THE ACCURACY OF PRELIMINARY COST ESTIMATES IN PUBLIC WORKS DEPARTMENT (PWD) OF PENINSULAR MALAYSIA

MOHD AZRAI BIN AZMAN

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Name of Candidate: **MOHD AZRAI BIN AZMAN** (I.C/Passport No: **840305-02-5623**)

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ABSTRACT

Public Works Department (PWD) is the largest public construction management in Malaysia. Preliminary cost estimate is prepared before a public project is carried out. It is used as a reference for the amount required for funding. Quantity Surveyors (QS) prepare the estimates before the design is completed. Accuracy of estimates is affected by pricing behaviour of quantity surveyors in relation to a number of factors. Preliminary cost estimate prepared by PWD involves public money, so continuous improvement is needed on the existing practices. The study analyses the factors that affect the accuracy based on 83 data collected from additional school projects and responses from 157 respondents from both public and private sectors. The questionnaires sent aimed to identify approaches that can improve estimating accuracy. In addition, this study explores the reliability of the alternative estimating method based on linear multiple regression method (MRM) using the project data. Comparisons are made on lowest bid, accepted bid and mean of the bids as the targets to measure accuracy of estimates. The data analysis uses several quantitative methods to examine the research questions. Findings show the estimates were overestimated with bias of 10.88% and consistency of 9.54% cv. Bias in the estimates was significantly affected by project size, number of bidders, location and types of schools. Contract period also affects the consistency. It was found the mean of the bids is the best linear model to describe the bias in the estimates and MRM is more accurate than the traditional area method. Design scopes, cost data, location and experience are perceived by QS as important. Quality of information supplied to the QS is one of the important areas that need to be improved. Investing in human resource, sharing cost data and introduction of the standard guidelines for estimating are recommended.

ABSTRAK

Jabatan Kerja Raya (JKR) adalah entiti pengurusan pembinaan awam terbesar di Malaysia. Anggaran kos permulaan disediakan sebagai petunjuk jumlah wang yang diperlukan untuk pembiayaan projek. Juruukur Bahan (QS) menyediakan anggaran sebelum rekabentuk selesai. Ketepatan anggaran dipengaruhi oleh tingkah laku penetapan harga oleh QS berkaitan dengan faktor-faktor tertentu. Anggaran kos ini melibatkan wang awam. Oleh itu, penambahbaikan berterusan diperlukan untuk meningkatkan amalan sedia ada. Kajian ini menganalisis faktor-faktor yang mempengaruhi ketepatan menggunakan 83 data projek sekolah tambahan dan 157 responden dari sektor awam dan swasta. Soal selidik bertujuan untuk mengenal pasti pendekatan yang boleh meningkatkan ketepatan anggaran. Kajian ini juga meneroka kebolehpercayaan kaedah alternatif berdasarkan model garis lurus regresi berbilang menggunakan data projek tersebut. Kajian ini membandingkan penggunaan tawaran paling rendah, tawaran diterima dan min tawaran sebagai sasaran ketepatan anggaran. Beberapa kaedah kuantitatif digunakan untuk menjawab soalan penyelidikan. Penemuan menunjukkan anggaran adalah terlebih kira dengan kesilapan sebanyak 10.88% dan kekonsistenan sebanyak 9.54% cv. Berat sebelah yang ketara dipengaruhi oleh saiz projek, bilangan pembida, lokasi dan jenis sekolah. Tempoh kontrak mempengaruhi konsistenan anggaran. Min tawaran pembida adalah model garis lurus terbaik untuk menerangkan berat sebelah dalam anggaran. Model regresi berbilang adalah lebih tepat berbanding kaedah kawasan tradisional. Skop reka bentuk, kos data, lokasi dan pengalaman dianggap penting. Kualiti maklumat diberikan kepada QS adalah salah satu perkara penting yang perlu dipertingkatkan. Melabur dalam sumber manusia, perkongsian data kos dan pengenalan garis panduan standard untuk menganggarkan kos adalah disyorkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
ANOVA	Analysis of variance
ATDA	As Tendered Detailed Abstract
BIM	Building Information Modelling
BRB	Building Research Board, United States
CKUB	Contract and Quantity Surveying Branch, Public Works Department
CV	Coefficient of variation
EPRI	Electric Power Research Institute
GFA	Gross Floor Area
HODT	Head of Design Team, Public Works Department
HOPT	Head of Project Team, Public Works Department
m^2	Metre square, unit of area in the International System of Units
MRA	Linear Multiple Regression Analysis
MRM	Linear Multiple Regression Cost Model
MOF	Ministry of Finance, Malaysia
$\eta 2$	Partial eta-squared
N9	Negeri Sembilan (State of Malaysia)
NRC	National Research Council, United States
PDA	Preliminary Detailed Abstract
PI	Price Intensity Theory or Price Intensity (cost/m2GFA)
PWD	Public Works Department
QS	Quantity Surveyor or Quantity Surveyors
RII	Relative Importance Index
RM	Malaysian Ringgit, currency of Malaysia
SD	Standard deviation
UK	United Kingdom
US	United States of America
VOP	Variation of Price for selected building materials

CHAPTER 1: INTRODUCTION

The government often considers preliminary cost estimates as the cost limit of projects. Estimates are based on size and functional unit of buildings using cost indicators of similar projects (Morton & Jaggar, 1995). It depends on information gathered at early design stage. It ensures projects are built according to desired quality, in accepted time and within budget (Karlsen & Lereim, 2005). Chappell, Marshall, Power-Smith, & Cavender (2001; 149) describes the general term of early estimates:

> *"Colloquially and in the industry generally it means 'probable cost' and is then a judged amount, approximate rather than precise"*

Seeley (1996; 154) describes the QS consultants' standpoint on preliminary cost estimates:

> *"The primary role of estimated or preliminary estimating is to produce a forecast of probable cost of a future project, before the building has been designed in detail and contract particulars prepared. In this way the building client is made aware of his likely financial commitments before extensive design is undertaken"*

Common term for estimating and bidding (Skitmore, 1988; 2):

> *"Estimating is the process of working out likely costs and bidding is the process of converting an estimate into a tender price".*

Architects' responsibility during tender stage (Chappell, et al., 2001; 7):

> *"It is important for architects to make sure that they work within the budget by having regard to the quantity surveyor's estimates of cost".*

Standard and cost guideline prepared by the government is to ensure value for money. This standard states the general requirements and features for planning i.e. space per pupil as the standard for school buildings (Morton & Jaggar, 1995). This ensures the users' needs are established unlike in private sectors where the needs are defined by profit (Ferry, Brandon, & Ferry, 2007). Normally, the Public Works Department (PWD), which is the largest construction management organisation in Malaysia, supervises the public projects (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004). The design and planning must conform Standard and Cost Guideline prepared by Standard and Cost Sub-committee of Economic Planning Unit (EPU) under the Prime Minister's Department. This guideline provides the standard practice for land use, schedule of accommodation and standard general spaces (Prime Minister's Department, 2005). However, not all projects require this guideline. Projects, which are not exceeding RM 5.0 million for construction and rental not exceeding 465m2GFA, are not required to follow the guideline. The purpose of this guideline is to instil the importance of cost saving for planning, design and implementation of projects. It provides maximum benefits within reasonable cost (Prime Minister Department, 2005). Preliminary Cost Estimates are prepared according to initial design forwarded by various ministries or other government agencies. The estimates are prepared in order to ensure the budget of projects is sufficient.

Cost estimates are not an exact science, but it needs knowledge of construction and common sense in order to have accurate estimates (Peurifoy & Oberlender, 2006). Sinclair, Artin and Mulford (2002) point that a 100% estimating accuracy is not achievable since it involves the consideration of probabilities, risks and other factors. The early cost advice of public funded projects is essential because budget constraint will limit the capacity of government to spend (Morton & Jaggar, 1995). In addition, estimates provide the basis for budgeting and cost control for construction projects. If the estimates are too low, the proposed project design could be abandoned, and it may also lead to a lawsuit (Ashworth, 2010). The role of preliminary cost estimates is essential to government procurement activity. Therefore, the accepted levels of accuracy are very important. The selection of contractors vis-à-vis government budget constraint depends on the estimates presented. The factors that influence the accuracy of estimates will be studied. In addition, this study looks into ways to improve the accuracy of estimates.

1.1 Problem background

Currently, only a few number of researches on cost estimating conducted in Malaysia. This shows the research area has a very large gap if compared to developed countries. In the UK, extensive research started as early in 1980s when a number of postgraduate students e.g. Barnes, Flanagan, McCaffer, Morrison, Ogunlana, Skitmore, Stevens and others completed their PhD thesis on cost estimate and bidding. They have contributed a lot of high impact cost estimating researches. Only a few number of researches in Malaysia used project data i.e. PhD thesis by Ng (2007) on probabilistic estimating method, Bachelor degree dissertation by Kiew (2009) on cost estimate accuracy in Sarawak and journal paper by Chan (2001) on the prediction of contract period. Others did not used project data to offer empirical evidences as they were prepared mainly for introductory research papers.

One of the problems facing Quantity Surveyor is the suitability of tender prices submitted by bidders if compared to the estimates prepared by QS. There will be disagreement in determining the level of prices before it is accepted (Ashworth, 2010). There are various researches conducted on the accuracy of estimates. In construction industry, the transaction is made through tendering procedures and the cost must be estimated in advance (Runeson, 2000). The project stakeholders need to know the possible cost of the project before making monetary investment. The actual cost is known after the project is completed but investment decisions need to be made before the construction begins.

The drawback of traditional estimates is that only a single amount of estimates present to clients (owner of the project). It contradicts the rationale of estimating as the estimates could give different possibilities and there should be a level of accuracy presented to the clients (Cheung & Skitmore, 2005). This approach does not show the range of possible accuracy and the pricing of risks (contingencies) (Ashworth, 2010; Karlsen & Lereim, 2005; Mak, Wong, & Picken, 1998; Picken & Mak, 2001). Raftery proposes the use of a probability curve in order to measure the probable accuracy of the estimates (Skitmore, 2002). The clients should be advised based on the factual parameter of estimating accuracy, as this would ensure the reliability of his estimates scientifically.

The estimates are influenced by a number of variables (Ashworth, 2010; Morton & Jaggar, 1995). Different methods of procurements and lack of basic information can also influence the accuracy of estimates (Hughes, Hillebrandt, Greenwood, & Kwawu, 2006). Intercorrelation among variables could result in confounding effect (Gunner &

Skitmore, 1999b). Limited time to prepare estimates and incomplete design scopes could result in inaccurate estimates (Aibinu & Pasco, 2008; Akintoye, 2000). Overestimation will lead to the tender being unacceptable to the client and underestimation will result in the contractors losing money (Akintoye, 2000; Odusami & Onukwube, 2008). To resolve these issues, PWD could recommend design amendment or the allocation of more budget (Public Works Department, 2010a). Even so, these recommendations do not resolve the inaccurate estimation. Preliminary cost estimates must be prepared using reliable estimating methods. Budget must be ready before project is implemented. Thus, inaccurate estimates could result in resource mismanagement. However, clients are more tolerated to overestimation of preliminary cost estimates (Cheung, Wong, & Skitmore, 2008).

Currently, there are two (2) types of estimating methods used by PWD which are single rate method and estimated quantities Both are prepared using Preliminary Detailed Abstract Form PWD142 (Ministry of Finance, 1958; Public Works Department, 2010a). Nevertheless, other alternative estimating methods could provide a more reliable and quick estimates (Skitmore & Patchell, 1990). PWD has introduced a method of selecting acceptable prices for projects by using “cut-off method”. This is to reduce underpriced suicidal bids. This method is derived from the calculation of the “average bid method” in order to select acceptable tender prices for open tender (10 bidders or more). Nevertheless, projects for less than 10 bidders i.e. selective tender and direct negotiation used other basis of selection. “Cut of method” was introduced to public procurements because PWD is sceptical with the reliability of its estimates and the bidders’ pricing errors (Public Works Department, 2004, 2005). This indicates the estimates prepared by PWD are more likely to be inaccurate. There are a number of targets that could be used to measure the forecast quality but not all researchers have same view on this (Skitmore, 1991). They are mean of the returned tenders (mean of the bids), lowest bid and designers' judgement (accepted bids).

Estimates provided to PWD could be from internal or external sources. PWD may engage private consultants QS to provide the department with the estimates (Ministry of Finance, 1958). The main reason for outsourcing is the restriction to employ more staff while public expenditure is growing (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004). Cost estimates could be influenced by different managements and firms' competencies (Morrison, 1984). The use of different sources of estimates could provide the PWD with a different quality of estimates. In public procurement, preliminary cost estimates are subjected to standard cost guideline issued by the Economic Planning Unit under the Prime Minister Department (Economic Planning Unit, 2005). Ministry of Finance (MOF) as project financier approved the cost limit (Ministry of Finance, 1958). The cost limit is supported by preliminary cost estimates prepared. Thus, estimates are important decision tools for public agencies to predict market price value of the project.

1.2 Problem statement

Park and Chapin (1992) suggest +/- 5% deviation from the mean of submitted tenders as accurate. Ashworth (2010) considers that margin of +/- 10 is appropriate when Bills of Quantities is used. Studies from countries such as the UK, Singapore, Australia, Hong Kong, United States and Belgium show different outcomes (Aibinu & Pasco, 2008; Ashworth & Skitmore, 1982; Skitmore & Drew, 2003; Skitmore & Picken, 2000). The bias varies according to its location. Studies show QS are normally overestimated the estimates.

A study made in Australia shows the accuracy of QS' estimates did not improve overtime (Aibinu & Pasco, 2008). A recent data of 43 contracts collected from Quantity Surveyor Consultants in Sarawak shows the error of estimates was 5.35% and the coefficient of variation 7.35. Most of the time, QS overestimated the estimates (Kiew, 2009). QS consultants in Sarawak are quite accurate with their estimates but it could be caused by the use of accepted bid as the target. This study allows the comparison between the performance of QS in Malaysia and other countries to be made. Estimates are influenced by location factor and the person who provides the estimates (Skitmore, 1991). As usual, lowest bid is the target to measure the accuracy in most countries because most clients prefer the lowest bid due to competitive price. In addition, the best model for price prediction is the model, which is able to predict the lowest price. However, there are some problems because lowest bid is not always be accepted because of the suicidal prices (Skitmore & Lo, 2002). The use of accepted tender bids may be influenced by QS and not done independently (Skitmore, 2010). The use of different targets to measure quality of estimates could give an entirely different result.

