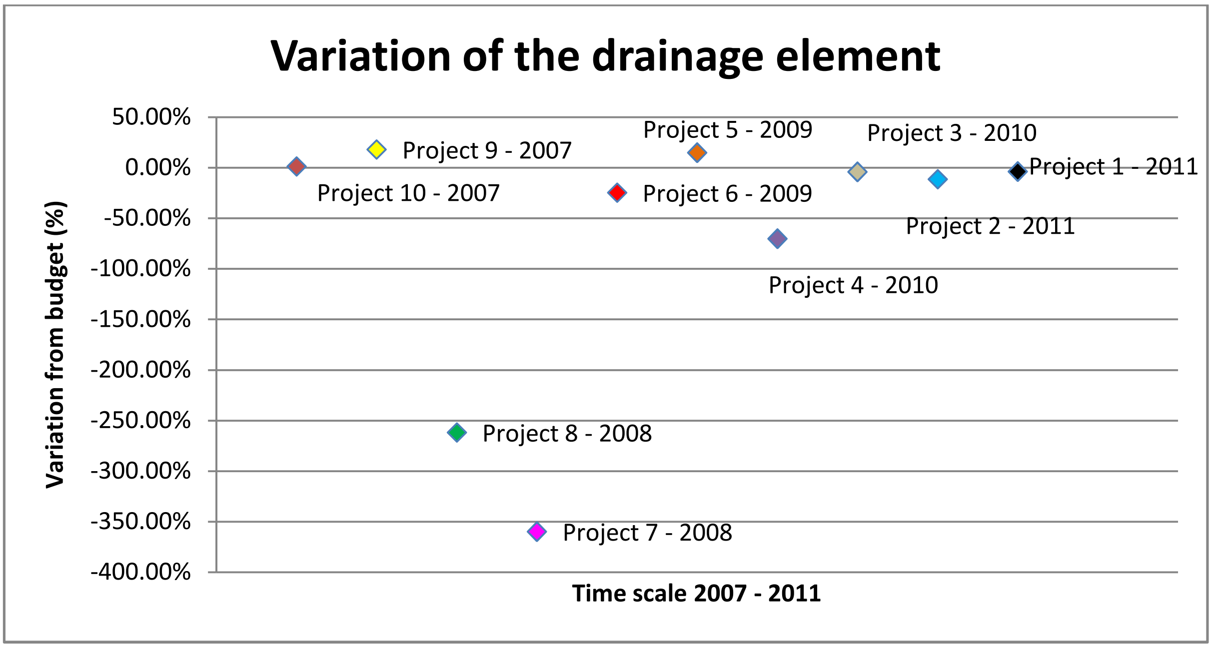

Figure 1: Variation of the drainage element

The projects which have the element classified as a provisional sum are within a close proximity of the budget. Whereas Project 8 – 2008 and Project 7 – 2008 are completely outside of the budget and have resulted in a negative value. This is an important form of cost expenditure; it is not a automatic guarantee of the estimators accuracy, but instead, forms a basis for the estimates being open to cost fluctuation for unknown risks in the project (Kaming, Olomolaiye, Holt, and Harris, 1997, p 92).

Estimating for elements in a project as described by Choon (2008) consist of quantities of the work, method of construction, production rate of resources, and the factors which affect these items. This is relative to fixed-cost expenditures where the work can be quantified and methods are identifiable; however, it is apparent that the inconsistencies are being repeated with the underground work which cannot be quantified for a detailed estimate.

Conceptual estimation methods are dependant on having historical cost information upon which the estimates are based (Dysert, 2005, p 5). The cost information used in the projects analysed indicate that the historical data is not updated or monitored as it should be. The discrepancies seem to be carrying onto the future projects which lead to losses on projects and opportunities lost due to over- or under-estimation.

The graph below displays the flooring element variation from the initial budget:

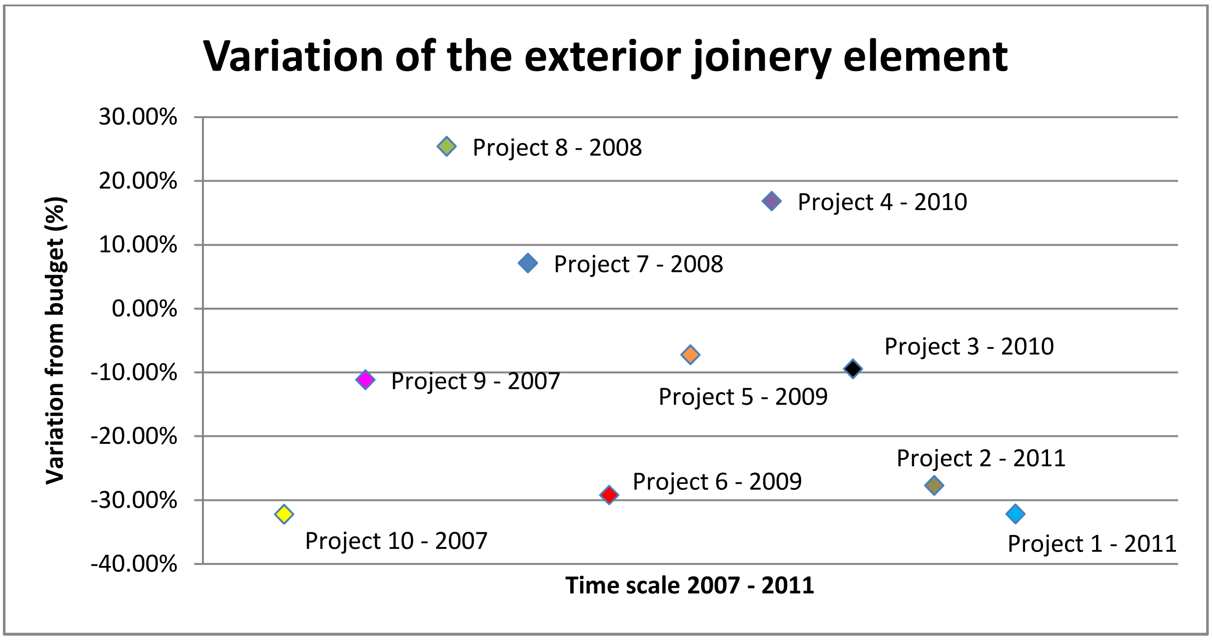

Figure 2: Variation of the exterior joinery element

The flooring element is a prime example of an element which has no consistency in the accuracy of its data. The variation between the budget vs. actual is completely outside of the range it should be within. This displays reoccurring inaccuracies which suggest that the historical data or model house pricing structure is not being updated as it should be, and the inaccuracies are being transferred onto future projects.

Flanagan and Norman (1983) emphasise that the feedback procedures of a project are intended to access the forecasting performance, and should have a number of characteristics that identify the issues. By not carrying out these feedback reviews, a significant problem arises and presents a barrier to learning from experience. It is suggested that the estimators' experience will block them from future learning; however, this is only relevant for idiosyncratic factors that affect estimation. The floor element, for example, is not an element affected by the uncertainties that underground work would be challenged by; instead, it is affected by market rates and cost for construction methodology which is not being updated regularly as it should be.

4.7 DIFFERENCES BETWEEN DATA FINDINGS

The projects seem to fall into two categories when being analysed:

- Standard designed houses
- Architecturally designed houses

The base rate which is created from the company's standard model house was still used in both scenarios when it came to forecasting the construction costs. It became apparent from the data analysed that the rate used could, in fact, be invalid for architecturally designed houses as it was outside of the scope of the model house completely.

Below is prime example of a project which had significant overruns in nearly all elements:

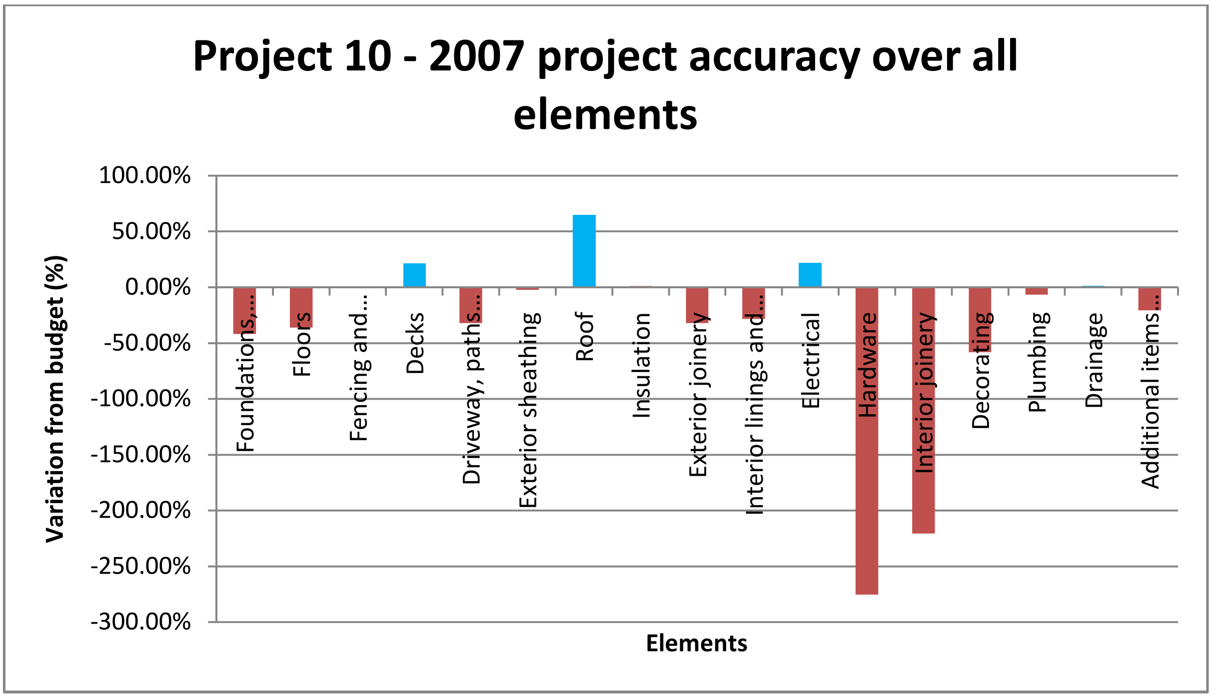

Figure 3: Project 10 – 2007 project accuracy over all elements

Project 10 - 2007 has inaccuracies in nearly all elements which is the result of an underestimated conceptual estimate. The top two factors identified in the literature are the scale and scope of construction and the type of client. These factors are crucial to the success of a project, and estimates that fail to take them into account produce invalid conceptual estimates. The level of accuracy of cost estimates at the pre-tender stage is an important indication of effective estimation (Liu and Zhu, 2007, p 94). The contracts are fixed; therefore, cost fluctuations are not appropriate to on-charge to the client; however, the provisional sums are indicative and subject to the actual cost replacing the budgeted figures. This poses a risk to the contractor as the price escalation of the provisional sum allowance must be justifiable. Should the increase in cost be a result of underestimation in the early stages of the project —without any change of scope — then the contractor bears the risk of payment claim rejection. This is seemingly a common dissatisfaction for the client when the unpleasant shock comes because the tender prices substantially exceed the budget. This reinforces the argument that Oberlender and Trost (2003) have as to the accuracy being dependant upon who prepared the estimate, how it was prepared, what was known about the project, and the factors that were considered when preparing the estimate.

4.8 SIGNIFICANT FINDINGS

The variation of the project totals are clear in showing which projects came within the budget range and which projects did not. The 17 elements, on the other hand, fluctuate from element to element when compared over the 10 sampled projects.

The following graph displays the elements percentage of accuracy over the 10 sampled projects analysed:

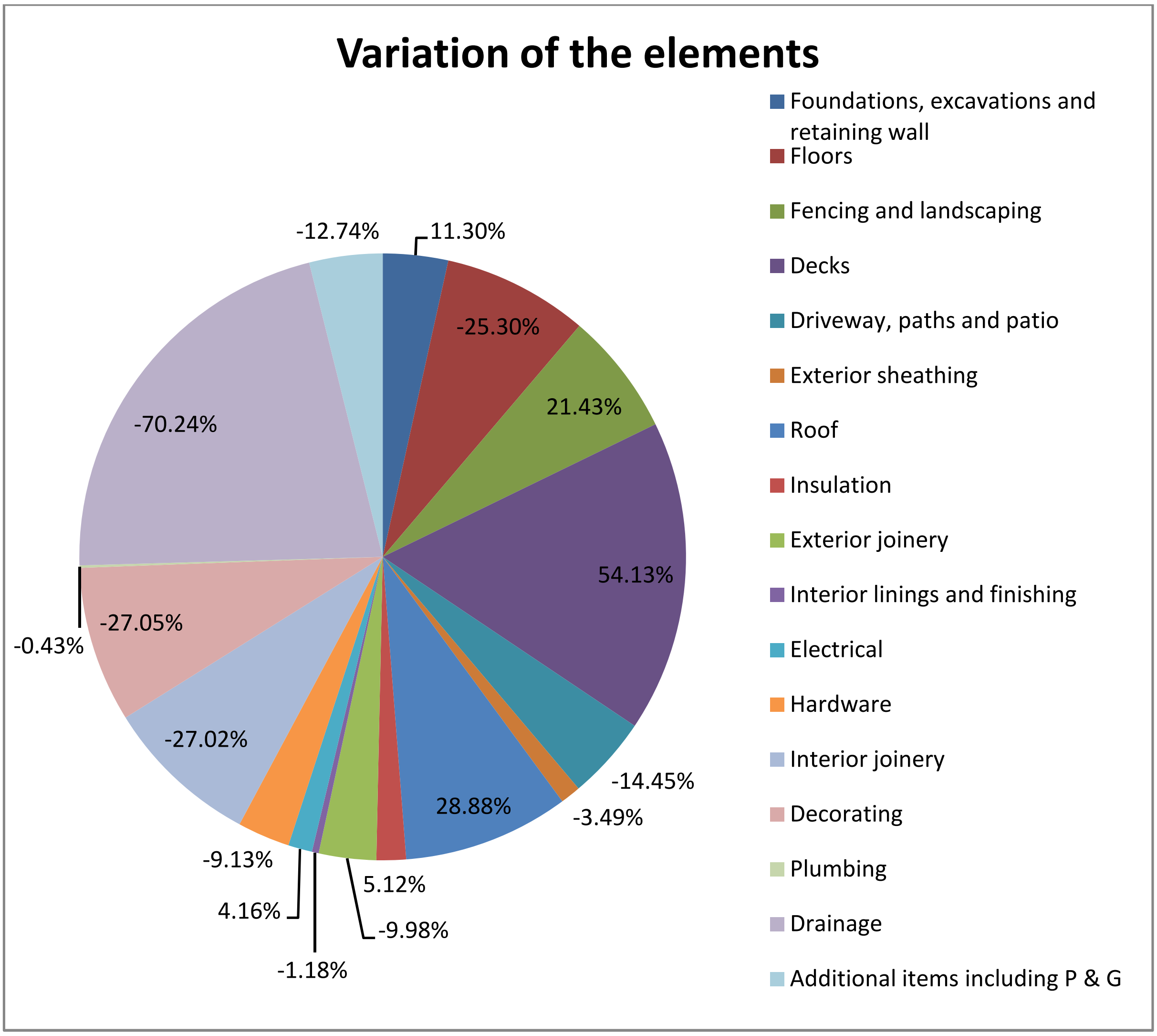

Figure 4: Variation of the elements

The elements with the highest discrepancies seem to be affected by the following influences:

- Selection of provisional sum expenditures
- Historical data validity
- Factors affecting the accuracy of the estimate
- Model house base rate

Selection of provisional sum expenditures

It is apparent that the projects which require provisional sums have either not been accounted for or inadequately estimated which led to under claiming from the client. This is a argument that Morrison (1984, p 59) had which was that the provisional sum expenditures when ignored, the estimating performance becomes remarkably inconsistent.

Historical data validity

Odusami and Onukwube (2008, p 1) explain that the estimating process is not a precise technical and analytical process, but to an extent, a subjective process where the estimator considers factors relevant to the successfulness of the project. The estimation over time, whilst only a sample representation, still shows that major elements such as floors, fencing and landscaping, decks, roof, interior joinery, decorating, and drainage require attention as the inaccuracies can be carried forward onto future projects and are costing the company money.

The accuracy of a project's construction costs, as emphasised by Liu and Zhu (2007, p 98), are extremely dependant on the source of quality historical data along with the expertise of the estimator. The projects, whilst only a small sample, seemed to display inaccuracies over a number of projects which would usually have been corrected by feedback processes. The historical data used displayed signs that it was not being updated and revisited after every project. This caused the inaccuracies to be carried forward onto new projects and further affected the margins of the contractor. The detail in the early stages of a project is limited and is based on the quality of the historical data and estimators' assumptions and/or judgements. With the lack of quality historical data, the information used is invalid and poses a risk of losing clients in the early stages or completing a project with a loss.

Factors affecting the accuracy of the estimate

The estimates seem to be affected by factors which are identified in the literature as having affected their accuracy. These have been identified by Liu and Zhu (2007, p 99) as control factors and idiosyncratic factors. The control factors are those that can be determined by the estimator to increase the performance of the estimation; however, the idiosyncratic factors are outside of the control of the estimator, and are those which require judgement decisions and expertise to facilitate so as not to risk a project. The case study company has displayed areas of judgement which have resulted in inaccuracies such as the drainage element. This may be a factor which is only influenced by the estimators' experience and expertise and can determine whether a project is successful.

Model house base rate

The majority of discrepancies and inaccuracies in the data analysed from the projects reinforced the argument which Akintoye (2000, p 78) had for the biggest factors that influence a projects cost estimating practice. These are complexity of design followed by the scale and scope of construction. The project which had the largest inaccuracy was an architecturally designed house that used the same method of estimation and the base rate of a standard model house. This seemed to be inadequate and simply outside of the scope of the construction.

An estimate is defined by the literature as a close forecast of what the actual cost should be, and the accuracy of the estimates are determined by the techniques and methods used. The case study company has employed only one method for every sampled project; this consists of a base rate created from the standard model house and then additions of 'extras' over the standard model house inclusions. This has proven to be accurate in some projects and inaccurate in others. Ashworth (2004, p 264) explains that the estimation is an important factor in a client's decision to build, as it determines the feasibility of a project. Therefore, the success of the estimates is dependant on the accuracy of their preparation. The projects, when dissected to the exact element costs, seemed to show inaccuracies and discrepancies which question methods and data used for estimation. The overall variation between the total budgets vs. actual cost of construction has a better representation of the accuracy of the projects.

The following graph indicates the variation of project accuracy over time for all 10 sample projects analysed:

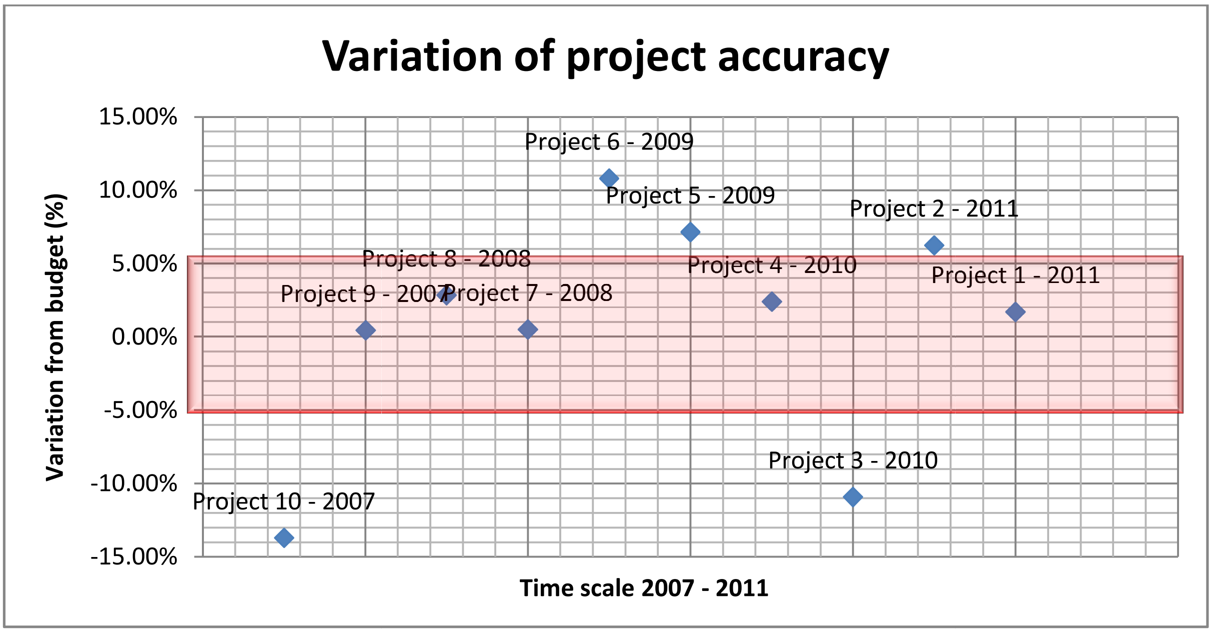

Figure 4: Variation of project accuracy

The red line is the bracket the projects aim for in order to be considered as an accurate project. The projects outside of this bracket are inaccurate in the sense that they are either over- or under-estimated. The under-estimates represent a loss, but the over-estimates, while they indicate a higher margin achieved by the contractor, are still inaccurate — and when estimating a project in the early stages, pose a risk to even obtaining the job from a client (Aibinu and Pasco, 2008, p 1257).

4.9 CONCLUSION

This chapter has discussed the data findings in terms of the similarities between the findings, differences between the findings, significant findings, and the actual findings compared with the literature. It investigated the inaccuracies and discrepancies in the data which drew discussions of where the issues have risen.

The significant findings consist of the actual data from the case study company backed by the literature theory as it relates to the research question to illustrate that the research question has been answered. Throughout the chapter, the issues with data collection and the process of analysing the data have been described to identify the flaws in the analysis. The overall comparison of the data findings has been critiqued and conclusions from the literature have been drawn to specify the similarities and differences in the case study company.

The findings and discussions in this chapter will be transferred into the following chapter to provide a complete conclusion for this research. The limitations of the research, recommendations for future practice, and future research areas derived from this research will also be presented.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

The results of this study indicate that there are indeed inaccuracies in the projects analysed. From the literature theories compared to the actual construction data and the author's interpretation of the data, the conclusion can be drawn that the process and the estimation of the projects' actual cost forecast is under-utilised.

Throughout the entire project, the variation between the budget and the actual costs seemed to fluctuate between an accurate and a very inaccurate project. When this is dissected into the elements, it shows that the historical data and quality of resource information used is not being updated and reviewed as frequently as it should be. This has resulted in inaccuracies in the elements which are then being carried forward into future projects. The technique and method of estimation of the case study company comprises a base GFA rate based upon a model house with additions of extra allowances for deviations from this standard house. From one of the most inaccurate projects, it is apparent that the base rate used is not valid when houses are architecturally designed as the scope of construction of a standard model house differs completely.

Where idiosyncratic factors such as the drainage element — where the uncertainty of the underground work and local authority requirements among other conditions — need to be considered in the early stages of a project, then the estimator must make decisions that will minimise, eliminate, or transfer the risk. The projects analysed showed that judgement has been made for selection of provisional sums when it is applicable and when it is not. However, in some projects this has resulted in the underestimation of a fixed price element, and as it is not a provisional sum, the risk is not transferred to the client where further payments can be claimed for the extra costs. This, while not completely certain based on the limited information collected, is a result of the estimator's expertise and experience which is one of the primary requirements for a successful project.

5.2 RECOMMENDATIONS

From this research, the discussions and conclusions have highlighted a number of areas where improvements can be made within the case study company in order to provide more accurate project estimates.

This residential construction company should consider a system of feedback processes which will comprise an analysis of projects' costs vs. their budgets to determine where the areas of inaccuracy are and make amendments to the pricing structure to correct the discrepancy. This can mean that the company will be able to see the factors that affect the estimates, and examine the level of risk that the estimate can have when incorrectly determined. This poses two advantages when the feedback system is in place: as a learning curve for juniors and even the seniors and as a procedure for improving the projects' margins to arrive on budget.