Effects from project characteristics produce different range of errors. This happens because of the systematic bias during the preparation of estimates. It is also because of imprecise process and subjective decision (Ashworth & Skitmore, 1982). These project characteristics include building functions, conditions of contract, basis of selection, contract sum, price intensity theory, contract period, number of bidders, good and bad years, project sector and location (Skitmore, 1991). In Sarawak, types of projects and contract period affect the bias of cost estimates. Consistency of estimates is affected by type of project, project value, year, type of client and types of works (Kiew, 2009). Nevertheless, the sample collected was not large enough to allow parametric assumptions. According to Serpell (2004), in theory, the accuracy is affected by scope quality, information quality, uncertainty level and QS performance. In addition, inaccurate estimates could happen because of deliberate QS bias during estimation rather than due to random effect (Flyvbjerg, Holm, & Buhl, 2002). They explain that bid price by a contractor for infrastructure project is more likely to be underestimated during bidding because public client prefers cheaper prices. All these factors could influence the outcome of estimating accuracy, and this study could address some of these factors.

This study looks into the factors, which affect the accuracy of estimates and the ways to improve the policies and procedures of estimating practices in the PWD. The significance of these factors could provide the QS with a new knowledge to overcome the inaccurate estimates. The current estimating procedures will remain the same. Most QS are not willing to change into new ways of preparing the cost estimates (Fortune & Cox, 2005; Raftery, 1991). Nevertheless, researchers have proven that the alternative estimating methods are more reliable than the traditional methods (Butts, 2006; Li, Shen, & Love, 2005; Lowe, Emsley, & Harding, 2006). In addition, improvement methods to certain estimating process are the ways to improve the current procedures. This study suggests the introduction of new approaches in the near future for long-term improvement. The clients in the UK are not satisfied with cost advice from Quantity Surveyors (Jackson, 2002). This leads to the development of new cost models and approaches to deal with uncertainties. Some said the traditional cost models have failed to achieve the required accuracy (Cheung, et al., 2008). Flyberg et al. (2002) point out that underestimation of biddings by contractors is at same level for years even though new estimating methods and approaches are available. The PWD on the government behalf could hire these consultants to provide preliminary cost estimates. Only 57.8 % of QS consultants met the expectation to complete this task (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004). Study made in Singapore by Ling and Boo (2001) show the expected accuracy assured by QS are way off from the true values when compared to analyzed samples. This shows the need to examine the sample of projects in order to assess the level of estimating accuracy.

1.3 Research questions

1. What are the factors, which affect the accuracy of preliminary cost estimates?

2. What approaches can improve the problems related to inaccurate estimates?

3. To what extent the project characteristics, measures of target, elemental costs, contingencies and variation of price and other theories could significantly affecting the preliminary cost estimates prepared by the PWD?

4. How reliable is the estimating using linear multi regression method (MRM)?

5. How accurate are the preliminary cost estimates prepared by PWD?

1.4 Aims

This research attempts to contribute to the understanding of the pricing behaviour of quantity surveyors in relation to the factors, which affect the accuracy of preliminary cost estimates in PWD. The results from this research could assist the PWD in preparing the estimating policies and procedures. Thus, it could improve the quality of Preliminary Cost Estimates in the department.

1.5 Objectives

1. To identify the factors which affect the accuracy of preliminary cost estimates.

2. To identify the ways that can enhance the accuracy of the estimates.

3. To explore project characteristics, measures of target, elemental costs, contingencies and variation of prices that influence the accuracy of the preliminary estimates.

4. To explore the reliability of the linear multiple regression estimating model (MRM).

5. To evaluate the accuracy of preliminary cost estimates in Public Works Department of Malaysia.

1.6 Scope

This dissertation focuses on the accuracy of preliminary cost estimates in the PWD. Primary data of "Preliminary Detailed Abstract (PDA)" and "As Tendered Detailed Abstract (ATDA)" were collected from completed additional school projects. All projects are from Peninsular Malaysia. Refurbishment and rental projects were excluded to limit the scope of the research. Data analysis does not use other types of project due to limited data. This research looks for the differences of accuracy in different types of schools (primary and secondary school) and types of buildings (main and ancillary buildings). The data collected is from 1st quarter of 2007. This research looks into the contingencies and Variation of Price (VOP) in the PDA and ATDA and how they could influence the accuracy levels. The PWD design department designed these projects. This research makes comparisons among lowest bid, accepted bid and means of the bids as the estimating targets to measure the quality of estimates.

This research looks into factors, which affect the accuracy of estimates and ways to reduce the inaccuracy. Thus, questionnaires were sent to staff of Contract and Quantity Surveying Department of PWD (CKUB)[1] and private quantity surveying consultants hired by PWD. The reason to include private QS consultants in this study is because the PWD also hires them and any changes in estimating policies could affect their performance. The cost data available from accepted bid creates the MRM for estimating. This study tests the model against holdout samples for cross-validation purpose in order to measure its reliability.

[1] Malay acronym.

1.7 Significance of the study

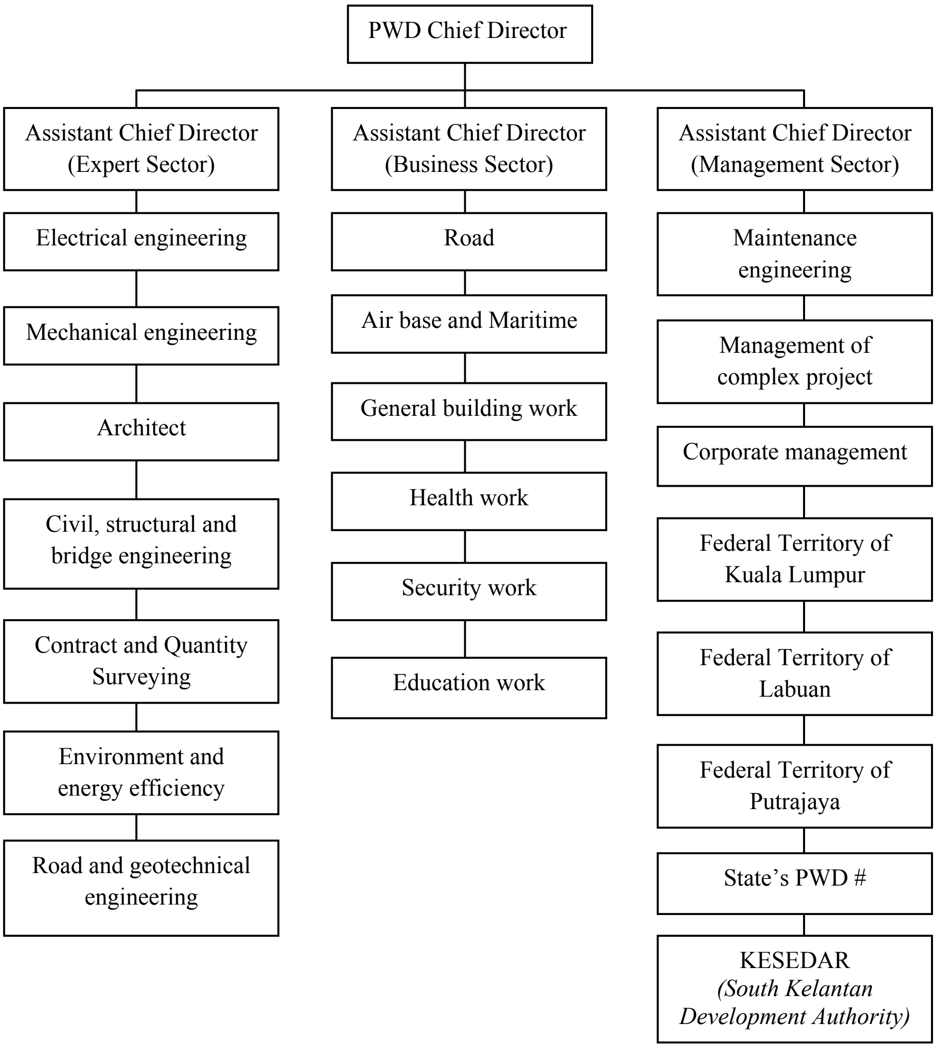
The significance of this research gives us the parameter of accuracy of estimates by comparing this study to previous researches from other countries. The decision maker should be advised realistically. This is because estimates could lead to different possibilities rather than a single deterministic value. This provides the QS in PWD the important factors, which influenced the accuracy of estimates. This research helps the QS to understand the nature of accuracy and its reliability. It could help the decision maker to make the decision based on the various factors. This research also looks into how the QS allocated the contingencies and Variation of Price (VOP) in their pricing. It is very important for QS in PWD to establish acceptable sums for these allocations accordingly during the preparation of estimates. Estimating targets used to measure the forecast quality are essential as they measure the estimating quality. Lowest bid, accepted bid and mean of the bids could be used as a target to measure the accuracy. It is predicted that these estimating targets give different results of accuracy levels. This research studies in depth the difference of different estimating targets. One of these could be the best to explain the systematic biases that happen during estimation.

Besides, this study presents the systematic bias in the estimates. We will know how the accuracy differs according to project characteristics. In addition, the new approaches to improve accuracy can offer the QS in PWD the steps to improve the current estimating procedures and policies. The price intensity theory (PI) could be a significant factor which affects the accuracy of cost estimates (Gunner & Skitmore, 1999b). Estimating model made from linear multiple regression explores the reliability of using alternative estimating method. The result obtained may give the possibility of using this method in PWD. The outcomes of this study are different because of the differences in location and organisation studied. The results of this research could improve the accuracy of Preliminary Cost Estimates prepared by PWD. Hopefully, it may help PWD in the formulation of policies and procedures in the current and future undertakings.

CHAPTER 2: PUBLIC WORKS DEPARTMENTS PRE-CONTRACT PROCEDURE

Chapter two (2) to six (6) reviews the theories and empirical evidences on the accuracy of preliminary cost estimates. This literature review explains the estimating variables, procedures, policies, cost and methods, which are the components of estimating practice. This part explains the PWD procedure during pre-contract stage that includes the procurement routes, estimating procedure and the bid price selection. It looks for similarities and differences between theoretical views and research results. This helps to interpret the data analysis and discussion in Chapters 8 and 9 respectively.

The PWD manages the federal and state governments' buildings and infrastructure works. It includes the management and maintenance of built facilities. The department is responsible in giving technical advice to other public agencies. The procedures at the pre-contract stage are important because they are related to the subject matter of this study. Figure 2.1 shows the PWD's organizational chart.



Note: # Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu and Kelantan (states in Peninsular Malaysia)

Figure 2.1**:** PWD organizational chart (abstracted from: Public Works Department, 2010a)

2.1 Procurement route

There are a number of procurement routes available to PWD. The basis of contract depends on the type of project. Wahid Omar (2004b) mentioned the types of procurements in PWD as the following:

a) Voting and rotation

b) Quotation

c) Conventional (traditional)

d) Design and build

e) Emergency

f) Foreign Financing

g) Provisional Sums

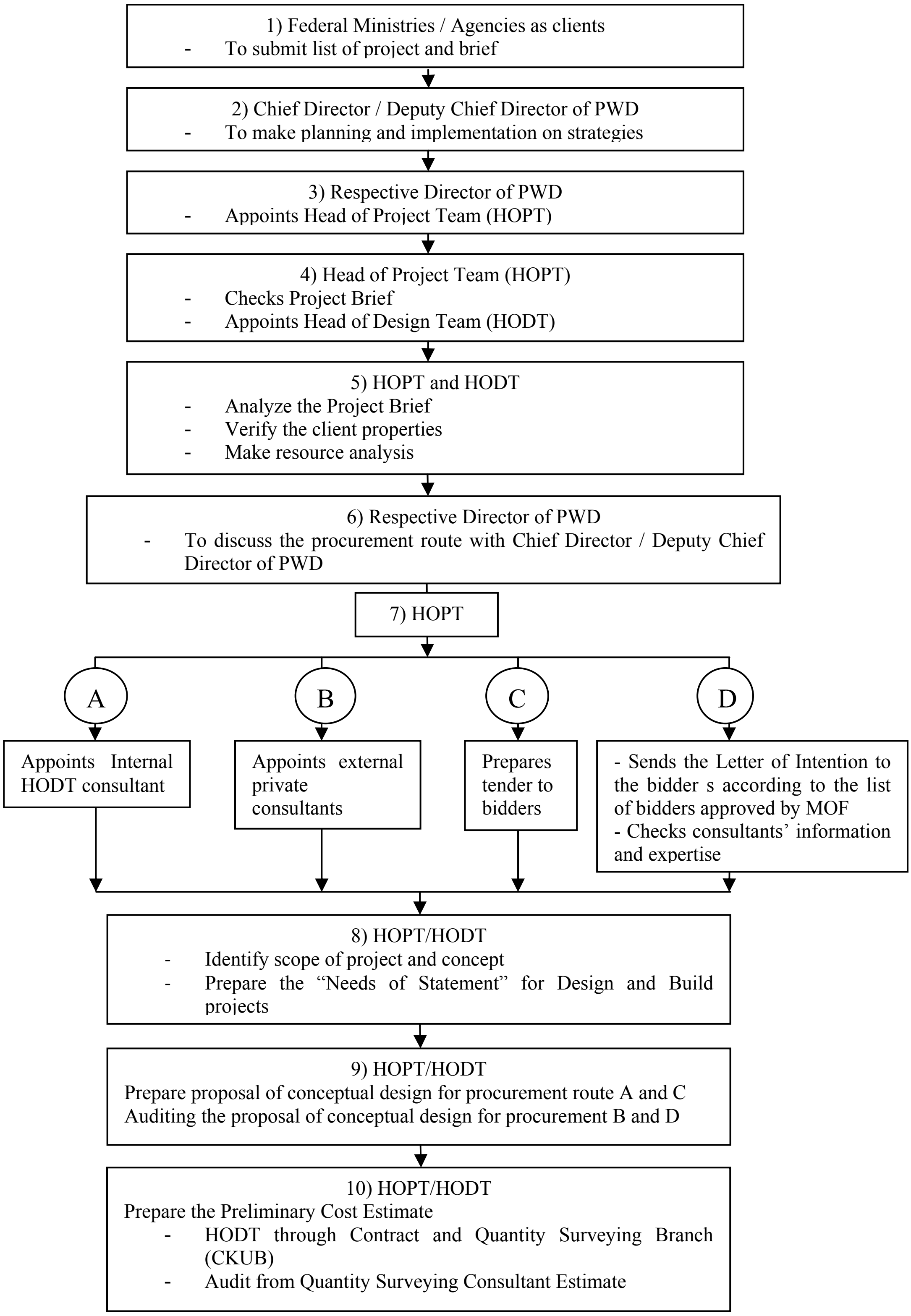
This study focuses on the procurement routes for conventional and design and build. Basis of selection includes open tender, selective tender and direct negotiation. Figure 2.2 shows the flowchart of client's intention to preliminary cost estimate. The stage is from no.1 to no. 10 (refer page 19). A client (ministry) submits list of projects and brief to the Chief Director of PWD (Refer to no.2). The Chief Director of PWD sends the project details to the respective Director of PWD. He appoints the Head of Project Team (HOPT) from project management division of the Business Sector (Refer to no. 3). The HOPT checks the project brief and appoints the Head of Design Team (HODT) from the Expert Sector. The HODT provides the consultation and expertise to HOPT (Refer to no. 4). Table 2.1 shows the number of ministries' projects under the management of PWD.