The case study company is working with only one method of estimation — using the standard model house base rate plus the addition of extra allowances required for the project. While this may be an effective process when adhered to correctly, it may only be valid when the house does not deviate from the existing design. Architecturally designed houses may require a more substantial estimation process which is also referred to as a traditional estimation method. This consists of each element having a complete cost and no base rate is applied. While this is a more time-consuming task, it will provide a more accurate indication of the project's actual cost forecast.

The estimators' experience and expertise is one of the primary requirements for a successful project, so these suggestions for improvement may only be considered as a process similar to the feedback system to train the juniors by looking at past mistakes, discrepancies, inaccuracies, factors for estimation, and the methods to be employed when estimating. While change does not happen overnight, this can provide a starting point for estimators to establish a routine for reviewing all projects after completion.

5.3 Limitations

All research papers, journals, and books used to understand the literature theory behind the estimating practice originated outside of New Zealand. This literature was also based mostly on a general or commercial sector interpretation which can be argued to be limited in relevance to the New Zealand residential construction industry.

The data divulged in the data findings chapter is not a proper representation or presentation of the actual costs vs. budget value variations as the values are shown not as a dollar value but as a percentage difference. In some instances, the percentage difference is dramatic in the sense that while it is a minor variation in terms of a dollar value, it actually shows as a high percentage of deviation.

This study did not distinguish the estimator's perceptions or the case study's estimators experience and expertise; therefore, the conclusions given for inaccuracies due to this are only from observation of the data findings.

This study, while specifically concentrated on the case study company, is only limited to this; it is not a representation of the entire construction industry or even the residential construction industry.

5.4 FUTURE RESEARCH

There has been little or no research into the accuracy of estimation in New Zealand — and especially in the residential sector. The literature is focused overseas, and based on the literature analysed and considered when compiling the data of the project, there is a gap which can be filled with future research.

Further research to identify the factors that the estimator considers and the process of how the estimates are arrived at would benefit the New Zealand residential construction industry. This could pinpoint the very issues in the estimates which are affected by the idiosyncratic factors. Currently, the industry is somewhat reliant on theory-based literature, and there has been no empirical analysis of the estimator's perceptions and judgements on the estimating influences.

Also, further research into alternative methods of estimation that a residential construction company can employ could be very beneficial as the current method that the case study company is using is limited in versatility. There are obvious problems for projects which step outside the scope of the model house. Resolving this would increase the likelihood of companies ensuring budgets are achieved and the client getting value for the money estimated.

These suggestions for further research would provide a better understanding of estimation as a practice of forecasting the actual construction costs. It will not only benefit the case study company by improving on the current system they are working with, but would also provide the industry with an example of how one company is carrying out the estimation practice.

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APPENDICES

APPENDIX 1: TABLE 14: LITERATURE REVIEW MATRIX

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Aibinu, A. A. and Pasco, T.	The accuracy of pre-tender building cost estimates in Australia	2008	To investigate characteristics influencing the accuracy of pre-tender building cost estimates for practical improvement	Quantitative case study on 102 quantity surveying firms	Australia, estimating accuracy, pre-tender estimates, quantity surveying, tendering	Accuracy of estimating in the early stages of design comprising of two aspects, bias and consistency of the estimate when compared with the contract or tender price	Accuracy of estimating, factors affecting estimating accuracy, reducing inaccuracies	Accuracy of estimating, feedback and review of accuracy Factors affecting the accuracy of cost estimating
Akintoye, A.	Analysis of factors influencing project cost estimating practice	2000	To gain an understanding of the factors involved in costing construction projects	Two Qualitative case studies	Cost estimate, factor analysis, tendering, cost estimate	Importance of cost estimating when trying to determine the bottom line figure for direct costs to be incurred	Factors affecting estimating Mark up and adjudication of net cost estimates	Factors affecting the accuracy of cost estimating

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Ashworth, A.	Pre-Contract Studies: Development Economics, Tendering and Estimating	2002	Aspects of pre-contract phase of building development, excluding the actual design process	Qualitative case study	Estimating, design economics, tendering, quantity surveying, accuracy of bids	Cash budgeting and interpretation of financial data, project construction costs Forecasting construction costs	Forecasting construction costs, accuracy of predicting construction costs with changes in scope	Accuracy of estimating, Estimating to a budget, Value of historical data
Ashworth, A.	Cost Studies of Buildings	2004	Understanding and application of costs to building and other structures Ensure that scarce and limited resources are used to the best advantage	Qualitative case study	Cost planning, pre-tender estimating, price forecasting, cost control, value for money	Cost planning, importance of cost control, construction economics, pre-tender estimating, accuracy and consistency, cost and price analysis	Accuracy of estimating, pre-tender estimating, construction economics	Accuracy of estimating, quality of estimates
Azhar, N., Farooqui, R. U., Ahmed, S. M.	Cost Overrun Factors In Construction Industry of Pakistan	2008	Identify the issues involved in cost overruns in construction projects in Pakistan	Qualitative case study	Cost overruns, macro economic factors, management factors	42 key factors that affect the accuracy of estimating construction costs	Factors for cost overruns, accuracy influences	Factors that affect the accuracy of estimating
Cheung, F. K. T., M. W. L. Wong, et al.	A study of clients' and estimators' tolerance towards estimating errors	2008	To study estimating practice and in particular the attitude of clients and estimators towards estimating errors	Qualitative case study	Expert judgement, cost planning, client, accuracy, survey	Characteristics of good estimates, client and estimators being risk adverse, tolerance for overestimating and underestimating	Under estimating, over estimating, tolerance for error, accuracy of measurement	Accuracy of estimating, Estimators experience, pricing risk

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Choon, T. T., Ali, K. N.	A Review of Potential Areas of Construction Cost Estimating and Identification of Research Gaps	2008	To comprehend the various types of cost modelling, effective cost control and development for forecasting	Qualitative case study	Cost modelling, cost estimating, building construction	Standard methods of calculation, procedures for estimating, reliance in early stage estimating	Early stage estimation using cost models	Forms of estimating, estimating process and methods
Clough, R.	Construction contracting	1986	Resource for construction professionals in the industry for successful management of construction	Qualitative case study	Construction methodology, contracting, pre-tender estimating, sub contracting	Forms of estimating techniques, methodology of construction contracting	Types of estimating and uses for them	Forms of estimating
Dysert, L. R.	Sharpen Your Cost Estimating Skills	2003	To discuss estimation methodologies from conceptual to definitive estimates	Quantitative case study	Capital budgets, projects, cost estimates, estimation methodologies	Parametric cost estimation as a tool for preparing early conceptual estimates when very little information is given	Parametric estimating, early design estimating	Pre-tender estimating, experience of the estimator, forms of estimating

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Dysert, L. R.	So You Think You're an Estimator?	2005	To identify the estimating methodologies that can be used to prepare early stage estimating	Qualitative case study	Cost estimates, magnitude estimating, estimating methodologies	Conceptual estimating techniques using: capacity factoring, parametric modelling, end product unit methods, analogy and expert judgement	Conceptual estimating techniques, estimating methodology, accuracy of estimates	Accuracy of estimating, factors affecting the accuracy of estimates, forms of estimating
Dysert, L. R.	Is "Estimate Accuracy" an Oxymoron?	2006	A study for the predictive process used to quantify cost and price resources required in construction project	Quantitative case study	Estimating, accuracy of estimating, forecasting, prediction of construction costs, risk analysis and contingency estimating	Economic feasibility of a project by evaluating between project alternatives and project cost/schedule control	Topic debate on estimating accuracy	Accuracy of estimating forms of estimating, definition of estimating, definition of accuracy
Elhag, T. M. S., Boussabaine, A. H., Ballal, T. M. A.	Critical determinants of construction tendering costs: Quantity surveyor's stand point	2005	Identification of cost determinant variables and evaluation of their degree of influence when estimating	Quantitative case study	Cost influencing factors, pre-tender estimates, and construction projects	Cost estimation as an experience based process and practitioners being aware of uncertainties, incompleteness and factors affecting construction costs	The use of feedback systems and the factors which influence the estimating practice	Feedback and review of accuracy, factors affecting the accuracy of estimating

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Enshassi, A. and Mohamed, S. and Madi, I.	Cost Estimation Practice in the Gaza Strip: A Case Study	2007	A study of the fundamental part of construction practice for estimation for implications for influences	Quantitative case study	Cost estimation, accuracy, contractors, economy	Factors and their influences on construction cost estimating practice and the ranking	A compilation of factors that affect construction cost estimates in the Gaza strip	Factors affecting the accuracy of estimating
Flanagan, R. and Norman, G.	The accuracy and monitoring of quantity surveyors' price forecasting for building work	1983	Examines the performance of two quantity surveying departments when forecasting the tender price for proposed projects at design stage	Two Quantitative case studies	Price forecasting, accuracy, monitoring, quantity surveyor	Feedback mechanism, reliability of price forecasting using historical data , professional skill and judgement	Accuracy of estimating, feedback mechanism for improving estimating	Accuracy of estimates, feedback and review of accuracy
Gunner, J. and Skitmore, M.	Comparative analysis of pre-bid forecasting of building prices based on Singapore data	1999	Analysis of bias and consistency in designers price forecasts	Quantitative case study	Accuracy, building , estimating, pre-bid estimates, statistical analysis	Consistency attained in practise in the aspect of designers price forecasts Accuracy of estimates monitored and systematic errors improved	Accuracy of estimating, bias and consistent estimate forecasts, forecasting techniques, estimator capabilities	Accuracy of estimating, feedback and review of accuracy