HOPT and HODT conduct site visits and meetings to study the project brief, client's properties and resources analyses. This allows the HOPT and HODT understand the needs of clients, condition of existing site and the extent of human resources needed to manage the project (Refer to no.5). They consult the client about the possible procurement routes (conventional or design and build) and the basis of selection (direct negotiation, selective and open tendering). HOPT and HODT discuss the findings with the Chief Director of PWD (Refer to no. 6). The PWD may not have the final say on the procurement routes because the MOF or clients could provide the list of bidders. It is either the HODT consultant or the private consultants that could consult the projects. The HOPT and HODT check the consultants' registration and expertise if they need to hire private consultants (Refer to no. 7).

In design and build procurement, the HOPT and HODT identify the scope of the projects in order to prepare the "need of statements" (Refer to no. 8). The HOPT and HODT propose the conceptual design and prepare the tender drawing. If it requires the appointment of private consultants, the PWD does the audit on the design proposed (Refer to no. 9). The Contract and Quantity Surveying Branch (CKUB) prepares the preliminary cost estimate after the completion of conceptual design. However, if private consultants are hired, the CKUB provides the audit on the estimate (Refer to no. 10). The preliminary cost estimate is used as the reference for cost limit, tender price comparison, As usual; the estimates prepared by CKUB and QS firms are used in comparing with other tenders in tenders' prices assessment. However, the tenders are subject to other tender assessments. These assessments include the bidders' financial standing and technical capability. The tenders' prices assessment could be prepared using statistical "cut-off" method (average bid method) in order to remove unreasonable offers.

Table 2.1: Number of development projects from ministries under the management of PWD in 2009 (abstracted from: Public Works Department, 2009a)

Ministry	Pre-Contract	Post Contract	Completed	Total	Percent
Public Works	22	110	63	195	7.73%
Prime Minister	23	69	33	125	4.95%
Home Affair	11	32	3	46	1.82%
Rural and Regional Development	32	77	38	147	5.83%
Education	36	832	580	1448	57.39%
Finance	9	25	8	42	1.66%
Health	22	92	22	136	5.39%
Higher Education	5	84	20	109	4.32%
Others	28	164	83	275	10.90%
Total	188	1485	850	2523	100%



HOPT: Head of Project Team
HODT: Head of Design Team

Figure 2.2: The workflow for planning and execution of the work (abstracted from: Wahid Omar, 2004a)

2.1.1 Procurement of conventional projects

The respective director of the PWD decides the types of contracts to be used i.e. bills of quantities, drawings and design and build. They select the procurement route during the pre-contract stage. HODT or private consultants provide the tender documents. The basis of selection could be open tender, selective tender or direct negotiation. In an open tender, the PWD advertise the sale of tender documents in the mass media for example newspapers and on the Internet for interested bidders to submit their bids. The PWD sells the tenders only to bidders approved by the procurement board and the MOF for selective and direct negotiation projects. HOPT and HODT prepare the preliminary cost estimates in conceptual design stage. The estimates are meant for planning of budget allocation and for tender comparison (Refer to Figure 2.2). The selection of a successful bidder is based on the price offered, technical capability and financial standing. If the price offered by a successful bidder is more than the approved budget, the officer in charge needs to ask for new budget allocation from the MOF before the director of PWD approves it (Refer to Figure 2.3)

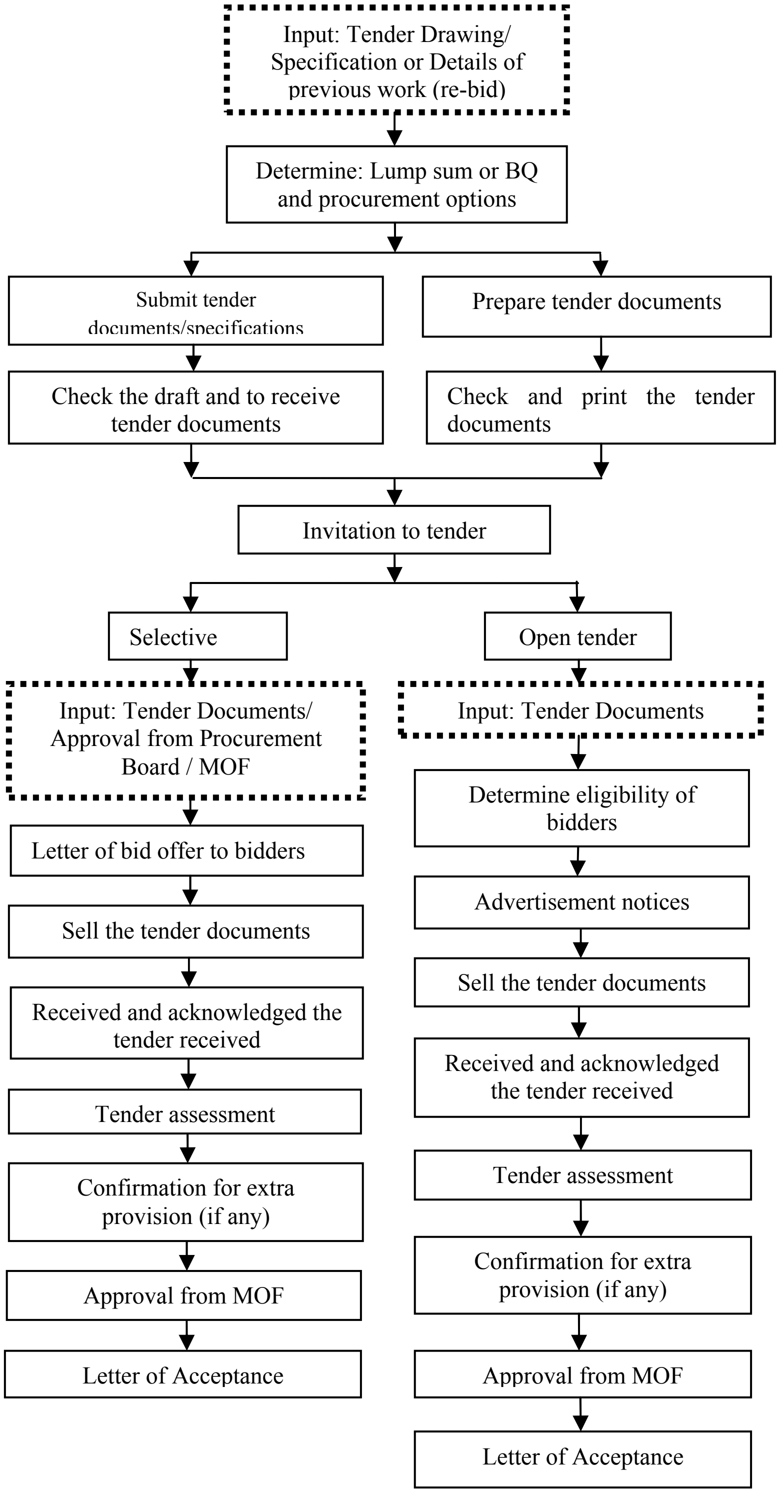


Figure 2.3: The procurement of conventional projects in Public Works Department (abstracted from: Wahid Omar, 2004b)

2.1.2 Procurement of design and build project

The respective director of PWD decides the procurement alternatives. The HODT prepares all the prebid[2] documents. The basis of selection is open tender, selective tender or direct negotiation. In an open tender, the PWD advertise the sale of tender documents in the mass media for example the newspaper and on the internet for interested bidders to bid. Nevertheless, if the tender is a selective tender or direct negotiation, the PWD sells the tender to only listed bidders approved by procurement board and the MOF. HOPT and HODT prepare the preliminary cost estimates for budget allocation planning during conceptual design stage and these are used for comparison in tender evaluation stage (Figure 2.2). A Successful bidder is selected based on the price offered, technical capacity and financial standing. If the price offered by a preferred bidder is more than ceiling budget, the officer in charge request for a new budget allocation from the MOF before the respective director of PWD approves it (Refer to Figure 2.4).

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[2] Need statement : government's requirements.

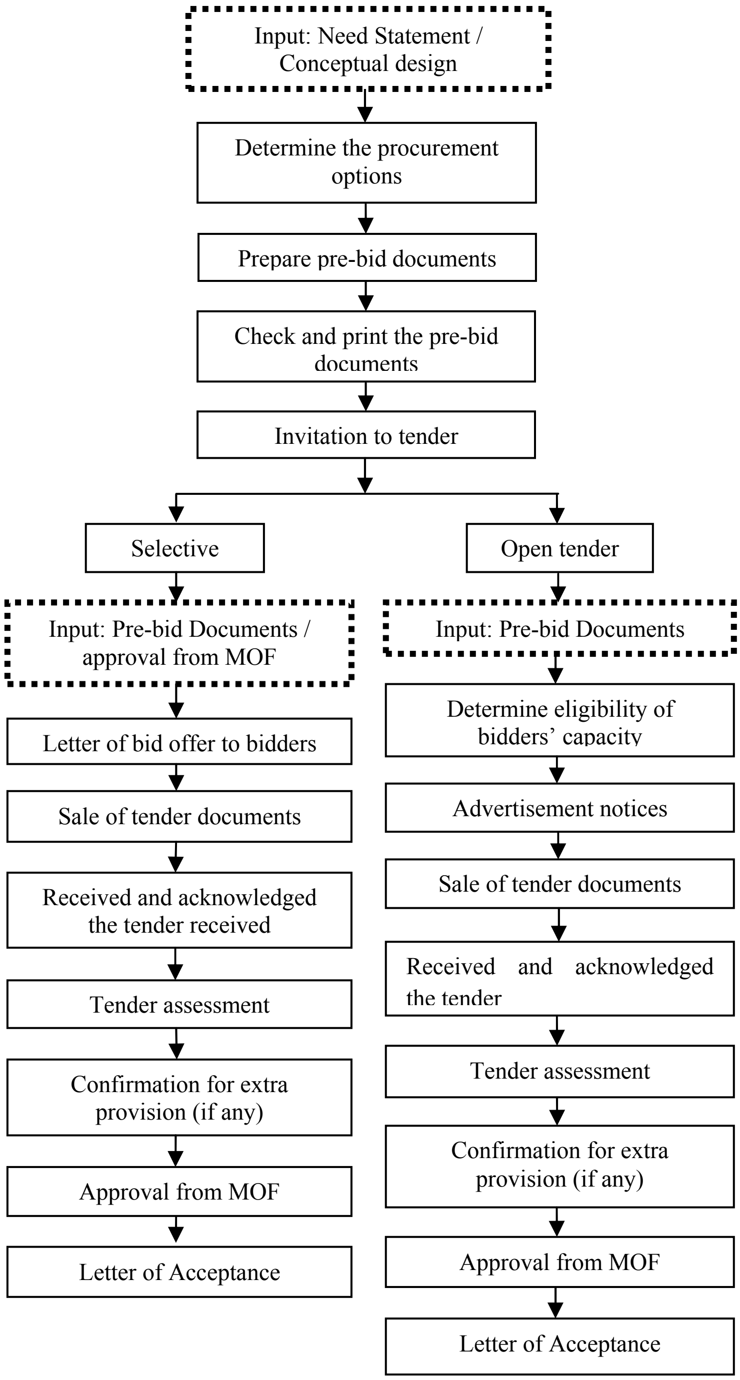


Figure 2.4: The procurement of design and build projects in Public Works Department (abstracted from: Wahid Omar, 2004b)

2.2 Bid price assessment

The earlier topic explains the procurement procedures in the PWD. It shows the PWD management process during the pre-contract administration. It involves the design planning to the selection process of contractors. The price offered by a bidder is not the only thing examined during the assessment. It also considers the technical and financial standing of the bidders. These two later criteria are not the subject matter, as this study focuses on tender price assessment. It is important because the accepted prices are related to the measures of quality that is the estimating target. In addition, the amount from accepted bid is used as cost data for cost estimate by the QS. In addition, some researchers are using accepted bid as the comparison to calculate the accuracy of cost estimates.