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Henderickson	Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects, and Builders	1989	The processes and techniques of project management for construction from life cycle, cost estimation and performance	Qualitative case study	Project management, construction fundamentals, life cycle costing, conceptual design estimation	Design and bid estimates, the planning and various estimation for design stages which reflect the progress of design	Split type of estimate being the conceptual estimate and detailed estimate which are commonly recognised	Forms of estimates
Liu, L., and Zhu, K.	Improving cost Estimates of Construction Projects Using Phased Cost Factors	2007	Critically assess the accurate prediction of construction costs when using quality historical data for information dependence	Qualitative case study	Cost estimates, construction projects, phased cost factors, cost modelling	The value historical data has along with the dependence estimators have on quality data	The heavy reliance on historical data when estimating	Use / Value of historical data, Accuracy of estimating
Lowe, D. and Skitmore, M.	Experiential learning in cost estimating	1994	Investigates experimental learning theory and the current perception of experimental factors in the accuracy of pre tender cost prediction	Quantitative case study	Cost estimating, experience, experimental learning, feedback, quantity surveyor, expertise	Importance of experience in pre-tender estimating practice Experiential learning to improve cost estimating over 8 methods	Estimator experience, accuracy of estimating	Accuracy of estimates, Estimators experience, Review accuracy of estimating, feedback on estimates

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Morrison, N.	The accuracy of quantity surveyors' cost estimating	1984	Examines the accuracy of cost estimates prepared by quantity surveyors during the design stages of construction projects	Quantitative case study	Cost estimating, cost planning, accuracy, variability, quantity surveyor	Accuracy of data used from historical data, improvement of cost performance through controlling influences of estimates	Accuracy of historical data, factors and influences of cost estimating	Use and value of historical data, factors affecting the accuracy of estimating, estimating accuracy review
Odusami, K. T. and Onukwube, H. N.	Factors Affecting the Accuracy of a Pre-Tender Cost Estimate in Nigeria	2008	To access the factors affecting accuracy of pre-tender cost estimates	Quantitative case study on 50 randomly selected quantity surveyors	Consultants, cost estimate, construction, design, quantity surveyors	Factors affecting the accuracy of pre-tender estimating	Accuracy of estimating, estimators expertise	Estimators experience, Factors affecting the accuracy of estimating,
Ogunlana, O.	Learning from experience in design cost estimating	1991	To aid learning from experience in design cost estimating practice	Qualitative case study	Design cost estimating, accuracy, learning, experience, feedback, stable, development	Learning from experience through awareness of errors/mistakes, determination of what is to be learnt	Feedback, learning from past estimating mistakes, concept of awareness of errors	Feedback and review of accuracy, Experience of the estimator
Shane, J. S. and Molenaar, K. R., Anderson, S. and Schexnayder, C.	Construction Project Cost Escalation Factors	2009	To assess escalation factors when assessing future project costs and mitigate the influence of factors to improve accuracy of cost estimates	Qualitative case study	Construction costs, estimation, construction management, planning	Accuracy of estimating from inception to initiation Cost escalation factors for internal and external influences	Accuracy of estimating, cost escalation factors	Factors affecting the accuracy of cost estimating, accuracy of estimates

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Shash, A. A., Ibrahim, A. D.	Survey of Procedures Adopted by A/E firms in Accounting for Design Variables in Early cost Estimates	2005	Investigate the techniques that are used by architectural engineering firms for forecasting the early cost estimates of residential buildings	Qualitative case study	A/E firms, Design variables, Early cost estimates, estimating techniques	The variables that estimators consider when estimating for work	Factors that affect and influence the decisions that estimators have on residential construction projects	Factors that affect the accuracy of estimating
Skitmore, R.	The accuracy of construction price forecasts A study of quantity surveyors' performance in early stage estimating	1990	To provide an understanding of estimates on the market price of construction contracts	Qualitative case study	Construction costs, cost forecasts, early stage estimating, quantity surveyor	The quality of cost forecasts to be accurate to the market rate, Influences on bias and consistent estimating	Cost forecasting, estimating techniques, market cost targets	Estimating techniques, forms of estimating, Use of historical data
Skitmore, R. M. and Marston, V.	Cost modelling	1999	Understanding of the various types of cost model for effective cost control and development of future forecasting techniques	Qualitative case study	Cost modelling, price forecasting, quantity surveyor, bidding techniques	Pre-contract monetary evaluation of building design Parametric estimating where historical data with adjusted factors are used	Cost modelling, price forecasting, parametric estimating	Use of historical data, factors affecting the accuracy of estimating

Author	Title	Year	Aims/Objectives	Methodology	Key words	Key findings	Comments	Themes
Stoy, C. and Pollalis, S. and Schalcher, H. R.	Drivers for Cost Estimating in Early Design: Case Study of Residential Construction	2008	To identify cost drivers for buildings during the early stages of design	Quantitative case study of 70 German residential properties	Cost estimating, early design estimation, residential construction, cost control	Variables and influences of estimating during the early design stage	Factors and variables that affect estimating practice	Factors that affect the accuracy of estimating
Trost, S. M. and Oberlender, G. D.	Predicting Accuracy of Early cost Estimates Using Factor Analysis and multivariate Regression	2003	Understanding of the accuracy of conceptual cost estimates for capital projects	Quantitative case study	Cost estimates, construction industry, decision making, methodology	Initial decision making on early stage estimates also known as conceptual estimating	Early stage estimating and the difficulty to obtain data for detailed estimating	Factors affecting the accuracy of estimating, forms of estimates