The lowest tender price is not the main criteria in the selection of a bidder to be awarded a contract. The PWD uses “average bid method” as against to “lowest bid method”. The latter implies the bidder could win the bidding by reducing some of his bid price until he feels his bid is the lowest (Ioannou & Leu, 1993). He recoups his loss through project management during construction. Average bid method allows reasonable profit to contractors. The contract prices are high-priced but could decrease risks of delay, substandard quality and disputes (Ioannou & Leu, 1993). The PWD states one of the reason of using this method is because the QS estimates are prone to errors and this could remove unreasonable bids (Public Works Department, 2004, 2005). Besides, accurate forecasts for new market prices rarely happened. It is adopted in order to discourage corrupt insider in the PWD from giving the estimate figure to the bidders (Sharinah Hamid, 2008). It also reduces the unreasonable estimates from being used as a benchmark (Public Works Department, 2004, 2005). Open tender is always subjected with "abnormal" low prices (Herbsman & Ellis, 2006). This type of price assessment has been done in Italy and Taiwan in order to reduce unrealistic low bids (Ioannou & Leu, 1993; Kumaraswamy & Walker, 1999)

The estimates calculated by PWD are treated as one of the bid prices. This estimate is calculated together with the bidders' prices to produce "*the lowest acceptable market price*" which is called as the "cut-off price". This cut off price is the main criteria of the selection. The bidders' bids (mainbuilder's work) should not be lower than the cut-off price. Those bidders who priced the tender lower than the cut-off price could also win a contract award if they have good record of accomplishment and good financial standing. The bidders' prices which are lower than 20% of building works, electrical and mechanical works and 25% of civil engineering works from the mean of builder's work price will be disqualified (Public Works Department, 2005). However, not all tender evaluations use the cut-off price. For selective tender, design and build tender and open tender which have less than 10 bidders are not required to use the PWD's guideline (Public Works Department, 2004, 2005). The calculation for cut-off price uses mean and standard deviation. The first step of cut-off calculation is to remove any tenders, which do not belong in the group of Z-scale of 2.33 to -2.33, which is the ideal range by the PWD. The tenders' prices that are outside this range are considered as outliers or "freaks" (Refer to Figure 2.5).

Faridah Halil (2007) said most contractors who bid for PWD tenders think the estimates provided by PWD and the lowest bid method should not be the benchmark in the selection of contractors. This view is also shared by Ioannou and Leu (1993). They believe the most reasonable ways to select a tender is to decide the price level of the market using the average bid method. Then, it is followed by the selection based on technical and financial capability of the bidders. This selection of price gives a logical and not too low a price to be accepted. The lowest bid is not the main criteria for the selection of tenders.

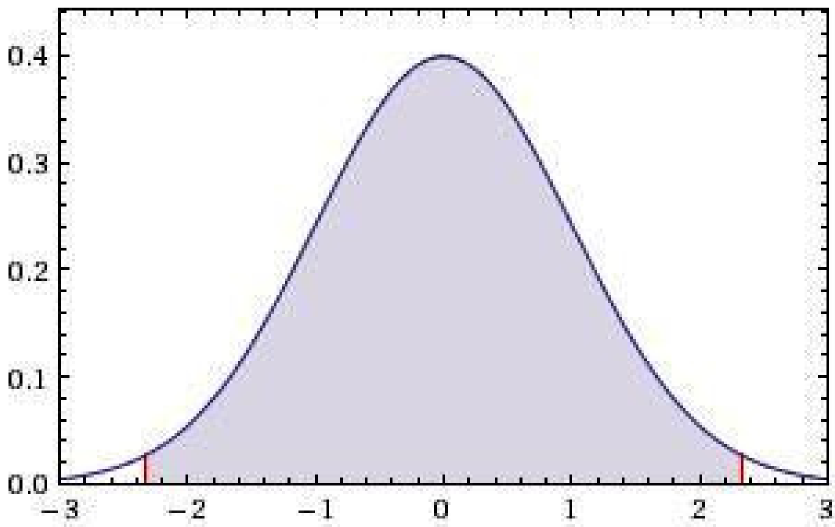


Figure 2.5: Normal distribution associated with two-sided 98.02 confidence level or Z-scale of 2.33 to -2.33 (abstracted from: Wolfram Alpha, 2012)

"Freak" tender price calculation is to exclude any tender prices with (-2.33 < z-score > 2.33), before the calculation of the mean mainbuilder's work is prepared using the following formula (Public Works Department, 2005):

$$z\ score = \frac{x - \mu}{\sigma}$$

x *is the bid price or QS estimate (total project cost)*

μ *is the mean of all tender prices including QS estimate*

σ *is the standard deviation of the population*

Then, the calculation of the mean mainbuilder's work is required after all "freak" tender prices are removed. The cut-off price calculations are different according to type of project:

$$\left.\begin{array}{l} \textit{Mean} - \textit{X\% Mean} \ldots\ldots\ldots\ldots (1) \\ \textit{Mean} - \textit{Stdev} \ldots\ldots\ldots\ldots (2) \end{array}\right\} \textit{Whichever the highest}$$

$$\textit{Cut–off price} = (1 \text{ or } 2) + \textit{provisional sums} + \textit{prime cost sums}$$

$$\textit{Mean} = \textit{mainbuilder's work only}$$

$$X = \textit{not less } 15\% \textit{ (building, electrical and mechanical works)}$$

$$X = \textit{not less } 17\% \textit{ (civil engineering works)}$$

$$X = \textit{not less } 10 - 12\% \textit{ (special criteria project)}$$

2.3 Public Works Department estimating procedure

The previous part describes how the PWD performs its procurement strategy that is from project registration to the tenderers' prices assessment. This part of literature review explains the estimating procedure of the PWD. The Contract and Quantity Surveying Branch (CKUB) prepares preliminary cost estimates for the PWD. The CKUB represents the PWD as internal QS consultant. PWD could engage the private quantity surveyors to prepare the estimates. QS consultants still work under the administration of PWD and must conform with its procedures. The estimates are prepared by registered quantity surveyors and endorsed by CKUB officer (Public Works Department, 2010a, 2010b). There are two (2) forms used when preparing preliminary cost estimates i.e. the PDA and ATDA form. Preliminary Detailed Abstract (PDA) is used in preparing preliminary cost estimate, while As Tendered Detailed Abstract (ATDA) is used when approving the fund needed for the project after the government accepted the tender. In addition, ATDA form is used as data collection.

2.3.1 PDA Form

The PDA is used in the preparation of cost plan by public agencies in Malaysia. It tabulates the breakdown of the cost of the projects. It includes building project, civil and infrastructure project e.g. roads and highways. It is arranged according to major elemental cost breakdown (Public Works Department, 1992). The form for building project is coded as PWD 142A – Rev. 91 (printed on red pink colour paper). Refer Appendix 1 for the Preliminary Detailed Abstract (PDA) form. Public departments and agencies tabulate the fund needed for projects using this form. Requisition for more budgets is also made using this form. The cost estimate in the PDA form is calculated using historical and current prices (Public Works Department, 1992). The estimate in the PDA form is prepared using preliminary design drawings. Cost of building works is calculated using cost per square metre of previous building. The PWD publishes the cost data (cost/m^2GFA) of relevant buildings in "Average Cost per metre square of Building Construction Cost Handbook". The cost data handbooks are circulated in yearly basis to all QS in PWD departments. This cost data is obtained from the previous accepted tenders of ATDA form (Public Works Department, 2009b).

The QS officers adjust the average cost data (cost/m^2GFA) of suitable building categories using tender price index and locality factor. Then, the cost is multiplied by m^2GFA of the area, which in turn was calculated based on preliminary design drawing.

The cost for preliminaries, Internal Building Specialist Works, External Works and Professional Fees are calculated according to the average percentage of previous projects. Some of the items e.g. Piling Works and foundation may use other estimating method i.e. Approximate Quantities (if more details are provided). Other unusual or specialist items may need quotations from the suppliers or subcontractors (Public Works Department, 1992, 2009b).

2.3.2 ATDA form

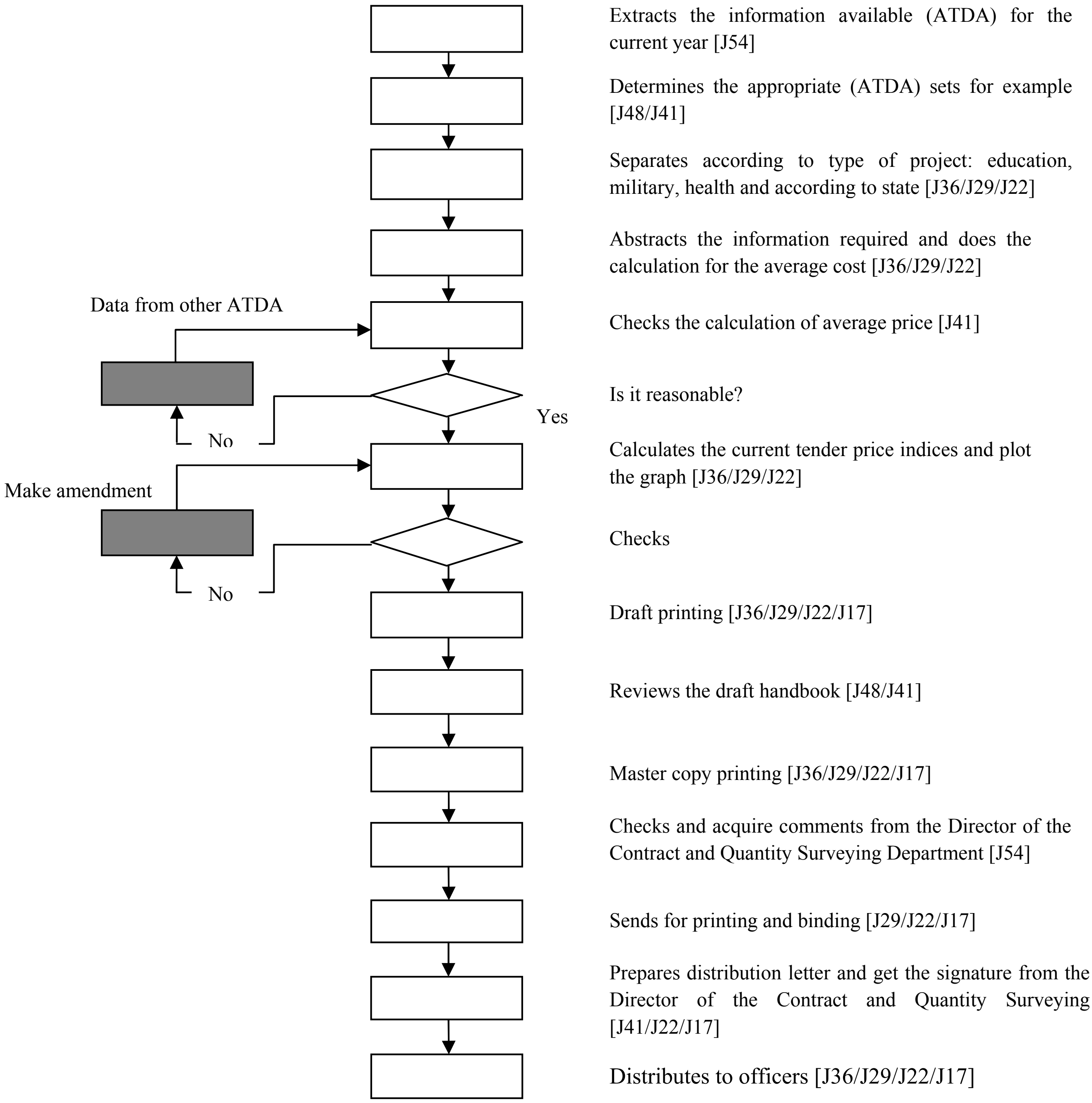
ATDA form is used for breakdown of costs of the actual fund needed for projects. It is used when confirming the sufficiency of government ceiling budget after the tender is submitted. It is prepared after the contract is awarded to a successful bidder. The breakdowns of costs are tabulated according to bid prices of a successful bidder. QS officers rationalize all the rates accordingly to reduce "front and back loading[3]" of a successful bidder. This form is coded as PWD 142B – Rev. 91 (Yellow in colour). Refer Appendix 2 for the As Tendered Detailed Abstract (ATDA) form. The PWD uses ATDA form for data collection for future projects. This cost data is published as Average Cost per metre square of Building Construction Cost Handbook (Public Works Department, 2009b).

2.3.3 Cost data collection

The collection of cost data is very important to the QS because it is used to calculate the estimates. The cost data are collected from accepted tender bids. The PWD through

[3] Unbalanced bid.

CKUB provides the cost data to all its QS. It is published as “Average Cost per metre square of Building Construction Cost”. The flow of cost data collection by the PWD is shown at Figure 2.6.



Notes:
J54 – Senior Principal Assistant Director; J48 – Senior Assistant Director
J41- Assistant Director; J36 – Technical Assistant
J29 – Technical Assistant; J22 – Technician; J17 - Technician

Figure 2.6: The flowchart for the preparation of cost data collection (Public Works Department, 2009c)

Senior officers in the procurement and cost advice department in CKUB received the ATDA from QS departments of Peninsular Malaysia[4]. They assign technicians to extract the ATDA using Elemental Cost Analysis (ECA) guideline and ECA form. Only suitable cost data will be included. It is separated according to type of project. The technicians do the abstraction of average cost/m^2GFA. Technicians check the data abstraction and plot the graph of tender price index. Senior officers check the draft before it is sent for printing. If the draft is acceptable and ready for printing, the Director of the Contract and Quantity Surveying Department (CKUB) does the review. If no correction, this master copy is ready for printing and binding. Finally, the cost data handbooks are available to all PWD QS officers in Peninsular Malaysia.

2.4 Chapter summary

The PWD procedure for preliminary cost estimates is documented and regulated through its bureaucracy system. There is a system for data collection and its department publishes cost data to all its QS. However, the introduction of procedure on some estimating components is essential to facilitate the QS. The procedure for contingencies is one of few things that could be available. Like most QS practitioners, the PWD is also using traditional methods to prepare the estimates. In an open tender process when more bidders enter the bidding. PWD feels estimates are prone to error and low bids may present in the bidding. In order to overcome this shortcoming, the PWD uses a statistical method, which is based on "average bid method" or "cut off price" to eliminate the suicidal lowest tender bids in order to select acceptable prices for contract award. When preparing "cut off price", the PWD cost estimates are calculated together with other

[4] the PWD of Sabah and Sarawak are not under the jurisdiction of Federal PWD because of federalism in the constitution.

bidders' prices. This method calculates the mean price according to "mean of the returned tenders". The minimum price for the lowest bid must be at least not less than 15% or 17% (according to type of project) of the mean of the returned tenders. The PWD adopt this method if they are 10 or more bidders. Preliminary cost estimates are used as benchmarks for other type of tenders. In conclusion, the PWD has a different tender price selection. These are as follows:

a) Average bid method - mean of the returned tenders (mean of the bids)
b) Selection of prices using QS judgement

Accuracy of estimates could be different because of the use of different targets. This study uncovers the difference of using different estimating target i.e. accepted bid, lowest bid and mean of the bids. Some authors said the "price fixing" or "bid rigging" happens when using mean of returned tenders or even in lowest bid method. The bidders agreed to fix their prices to accommodate "a preferred bidder" as all bids were priced accordingly to beat the system. It is believed that the price will be cheaper when using the lowest bid method. Nevertheless, the merit of mean of the returned tenders is that it can reduce the possibility of stall projects, low quality construction and unnecessary claim to the client. However, it will not be discussed in detail due to a limited scope of study.

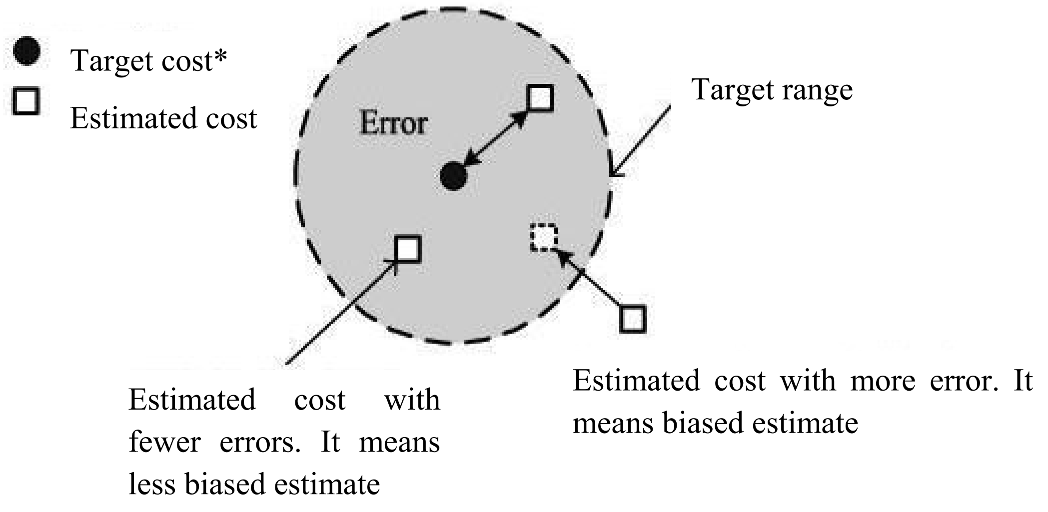
CHAPTER 3: ASSESSMENT OF THE ACCURACY, ESTIMATING METHODS AND COST DATA

Bid price assessment chooses the price range of preferred bidders. Most tenders are chosen according to "average bid method" for open tender if it is 10 bidders or more. The assessment was made in order to determine if bids are offered within the price range. The estimates prepared by PWD are used as a point of reference for other types of procurements. This procedure gives a basis for PWD to determine the accepted price. This chapter discusses on the assessment of the cost estimate accuracy. It is followed by discussion on different types of estimating methods and the importance of cost data.

3.1 The accuracy of preliminary cost estimates

Lack or absence of error defines accurate estimates. QS estimating quality in terms of bias and consistency measures the accuracy (Morrison, 1984). Skitmore (1991) suggests that the measurement on the quality comprises of two (2) aspects (Refer to Figure 3.1). These qualities are "bias" and "consistency" of the estimates (Skitmore 1991; 22). He describes it as follows:

> *"Quality has been defined as the difference between the forecast and contract price, and in terms of bias (mean difference) and consistency (spread of difference)"*



* lowest bid, accepted bid, mean of the bids and final account

Figure 3.1: Quality of preliminary cost estimates (abstracted from: An, Cho, & Lee, 2011)

3.1.1 Bias (error)

Bias concerns with the average of difference between tender price and forecast. It is measured according to arithmetical mean of percentage error (Cheung & Skitmore, 2005). This value refers to underestimate or overestimate (Skitmore, 1991). Ashworth (1982) says the bias shows the closeness to the value. Less bias means less error. The greater the average difference, the more bias is the estimate. A less bias estimate is associated with accurate forecast or having a less biased estimate. Refer to Measurement of error (bias) (page 146).

3.1.2 Consistency

Consistency of estimates is the degree of variation around the average (Skitmore, 1991). This explains how efficient the QS performance when preparing a number of estimates. It measures how often accuracy can be relied on (Ashworth & Skitmore, 1982). Refer to Measurement of consistency (page 147).

3.2 Target measures of forecast quality

The purpose of estimating is to make a prediction. There must be a target or a reference point to measure the performance of estimates (Cheung, et al., 2008). Skitmore (1991) explains the quality of estimates is a measure of satisfaction obtained by the client. It measures the relationship between forecasts and contract bids. Some agree to the lowest tender price as the estimating target (Gunner & Skitmore, 1999a; Morrison, 1984; Skitmore, 1991). The quality of the estimating models depends on how accurate the model to predict the bid value, which is usually an unknown value, but due to nature of competition in bidding, a lowest bid is the target for most contracts. However, to some extent, using the lowest bid may not represent the economic value as it could be a suicidal low bid price offered by a bidder (Skitmore & Lo, 2002). The unrealistic low bids are as a result of some bidders want to win the contract at any cost (Runeson, 2000). Vickrey (Nobel Laureate in Economic Sciences) was able to show the second lowest bid is in fact, better economically than the lowest bid[5] (Lowe & Skitmore, 2006). The lowest price cannot guarantee the best value as a bidder who wanted the contract has adjusted his price to underbid the other fellow bidders in order to win the contract

[5] This is true only under certain, very restrictive conditions such as when the bid estimate is perfectly correct.

with suicidal low bids regardless of the consequences (Murdoch & Hughes, 2007). Brockmann (2011) describes it as follows:

> *"The award to the low bidder will, however, favour the company with the largest estimating error (winner's curse)"*

To resolve this problem, McCaffer, (1976) suggests the use of mean of the returned tender prices – mean of the bids instead. His argument is that the mean has less interference variable (suicidal low bids), and more likely to be more accurate. The bid prices assessment in PWD is prepared by "average bid method" in order to select a bidder for contract award. However, accepted tender bids can also be used to measure the estimating errors (Aibinu & Pasco, 2008; Gunner & Skitmore, 1999a). The drawback of using accepted bid is that it may have been influenced by the QS and therefore it is interdependent to some extent with the estimates prepared (Skitmore, 2010)[6]. Some other authors used the final completed cost as the reference target (AbouRizk, Babey, & Karumanasseri, 2002). The accuracy of early project cost can be measured using both bid prices and final cost (Shane, Molenaar, Anderson, & Schexnayder, 2009). These show that there are many views pertaining to estimating targets. However, there is a criticism of using the final completed costs. Skitmore (2002) and Runeson (2000) explain the problem is that the data are not readily available and when it is available, it is not well recorded. They point out, due to long delay between the estimates and accounted costs, significant changes of design and price fluctuation have occurred during construction. It has also been known that cost data for estimates are collected from accepted (or lowest bid) tender bids. The tender bid is the ideal price known after taking into accounts most of the considerations during the pre-

[6] Personal communication through email.

tender stage. It measures the relationship of pre-contract and bidding. The final account is an accounted cost after a project is completed. These are reasons why most authors are using tender bids as the target to measure accuracy of estimates. Refer to Table 3.1 for measures of forecast quality.

Table 3.1: Measures of forecast quality (abstracted from: Skitmore, 1991)

Quality	Researchers	Measure	Statistics
Bias	McCaffer	Lowest bid / Forecast ratio	Arithmetic mean
	De Neufville et al.	Lowest bid / Forecast ratio	Arithmetic mean
	Wilson et al.	Lowest bid / Forecast ratio	Median
	Runeson and Bennett	Lowest bid / Forecast ratio	Pearson's r
	Hanscomb Associates	Lowest bid / Forecast ratio	Pearson's r
	McCaffer	Lowest bid / Forecast ratio	Spearman's rho
	Harvey	Lowest bid / Forecast ratio	Coefficient of regression
	Hanscomb Associates	Lowest bid / Forecast ratio	Coefficient of regression
	Jupp and McMillan	Forecast / Lowest bid ratio	Arithmetic mean
	Morrison & Stevens	Forecast / Lowest bid ratio	Arithmetic mean
	Skitmore	Forecast / Lowest bid ratio	Arithmetic mean
	Skitmore and Tan	Forecast / Lowest bid ratio	Arithmetic mean
	Tan	Forecast / Lowest bid ratio	Pearson's r
	Flanagan and Norman	Lowest bid - estimate	Coefficient of regression
Consistency	McCaffer	Lowest bid / Forecast ratio	Standard deviation
	McCaffer	Lowest bid / Forecast ratio	Coefficient of variation
	McCaffer et al.	Lowest bid / Forecast ratio	Coefficient of variation
	Ross	Lowest bid / Forecast ratio	Coefficient of variation
	Jupp and McMillan	Forecast / Lowest bid ratio	Standard deviation
	Skitmore	Percentage forecast exceeds lowest bid	Standard deviation
	Skitmore and Tan	Percentage forecast exceeds lowest bid	Standard deviation

Table 3.1: Measures of forecast quality (abstracted from: Skitmore, 1991) (cont'd)

Consistency (cont'd)	Morrison and Stevens	Percentage forecast exceeds lowest bid	Coefficient of variation
	Skitmore and Tan	Percentage lowest bid exceeds forecast	Standard deviation
	Bennett	Number of 'serious errors'	Total
Accuracy	Morrison and Stevens	Modulus percentage forecast exceeds lowest bid	Arithmetic mean
	Flanagan and Norman	Modulus percentage forecast exceeds lowest bid	Number observations in ranges
	Skitmore	Modulus percentage forecast exceeds lowest bid	Arithmetic mean and standard deviation
	Skitmore and Tan	Modulus percentage forecast exceeds lowest bid	Arithmetic mean and standard deviation
	Tan	Modulus percentage forecast exceeds lowest bid	Pearson's r
	Skitmore and Tan	Modulus percentage lowest bid exceeds forecast	Arithmetic mean and standard deviation
	Tan	Modulus percentage lowest bid exceeds forecast	Pearson's r
	Skitmore	Modulus percentage lowest bid exceeds forecast	Square root of arithmetic mean

3.3 Benchmarking quantity surveyors' estimates quality

Ling and Boo (2001) point out the range of acceptable level of accuracy should be determined in order to measure the difference between the estimate and the tender bid. This is important because QS is not aware of the persistent error trend they had developed during estimation (Morrison, 1984). They did not change their estimating policy in reaction to previous estimating performance (Aibinu & Pasco, 2008). As a result, the quality of estimates has not improved over time. Flyvbjerg et al. (2002) argue that the errors of estimates happened randomly because they are distributed far from the zero mean. It means forecasters are biased to get the preferred results. QS estimating quality is not rigorously addressed by the clients and academic researchers unlike the evaluation of building contractors (Yiu, Ho, Lo, & Hu, 2005). In addition, they found out the performance of QS in determining the quality of cost estimates is not given much emphasis by the clients in Hong Kong. Clients are more concerned with QS roles towards quality assurance during construction stage and proactive in giving suggestion at planning stage. They stated the criteria that were critical in preliminary cost estimates as in the following:

a) Estimation based on preliminary design
b) Estimation calculated with updated cost data
c) Assumption on items and works to be constructed

3.4 Probability of estimating accuracy

Magnussen and Olsson (2006) point out the Norwegian government emphasize on quality assurance of estimates based on the range of probability that the project will be completed within the estimated cost. It is important because confidence level determines whether the assumption on the accuracy range is appropriate. This method determines how much contingency should be allocated (refer to Contingencies and variation of price (VOP) at page 96). The probability of estimating accuracy could be determined by giving the range of the most likely cost (Magnussen & Olsson, 2006; Skitmore, 2002). It assures the clients to be more realistic when making a decision, as they should know about the true nature of the estimates as it has its own reliability. The selection of a lowest tender should not be the main priority when making a decision (Fellows, Langford, Newcombe, & Urry, 2002). According to Skitmore, (2002) and Raftery (1993), the easiest way to prepare the probability distribution for estimating accuracy is to create 'Raftery curves'. The use of this curve is to predict the likelihood of the lowest tender price being above or below some percentage of the forecast. Skitmore (2002; 83) explains about this curve as follows:

> *"It presents the practitioner decision-maker with an unbiased, consistent and unequivocal statement of the true nature of the forecast".*

The curve is prepared by using relative frequency of a lowest bid above the estimate (Refer to Figure 3.2). As we know, most of the time, QS uses single point estimate as the estimated cost.

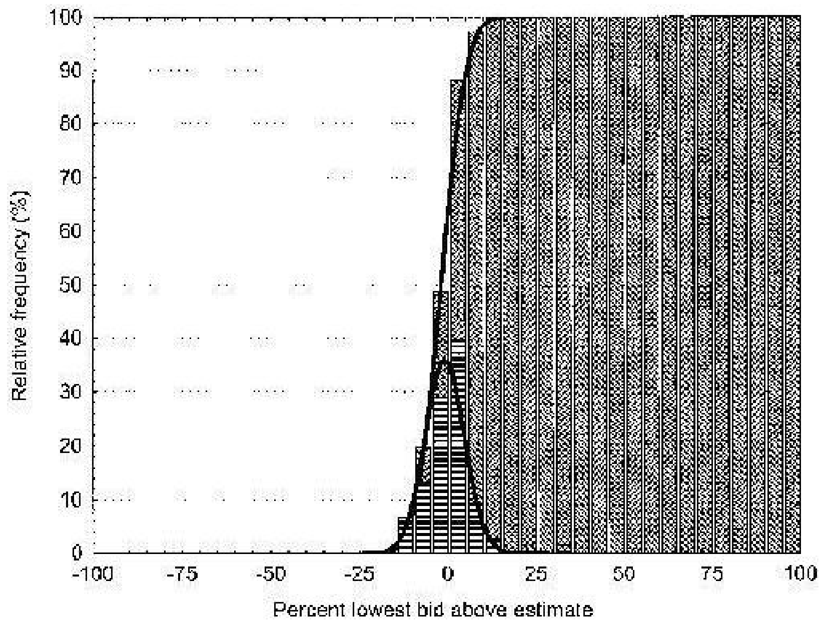


Figure 3.2: Example of "Raftery curves" (abstracted from: Skitmore, 2002)

3.5 Parameter of estimating accuracy

Chappell et al. (2001) concluded the error should be around ±15% at early stage and ±5% when final estimate is made. Park and Jackson (1984) state that error for rough estimates at early stage is ±15%. It follows with semi-detailed estimates at ±10% and detailed estimates at ±5% of the final accounted cost. Accuracy of estimates are +/-

22.5% for a uniform distribution and +/- 26% for a normal distribution[7] (Morrison, 1984). Morrison and Steven, (1981) and McCaffer, (1976) and Skitmore, (1982) concluded that the coefficient of variation is 15% to 20% for early design and 13% to 18% for detailed design. Meanwhile, Skitmore, (1988) suggested the coefficient of variation at around 5% to 9% is acceptable during detail design. Refer to Table 3.2.

Contrary to contractors' price estimates, the preliminary cost estimates prepared by QS do not involve with resource estimation of materials, plants and labours. These are mostly unknown during the conceptual design stage. Estimates by contractors are resource analysis on the works that will be constructed at sites while QS consultants' estimates are based on past projects' cost data. Contractors could have the accuracy range of +/- 10% if they have access to large information on construction but at +/-30% if the details are not fully provided (Page, 1996). Skitmore (2002) found contractors' estimates are more consistent than the QS consultants. He found contractors have better access of information and spend more resources to prepare their estimates. Beeston (1974) says that the way could improve the QS consultants' estimates is to use the estimating technique used by the contractors. Nevertheless, this suggestion may not be feasible because the function of QS consultants and contractors are different.

[7] At 95% confidence level.

Table 3.2: Summary of accuracy for early cost estimates (abstracted from: Aibinu & Pasco, 2008; Skitmore & Ng, 2003; Skitmore & Picken, 2000)

*positive value of average error (%) indicates an overestimate

Rank	Organization	Location	Period	N	Average Error (%)	CV
1	Hanscomb	USA	1973-75	62		7.71
2	Hanscomb	USA	1980-92	217	+5.19	7.82
3	Levett and Bailey	Singapore	1980-91	86	+3.47	8.46
4	QS Office	UK	pre1984	55	+3.72	9.37
5	PW QS Office	Australia	1970s	153	+5.85	9.73
6	QS Firm	Australia	1999-2007	56	+4.29	10.17
7	QS Office	UK	pre1984	62	+2.89	10.88
8	County Council	UK	1980s	61	+12.77	11.00
9	QS Office	UK	pre1984	89	-0.33	11.29
10	QS Office	UK	pre1984	222	+2.61	11.50
11	QS Office	UK	pre1984	62	-5.76	11.68
12	QS Office	UK	pre1984	115	+4.38	12.22
13	County Council8	UK	1971-77	63		c12.50
14	QS Firm	Hong Kong	1995-97	89	-1.78	12.95
15	PW Dept	Belgium	1971-74	132	-5.17	13.13
16	QS Office	Singapore	1980s	88	-0.18	14.13
17	County Council	UK	1975-78	103	+11.50	c15.00
18	QS Office	UK	1978	310	+5.86	15.52
19	City Council	UK	1983-87	33	-4.91	18.11
20	PW Dept	Belgium	1971-74	168	-1.45	18.37
21	Govt Agency	USA	1975-84	292	+9.22	23.99
22	Levett and Bailey	Singapore	1980-91	181	+10.32	28.30

The consistency of estimates should be increased when design stage is progressing (Potts, 2008). According to Skitmore and Ng (2000), the typical consistency during early design stage is 15% to 20% of the coefficient of variation. Most authors have varied opinions on the accuracy. However, they agree consistency must be improved when the design stage is progressing (Refer to Table 3.3 and Table 3.4).

Table 3.3: Summary of accuracy against the stage of tendering (abstracted from: Ashworth & Skitmore, 1982)

Stages	Average CV % (Consistency)	
	McCaffrey (1981)	Marr (1977)
Forecast brief	17	20 - 40
Sketch plan	10	15 – 30
Detail design	9	8 -15
Tender design	6	5 – 10

Table 3.4: Summary of accuracy against the stage of design (abstracted from: Potts, 2008)

Project stage	Estimate Type	Estimate Accuracy (%)	AACE Class of Estimate
Feasibility	Order of Magnitude	-25 to 50	Class IV
Concept design	Appropriation estimate	-15 to 25	Class III
Preliminary front end	Budget	-10 to 15	Class II
Detailed design	Definitive	-5 to 10	Class I

3.6 Estimating methods

Estimating methods are the cost models for the preparation of the estimates. QS are using traditional methods for many years. It may be used for years to come because it is the most popular method to prepare cost estimates (Fortune & Cox, 2005). The PWD uses traditional methods because it is its procurement policy and no other method is introduced (Public Works Department, 2010a). The estimating methods work according to specific conditions and at different design stages. There are a number of methods used by practitioners (Fortune, 2006). These are as follows:

a) Traditional (cost per m^2GFA, approximate quantities, elemental analysis and judgement)
b) Mathematical models (parametric modelling, resource and process models)

c) Knowledge based models (propriety expert, in-house and CAD systems)
d) Value-related models (Monte Carlo simulation, risk analysis and whole life cost)
e) Neural models (artificial neural nets, Fuzzy logic and Environmental models)

There are two (2) traditional methods established by the PWD. These methods are single rate estimate and approximate quantities (Public Works Department, 2010a). In the UK, it has become a standard policy to prepare more rigorous estimate i.e. elemental cost estimate when it comes to bigger project (Soutos & Lowe, 2011). Study made in the UK by Fortune and Cox (2005) found out the traditional methods are used overwhelmingly to provide single point estimates. It is because the alternative cost models are unconvincing to be practical. Fellows et al. (2002) disputed the use of alternative estimating methods because the cost to employ these methods is expensive. They believe cost estimates, which use traditional methods, are feasible if it can achieve the needed accuracy. The use of more rigorous estimating methods cost more, but it produces better accuracy than less rigorous ones (Remer & Buchanan, 2000). A more rigorous method is used for projects, which involve more specialities, specifications and detailed references.

The traditional estimating methods are the most popular among QS in Malaysia while other methods are not favourable (Nor Azmi, Mohamad Razali, Napsiah Ismail, & Rosnah Yusuff, 2008; Nurul Azam, Salihuddin Hashim, & Mohamad Razali, 2006). However, this research did not emphasize on the reason why the QS in practice rejected the use of other methods in Malaysia. Traditional models are used widely because the

QS practices are unwilling to make the change from long-established methods to alternative ones, which are used mostly in academic studies (Raftery, 1991). He explains the traditional methods are familiar with designers and clients. However, the traditional methods are having some disadvantages in decision-making. One of the disadvantages of using the traditional methods is the model itself is non predictive (Harding, Lowe, Emsley, Hickson, & Duff, 1999). The clients depend on the judgement of his consultants to advise him about the accuracy of estimates. It could mislead the client because the advice may arise from non-actual facts. The accuracy should be calculated from previous project data, as this provides the actual range of accuracy (Skitmore, 2002). The range of accuracy is dissimilar if a different method of estimating is employed. The unit method is more likely less accurate if compared to approximate estimating (Ashworth & Skitmore, 1982). The reliability of traditional estimating methods depends on several factors (Skitmore & Patchell, 1990):

a) The reliability of each quantity value.
b) The reliability of each rate value.
c) The number of items.
d) The collinearity of the quantity and rate values.

Quantity and rate are often treated as an independent variable. Actually, these are correlated in some way or another. This correlation is known as collinearity. Most QS agreed that if measurement of quantity and rate were prepared perfectly, the estimates would be reasonably accurate. Yet, Barnes, (1971) believes quantity and rate have their own reliability. In his research, a constant coefficient of variation for each item is assumed; he was able to show that a selective reduction of the number of low valued items would have insignificant effect on the estimate reliability. According to Morrison

(1984) traditional estimating technique are inherited with variability. These factors are as follows:

a) The number of sub-estimates forms the total estimate.

b) The size distribution of the items forms the estimate.

c) The variability of sub-estimates.

According to his study, less detail estimates have less number of items. It reduces the incidence of cancelling errors, thus produce inaccurate estimates. It explains how some estimating methods perform poorly if compared to methods that are more rigorous (Refer to Table 3.5, Table 3.6 and Table 3.7).

Table 3.5: Accuracy of estimating methods excerpt from Resume of Estimating Methods (abstracted from: Skitmore & Patchell, 1990)

Estimating Methods	General Accuracy (cv)
Single Rate Estimate	
Functional Unit	*25 – 30%*
Floor Area	*20 – 30%*
Approximate Quantities	15 – 25%

Table 3.6: Accuracy of capital cost estimation methods (abstracted from: Boussabaine, 2007)

Estimating Methods	Contract type	Accuracy (%)
Conference	Process plants	Unknown
Functional unit	All	25-30
Floor area	Buildings	20-30
Cube method	Buildings	20-45
Storey enclosure	Buildings	15-30
Approximate quantities	Buildings	15-25
Elemental analysis	Buildings	20-25
Resource analysis	All	5-8

Table 3.7: Quantity Surveyors' estimating accuracy according to methods excerpt from Property Services Agency, 198; 25 (abstracted from: Smith & Jaggar, 2007)

Estimating Method	**Mean from Tenders (%)**	**Coefficient of Variation (%)**
Cost per square metre taken from one previous project.	18	22.5
Cost per square metre derived from averaging of previous projects.	15.5	19
Elemental estimating based on rates taken from one project.	10	13
Elemental estimating based on rates derived from averaging the rates of previous projects.	9	11
Elemental estimating based on statistical analysis of all relevant data in the database.	6	7.5
Resource use and costs based on contractors' estimating method	5.5	6.5

3.6.1 Single rate estimating

This method is divided into two (2) types. These are functional unit and superficial area. Functional unit is based on a unit factor of occupants. It is used as a yardstick to quantify the building size. This is provided by multiplying the number of unit and the cost per unit. The examples of these unit rates are cost per pupil for school, cost per bed for hospital and cost per space for parking (Ashworth, 2010; Ferry, et al., 2007). A functional unit is useful for budgetary estimation. It is mainly used for standard design project implemented by the public sector. It defines the cost limit of the scheme. However, this estimating method is not precise. It is created to establish a rough amount, so the clients have ideas about the amount of funding needed (Ashworth, 2010; Ferry, et al., 2007).

Superficial area method is based on total floor area. Gross Floor Area (GFA) from preliminary drawings is multiplied by single price rate per area of similar building available from cost data (Ashworth, 2010; Ferry, et al., 2007). The cost data is adjusted according to specification, market condition, site constraints and building morphology i.e. storey height and building arrangement (Ashworth, 2010; Ferry, et al., 2007). Seeley (1996) explains this method should be prepared by experience QS because it requires experience and knowledge to adjust the single rate cost data. This method is not flexible if compared to Approximates Quantities and Elemental Cost Estimates.

Most of the researches agree the single rate estimation is less accurate if compared to approximate quantities method (Ferry, et al., 2007; Seeley, 1996; Skitmore & Patchell, 1990). Nonetheless, the data from Hong Kong reveals the opposite (Skitmore & Drew, 2003). Single rate estimates are more accurate than the time-consuming approximate quantities. Yet, this finding did not specify whether the single rate method is used for typical building and approximate quantities are used for design, which is more complicated. Beeston (1987) explains the superficial area method is slightly improved if further design information is available. It is hard to determine the appropriate amount of adjustment needed to adjust the single rate. The items presented in bills of approximate quantities are easy to adjust because the items are listed in smaller components. There are some drawbacks of using single rate estimating. The QS allows average cost/m^2 and percentage allocation to each element but the allocation is not sufficient for the actual tender prices (Refer to Appendix 3 and Appendix 4 for average cost per square and the percentage allocation for the preparation of the estimate).

Gunner and Skitmore (1999b; 4) expressed their concerns as follows:

> *"Because of 'conservatism' and regression, the price forecaster is likely to select a price which represents the middle, or average, of the range of possible values for an initial anchor (starting point) but due to anchor effect, make insufficient adjustment towards to what will eventually be the actual contract price"*

It is necessary to make adjustments by allowing price according to new cost estimates. However, this could lead to systematic error. According to James (1954), the External Works and Internal Building Specialist Works should be separately estimated since these works are varied. He recommends that these items should be estimated using approximate quantities. The technical aid from the specialist consultants is essential because it could be difficult to predict the norm of works, which requires expertise.

3.6.2 Approximate quantities

This method produces a more accurate estimate if compared to single rate method. The components of building are itemized according to bills of items (Ferry, et al., 2007; Seeley, 1996; Skitmore & Patchell, 1990). Elemental rate for walls is measured and described as *"half thick brickwall including 13mm cement & sand (1:3) plaster and emulsion paint on the both sides"*. This rate is computed according to composite item by combining rates into a single rate (Ashworth, 2010; Ferry, et al., 2007; Seeley, 1996). The drawback of this method is the process itself is time consuming. Measurement and data analysis of items are required before the calculation. However, this method allows greater flexibility. It ensures a highest degree of cost check when new design information is available. It is suitable for projects that involve with more complex design (Seeley, 1996; Skitmore & Drew, 2003).

3.6.3 Multiple regression method (MRM)

This research focuses on the reliability of preliminary cost estimates using multiple regression method (MRM). It is an exploratory study for one of many alternative estimating methods that can be used at the early stage of design. MRM is a technique for cost modelling which focuses on interaction of multiple variables of costs since estimates are unable to be described by a single variable (Li, et al., 2005). It assumes the interactions among variables are in a straight line. This statistical manipulation of variables creates a set of equation for cost prediction. There are as follows:

$$Y = a + b_1X_1 + b_2X_2 \ldots\ldots b_nX_n + \varepsilon$$

Y is actual observation of cost data, normally cost of items

X_1, X_2 and X_n are variables for costs

b_1, b_2 and b_n are unknown and estimated by regression technique

ε is random error of Y

The data sets which are needed for robust prediction are at least 3 times the number of variables for the model (Skitmore & Patchell, 1990). A number of statistical packages can be used to create this model. Some basic assumptions need to be made which are as follows:

a) The predictor variables are exact
b) No correlation between the predictor variables
c) Y dependent variables are independent

d) Error is independent, random and normally distributed with a zero mean

Studies made in Hong Kong and the United States show the MRM is accurate within +/- 5% from the actual building cost (Butts, 2006; Li, et al., 2005). The reliability of this method is acceptable and more accurate than the traditional model. Research by Lowe et al. (2006) also found the MRM is better than traditional method with a mean absolute percentage error of 19.3% as compared to traditional model with a mean absolute percentage error of 25%. A study made in Jordan for public sector projects using this method (MRM) gave a margin of error +/- 0.035% (Hammad, Ali, Sweis, & Sweis, 2010).

3.7 Cost Data

Cost estimates rely on current and historical cost data (Serpell, 2004). It influences the estimating method used. The cost data used for preliminary cost estimates depends on tender bids. Hence, the cost data inherited various qualities of contractors' estimates (Ashworth & Skitmore, 1982). Drew and Skitmore (1992; 3) point out bidding strategy and its relation towards error:

> *"The bidder who makes the most mistakes wins the most contracts"*

3.7.1 Variability of cost data

Tender price errors occurred because of the adjustment of prices (addition or omission) in bids prepared by the bidders. Hence, cost data from previous projects are inherited with errors made by bidders who won the contract. The QS continues to use cost data for future cost estimates and thus tenders are still not free from errors. It happens because not all tenderers have the equal desire to win the contract (Runeson, 2000). The tenders submitted are not prices but offers. The bidders measure the compensation in order to win the tender according to risks and market conditions. The bidders, who submit their offers, do not have equal desires to win and they do not value it equally. This is because they have:

a) Different capacity utilisation.

b) Error in the estimate.

c) Different perceptions about current and future prices.

d) Availability of alternative projects.

The cost data variability could be improved if contractors used correct estimating practice (Beeston, 1974). Morrison (1984) concludes perfect cost data does not exist in practice because two exactly similar buildings were rarely built and the accuracy is subject to suitability and quantity of the cost data pool. He suggests the circumstance in which the previous cost data generated cannot be controlled by the QS. They have to make necessary adjustments on time, location, market conditions, site conditions etc. However, these adjustments could also increase the cost estimating error. According to Lowe et al. (2006), adjusting cost data using traditional method could not reflect the relationship between historical cost data and new project estimates. Thus, it cannot provide any clear relationship between cost and variables. This may encourage the use of alternative estimating method that provides a clear relationship between variables. As usual, most cost data will be chosen from similar characteristic but the data is subjected to different variability. This variability affects the estimates (Morrison, 1984). The estimated total average variability (cv) is about 15.5% (Refer to Table 3.8).

$$total\ variability = \sqrt{v_1^2 + v_2^2 + v_3^2 + v_4^2 + v_5^2}$$

$$= \sqrt{6.60^2 \ + v5.00^2 \ + 1.85^2 \ + 6.90^2 \ + 11.00^2}$$

$$= 15.50\%$$

Table 3.8: Variability in cost estimates (abstracted from: Morrison, 1984)

Cause	CV %
v_1=The variability in lowest tenders received in competition	6.60
v_2=The variability due to using cost data from previous lowest tenders	5.00
v_3=The inherent variability of the estimating methods (pricing bills of quantities)	1.85
v_4=The variability due to making adjustment to the chosen cost data	6.90
v_5=The variability due to imperfections in the cost data employed	11.00

Skinner, (1982) provides the evidence based on 80 case studies on a relationship between the number and value of items contained in bill of quantities. It shows that 86.3% of value is influenced by only 20% of measured items. This view is supported by Dell'Isola (2002) and according to Pareto principle, only 20 percent of the components of the building will represent 80 percent of the costs. The improvement of preliminary cost estimates should be focused on improving these significant items (Langston, 2002). Thus, Ashworth and Skitmore (1982) suggest this 80% insignificant items could be removed because most of these items are priced in a very subjective way. It ensures the variability inherited from the bills of quantities is reduced. On the other hand, Beeston (1974) argued that the cost data could only be improved if construction firms used enhanced estimating methods. Figure 3.3 shows the relationship of these items:

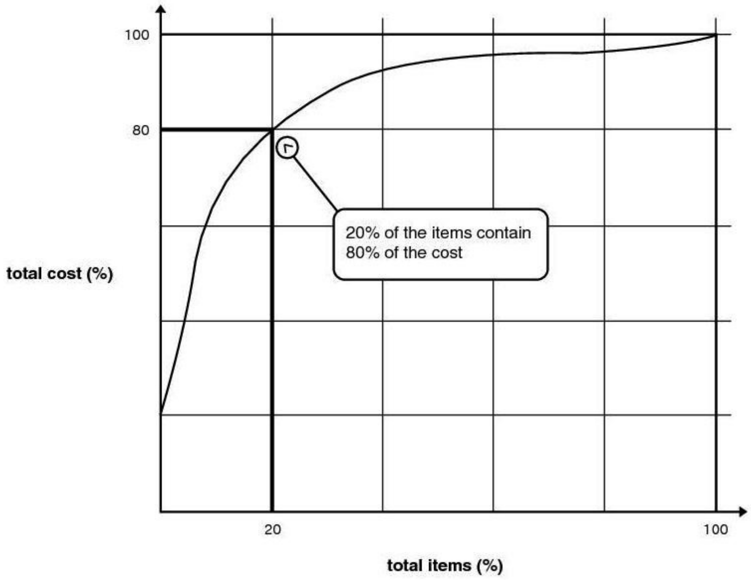


Figure 3.3: A Pareto principle describes 20% of significant items affects 80% of total cost (abstracted from: Langston, 2002).

Serpell (2004) explains the reliability of cost data based on historical information of previous cost data collected. In addition, the present cost data is also available from other sources of information i.e. vendors and designers. The use of cost data needs a certain consideration. It is because some items are performing the same function but with different cost implications. These are four (4) reasons why cost data are different according to Potts (2008):

a) Time (inflation)
b) Quantitative (magnitude of the works)
c) Qualitative (quality and performance)
d) Location

A study in the UK in 1982 – 1983 shows that a small change in contractors mark-up substantially affects the number of contract obtained by the contractors (Hillebrandt, 2000). Mark-up (profit and expenditure margin) is always included in the data collected from the tenders. It is because the historical cost data were used as cost data in future estimate. It was reasonable to determine the levels of profit and expenditure (overhead) of contractors, as this depends on the type of works and economic conditions (Ashworth & Skitmore, 1982).

3.7.2 Contextual requirements and variance of historical data

QS needs to identify the contextual requirements of historical data (Kiziltas & Akinci, 2009). These are classified differently. The main challenge is that there is different information on items and it depends on the type of work. A better way to select cost data is needed in order to resemble the accurate context and the nature of the project (Skitmore, 2001; Yeung, 2009). Building Information Modelling helps designers to provide more information that is accurate. It generates different levels of detail (LoD) ranging from depiction of approximate geometry, to precise geometry and then to fabrication level precision. Hence, different levels of estimation during cost planning can be enhanced according to design improvement. It improves the contextual requirements of project information. This system has improved the accuracy of estimates by 3% (Leite, Akcamete, Akinci, Atasoy, & Kiziltas, 2011). Here, there are two (2) types of projects, which are different according to its special needs (Refer to Table 3.9).

According to Yeung (2009), projects with less variance in the project specification using the same target group provide an acceptable level of accuracy. However, the problem regarding projects with large variances in the project specification[8] is that they are only few cost references available. Combination using same target group and non-

[8] Residential, carparking, social community, hotel, residential and school.

target group cost would improve the accuracy for projects with large variance[9]. In addition, cost-estimating performance could be improved if cost data groups are clustered in level that is more detailed. Table 3.9 shows scope differences produces different cost assessment. It is not possible for the cost data to suit perfectly any new projects.

[9] Hospital, university and commercial centre.

Table 3.9: Contextual differences in cost data

Element	Descriptions	Percentage from total cost (%)	
		Residential multi-storey (Smith & Jaggar, 2007)	Hospital / Healthcare (Boussabaine, 2007)
Preliminaries	The preliminaries are influenced by site access, storage, building height, scaffolding, adjoining properties, insurance, supervision, temporary works, plant and equipment and the complexity of the project (Smith & Jaggar, 2007). The cost depends on the contract period (Boussabaine, 2007). A project located at a restricted area is 50% higher than the average cost. A leveled site is lower than the average cost. A project at a steep slope is 20% higher than the average cost. A contaminated site is 23 % higher than the average cost (Boussabaine, 2007)	8 – 15	10 – 20
Piling and foundation	It is influenced by foundation type and subsoil condition (Smith & Jaggar, 2007). A site with a good and moderate soil condition is 24 – 39 % lower than the average cost. A site with a bad soil condition increases the cost 36 % more than the average cost (Boussabaine, 2007; Smith & Jaggar, 2007).	1 – 5	5 – 6
Frame (columns, upper floors)	The type of frames has a less influence on the total cost. The shape of building will influence the cost (Smith & Jaggar, 2007). A load-bearing building is 22 % lower than the average. Steel and reinforced concrete are 0.6% and 13% higher than the average cost respectively (Boussabaine, 2007). The preliminaries are expected to be higher in the reinforced concrete frame (Boussabaine, 2007).	10 – 20 (including upperfloor)	5 – 10 (excluding upper floor)

Table 3.9: Contextual differences in cost data (cont'd)

Stairs	It depends on regulation. It is hard to achieve cost reduction for quantity due to regulations but cost saving can be done from specification adjustments (Smith & Jaggar, 2007)	1 – 2	-
Roof	The multi-storey roof costs are not usually notable because a large built area will absorb the cost (Smith & Jaggar, 2007). The designers have to consider the type of roofs for construction i.e. pitch or flat (Boussabaine, 2007)	-	2 - 20
Envelope (walls and windows)	It depends on the shape of the building and the quality of materials (Smith & Jaggar, 2007). It includes technology, service zone requirements, complexity of the shape, building height, the ratio of the wall to openings etc. The cost can be minimized by reducing the floor-to-floor height. The complexity of wall's technology makes it difficult for QS to prepare an accurate price per m^2GFA. It is advisable to use similar type of buildings, shape and size (Boussabaine, 2007).	10 – 20	15 - 25
External Doors and Windows	These items are not cost significant (Smith & Jaggar, 2007). The cost of these element increases moderately if it needs fire safety requirements (Boussabaine, 2007). It is better to acquire quotations from sub-contractors and manufacturers (Boussabaine, 2007).	-	-
Internal Subdivision (Internal Walls, Screens and Doors)	It depends on the design and layout. Open layouts with minimal internal walls/screens will appreciate cost saving when it is multiplied by a large number of units (Boussabaine, 2007; Smith & Jaggar, 2007).	5 – 10	5 or more

Table 3.9: Contextual differences in cost data (cont'd)

Finishes (Wall, Ceiling and Floor).	Wall finishes are related to the design decisions of internal subdivisions (Boussabaine, 2007; Smith & Jaggar, 2007). Ceilings and floor finishes are related to the quality selection which are dependent on type and space (Smith & Jaggar, 2007).	-	Around 14%
Fittings	It depends on the quality of the provision. At residential projects, wardrobes, bathroom, kitchen and built-in fittings if multiplied by a large number of units can be a significant cost item (Smith & Jaggar, 2007). In a hospital project, the cost depends on the type of medical equipment to be supplied and installed (fixed, loose furniture, nurse stations) (Boussabaine, 2007).	5 - 10	5 - 9
Services	It takes a large proportion of cost if compared to the total cost. A spilt or integrated system may influence the system cost (Smith & Jaggar, 2007). Moderate and complex services are between 6 and 26 % higher than the average cost. (Boussabaine, 2007).	30 - 40	Around 25
External works	A site with a large area and extensive treatment could be substantial in cost (Boussabaine, 2007; Smith & Jaggar, 2007).	< 5	10 – 25

3.8 Chapter summary

Most results from other countries revealed that QS are more likely to overestimate than underestimate. Most QS are reluctant to underestimate the estimates, as clients are more likely to accept overestimate rather than underestimate. It is because the clients are more sceptical towards underestimated estimates. The clients believe the underestimation leads to cost overrun in the future. Historical project information used is one of the main reasons, which influence the accuracy of estimates because of variability of cost data. Most estimates are prepared in limited time. The accuracy depends on the availability of cost data and the estimating methods used. The use of more rigorous estimating methods is recommended for projects that are more complicated. Cost data is inherited with errors and it is collected from previous projects. A bidder who make the most errors is the most likely to be accepted because his offer is always the cheapest. He tends to reduce his margin in order to win the contract.

The contextual requirements of a project are very important to QS. He needs to pool / adjust the previous cost data in order to suit a new project. No cost data does perfectly suit the requirements of a new project. His sound judgement and the correct methods are the deciding factors for the preparation of accurate estimate. However due to anchoring effect and insufficient adjustments, cost estimates can become bias. The quality of estimates has not improved over time. It is because most QS practices have no performance review on quality. They are less likely to be aware the persistent trends. The accuracy benchmark set by QS is far from the target. In addition, the clients are not concerned with the performance criteria used by QS when preparing the early cost estimates. The accuracy of cost estimates will improve with the use of more rigorous estimating methods. However, QS must be reasonable when applying this method, as it needs more time to complete.

The targets to measure the accuracy as suggested by the some authors are different. Almost all authors have different views on the level of accuracy at design stage. Nevertheless, they suggest the estimates should be improved when the design stage is progressing. Alternative methods are not well accepted in Malaysia and in most other countries. It is because the traditional methods are straightforward, simple and easy to understand. Nevertheless, there are evidences that show the alternative methods may help QS to prepare estimates that are more reliable. The use of these alternative methods needs a simulation tool, which can help the designers, and clients to understand. This method should be more acceptable to all parties. If not, it will remain academic only.

CHAPTER 4: PROJECT CHARACTERISTICS WHICH AFFECT THE COST AND ACCURACY OF ESTIMATES

The previous part of review explains the accuracy of estimates, estimating methods and cost data. Most authors have a different view on the accuracy level and the measures of target. This chapter reviews the theory and empirical evidences on project characteristics, which affect cost and accuracy of the estimates. Actually, there are two categories of factors, which affect the estimates. (a) and (b) are actually interlink. They are:

a) Chapter 4: Project characteristics which affect the cost and accuracy of estimates
b) Chapter 5: Factors which affect the accuracy of estimates

Gunner and Skitmore (1999a) explained the factors which contribute to accuracy of the estimates could be influenced by more factors and interlink of variables may be presented. Project characteristics are the features of the projects i.e. physical and non-physical characteristics. It explains the nature of the target. These factors are objective and can be measured; therefore, researchers prefer to use statistical analysis on project characteristics using project estimates and bids for empirical study (Skitmore, 1991).

Skitmore (1991) established that the project characteristics determine the contract market, and this in turn will affect the price level. The factors are project type, project size, contract period, project scope, plan shape, location, procurement, competition, and economic climate. Gunner and Skitmore (1999a) introduced new variables to be included in project characteristics. Most of the variables from previous research remained. These variables are building function, contract type, contract condition, contract sum, PI, contract period, number of bidders, economic condition, procurement basis, project sector and location. According to Seeley (1996; 205),the purpose of cost modelling and its relation with factors which affect the estimating accuracy are as follows:

> *"A tender price prediction model, where the aim is to forecast the likely tender sum to be obtained from a contractor and also take cognisance of the contractor's estimating variability and the factors influencing market price. Because of the variable factors involved predictive models will be less reliable than design type models and some inaccuracy in forecasting is likely".*

Akintoye (2000) says project complexity, technology, information, the designers, contract type, duration and market conditions influence contractors' price. Skitmore (1991) standpoints on the project characteristics mentioned earlier are quite similar to Akintoye (2000). However, the contractors are more towards the ability to make profit and use more resource in estimating (Skitmore, 1988). Project characteristics, which affect the accuracy of estimates and costs, are as follows:

4.1 Building functions

Building functions are the physical features of a building. These features are building type, constraints, scheme priorities, space, arrangement, building form, plan shape, building size, perimeter to floor area ratio, circulation space, storey height, total height, specification and principal material (Ferry, et al., 2007; Seeley, 1996). These outline the scope of building construction. According to Dell'Isola (2002; 4), building scope is:

"How much portion of the process, to include the reasonable and quantifiable aspects of the facility: measures of program, building geometry and facility performance"

He explains the scope of a project should be consistent with project expectations and budget. The budget is secured if the designers are willing to make trade-offs between scope, quality and performance.

4.1.1 Type of building

There are various designs and types of buildings. The design influences cost estimates because buildings are made for a different purpose (Akintoye & Skitmore, 1990). They suggested that building function is design variable. Harvey (1979), Morrison and Stevens (1980), found that significant differences of accuracy between type of buildings in the UK, Belgium and Canada. Ling and Boo (2001) found the acceptable accuracy levels for estimates are different depending on the type of projects in Singapore.

Morrison and Steven, (1980) show estimates are more accurate for housing and school projects if compared to other sectors. McCaffer, (1975) found that the school projects demonstrated a high-level of accuracy at +/-5% and housing project at +/- 10%. According to Morrison and Stevens, (1980), the data of 256 school projects collected from five (5) public QS departments in the UK shows the mean error was 2.98% and standard deviation was 11.29%. Consistency of estimates are different between primary and secondary schools (McCaffer, McCaffrey, & Thorpe, 1984). Skitmore and Cheung (2007) studied the effect of types of buildings on accuracy. They have found that the QS are more sensitive to underestimating the commercial and residential buildings than the school buildings. The management of the PWD and other government agencies are categorised according to the type of project undertaken for example estimates for education and healthcare facilities are separately prepared by different departments as they have different project needs (Public Works Department, 2010a). Refer to Table 4.1 for evidence of type of project, which affect the accuracy of estimates.

Table 4.1: Empirical evidence on type of project affecting quality of estimates (abstracted from: Skitmore, Stradling, Tuohy, & Mkwezalamba, 1990)

Nature of target	Researcher	Evidence
Type of project	McCaffer (1975)	Buildings more biased and more consistent than roads
	Harvey (1979)	Different bias for buildings, non buildings, special trades and others
	Morrison & Stevens (1980)	Different bias and consistency for schools, new housing, housing modifications, and others
	Flanagan & Norman (1983)	No bias differences between schools, new housing, housing modifications and others
	Skitmore (1985)	Different bias and consistency for schools, housing, factory, health centre and offices
	Skitmore & Tan (1988)	No bias or consistency differences for libraries, schools, council houses, offices and other buildings
	Skitmore et al. (1990; 79-87)	No bias or consistency differences for primary school, sheltered housing, offices, unit factories, health centres and other buildings
	Quah, L.K (1992)	New works are more consistent than refurbishment
	Gunner and Skitmore (1999)	No bias or consistency differences for commercial, non-commercial and residential buildings. Renovation works are more biased and more consistent than new works

4.1.2 Constraints

Site constraints are related to site access, nearest service point and site condition. In addition, local government requirements for planning are also one of the constraints. In theory, client will impose constraint to design for e.g. manufacturing plant's machineries need a higher specification than the building which enclosed them (Ferry, et al., 2007). This factor is not available for data analysis because it is considered subjective.

4.1.3 Priorities of the scheme

The priorities of the scheme are the willingness of a client to pay more for his building i.e. for easy (cheapest) maintenance even though the building is usually more expensive at initial cost. In theory, the designers need to focus on a client's perspective e.g. profit, symbolism, welfare, religious affiliation, etc. (Ferry, et al., 2007). It is difficult to quantify the above factors (client's perspective) as they are considered subjective for data analysis.

4.1.4 Space, arrangement and form of the building

The arrangement of a building is strongly related to type of building. The arrangement could influence the space, requirements and the ease of movement. The layout has a major impact to costing because different type of building has its own set of needs (Ferry, et al., 2007). In theory, cost estimates are not accurate if fewer details are known except for standard repeated building (Morton & Jaggar, 1995). These details are space, arrangement and form of building. It could be based on the plan shape, size of building, perimeter to floor area ratios, circulation space and storey height. During early estimate, it is necessary to have the design sketch available to cost advisor. So, a higher degree of cost control could be implemented during this stage (Ferry, et al., 2007).

Building arrangement is important to building cost because it relates to buildings' usable, ancillary and circulation areas. Ogunlana and Thorpe, (1991) found that bias and consistency varied between different layout of office designs. Sometimes, the PWD employs standard design to some projects to ensure a minimum cost and construction methods are standardized. It ensures a faster project delivery than the customized design (Norwina, 2006). Space, arrangement and form of building need Elemental Cost Analysis (ECA), which is now unavailable for data analysis.

4.1.5 Plan shape

In theory, the unit cost of a building is lower if the design is simpler. Longer and narrow design is complicated and irregular. Therefore, the perimeter per floor area increases with a higher unit cost. It results in the increase of cost for corners in structural works, roofing and external works associated with drainage and others. The designers and clients should be aware that the shape could influence the cost of a building (Ashworth & Skitmore, 1982; Seeley, 1996). It seems that the relationship of plan shape and size towards the accuracy of estimates have been rarely discussed because appearances are hard to interpret by the researchers. It happens because no data is not available i.e. ECA only gives a slight indication about the plan shape. Nevertheless, in theory, most authors agree that rectangular shapes are more economical than round or irregular building shapes. When preparing for an estimate, QS allocate a certain percentage to allow previous cost data to stay relevant to new design proposed (Seeley, 1996). According to Skitmore and Tan, (1988) which is based on empirical evidence, bias and consistency are affected by contract period and basic plan shape.

4.1.6 Size of building

In theory, an increase in the size of buildings will decrease the cost per unit (cost/m^2GFA). However, some construction costs are fixed. These costs are transportation, erection of site cabin and storage of materials. This cost per unit will not increase drastically when the size of the buildings increases. The bigger the size, the smaller is the wall per floor ratio. It makes the room space bigger and reduces the cost per unit for partition and finishes. The decrease in cost/m2GFA could occur because of the economies of scale. The cost per unit is reduced when the volume of quantities is increased (Ashworth & Skitmore, 1982; Seeley, 1996). However, new evidence shows that economies of scale in construction industry is very difficult to achieve because it involves high intensity of labour and no standardized product (Hillebrandt, 2000; Valence, 2011). Morrison and Stevens, (1980) found that accuracy of estimates improved when size increased[10]. However, McCaffer, (1976) found out the size has no effect to accuracy. Aibinu and Pasco (2008) found that estimates of small buildings are more biased than larger buildings. In addition, the consistency of estimates for small buildings is inconsistent. In other study by Gunner and Skitmore (1999a) found that the consistency improves when the area is increased.

[10] It definitely worsens with size if it is a straight dollar difference between estimate and bid.

4.1.7 Perimeter / floor area ratios

In theory, a building is more economical if it has a lower wall per floor ratio. This ratio is influenced by planning efficiency of a building i.e. plan shape, size and storey heights. The irregular shape with more partitions needs more doors, windows and finishes (Ashworth, 2010; Seeley, 1996). It has some relationship with plan shape and space arrangement. This factor has a significant impact because of the additional cost for external walls (Stoy & Schalcher, 2008). The empirical finding shows if the wall per floor ratio of the building increases by 0.15 units, then building costs increase approximately 11%. However, it is not available for data analysis, as it needs the cost analysis of a single building.

4.1.8 Circulation space

The circulation space inside buildings provides the access for occupants. Entrance halls and corridors will give aesthetic value to building (Ashworth, 2010; Seeley, 1996). This factor is not available for data analysis because it needs the analysis of a single building.

4.1.9 Storey height and total height of buildings

In theory, storey height affects the quantity of internal walls, finishes and staircases. It affects the cost for mechanical and electrical works i.e. piping and lifts construction. The more the storey height increases the more the load of the building and foundation works, and it becomes more expensive to build (Seeley, 1996). The taller the building the more expensive plants are installed in order to provide hoisting work for construction materials. The cost for electrical and mechanical works such as fire fighting equipment are higher because of the safety requirement needed (Ashworth, 2010).

The cost per unit (cost/m^2GFA) of buildings is expected to decrease when the number of stories increases. But at a certain level of storey height (at level 3 or 4), the cost increases because some part of floor area need to allow for circulation space and lift shafts (Flanagan & Norman, 1978). This view is supported by Butts (2006). He explains the taller building requires more cost per square metre to build. It happens because of extra work is required to allow the elevator and its equipments to be installed. However, observation made in Hong Kong shows a different result, cost per unit decreases up to level 100 metre (at 30-storey height) but it increases after that (Picken & Ilozir, 2003). It happens because constructions of buildings in Hong Kong are more often high-rise and the contractors are more experience to construct tall buildings, which means positive height-cost relationship does not apply here. Blackman and Picken (2010) conducted a confirmatory study based on data collected from Shanghai, they found that a distinct height-cost relationship if it is compared to Hong Kong. The cost decreases up to 24 metre (at 8-storey height) but the cost increases rapidly after that. They concluded that the contractors in Shanghai are not skilled enough than their counterparts in Hong Kong, even though the former is characterised with tall buildings. According to research made in Australia, the estimates with less storeys are more consistent than more number of storeys (Aibinu & Pasco, 2008). They explained the number of the storey of buildings is the most important factor to explain the accuracy of estimates.

4.1.10 Level of specification and principal material

Performance of a building is related to its specifications. This performance is based on standard and quality of the materials. It fulfils the needs and functions of the buildings, especially for environmental comfort and prestigious quality. QS needs to prepare estimates and performance valuation for different materials as it involves capital, maintenance and operational costs (Ferry, et al., 2007). Most of the time, a normal standard specification is used by PWD. Usually, PWD projects do not emphasize on high standard quality, which is normally for luxury developments. Principal building material forms the structural works of buildings. Elinwa and Buba, (1993) and Elhag, Boussabaine & Ballal (2005) said that this cost factor is important because the volume needed is substantial. In Malaysia, building design employs reinforced concrete frame to build the substructure and superstructure works (Ahmad Fikri & Mohd Zulkifli, 1996). Steel frame structures are commonly used for factories and warehouses. According to McCaffer (1975), the accuracy of estimates for reinforced concrete frame is more accurate for medium and high cost projects. The principal material for this study is reinforced concrete structure.

4.2 Type and condition of contract

There are a number of conditions of contract forms used by the Malaysian government for buildings procurement. This study discusses only two (2) types of contracts. These are PWD203A (Revised 2007), and PWD Design and Build Revised 2007. Procurement methods and selection of bidders were ranked the highest factors which affect the cost estimates (Elhag, et al., 2005). The other important factors are payment methods and the spread of risks between parties. Aibinu and Pasco (2008) said the cost estimates for conventional projects are less biased than design and build projects. However, conventional projects are less consistent than design and build projects. Murdoch and Hughes (2007) explain that the design and build estimating is not similar to conventional projects. It happens because risks and uncertainties undertaken by the contractors are more for design and build construction. The contractors include risks pricing into their calculation. Refer to Table 4.2 for evidence on condition of contract, which affect accuracy of estimates.

Table 4.2: Empirical evidence on condition of contract affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Contract condition type	Wilson et al. (1987)	More bias for bill of quantities contracts
	Gunner and Skitmore (1999)	i) Bias difference between conditions of contract issued by Singapore Institute of Architects and Standard form
		ii) Consistency difference between contract with a fluctuation provision and contract without the provision

In Malaysia, for conventional project, the government reimburses for variation of building material prices but the government only pays for selected building materials. From 2008 onwards, the government decides to create a special additional provision to allow design and build projects to be paid according to market price fluctuation. The fluctuation price is shared equally by both parties (Ministry of Finance, 2008b). The risk for price fluctuation is expected to be minimum for public contracts in Malaysia because the government shares some of these responsibilities. The following are the common types of contracts used in PWD:

4.2.1 Conventional / general contracting (PWD 203A)

The PWD 203A is a fixed lump sum contract with quantities. This contract states that the Bill of Quantities shall form part of the contract (Public Works Department, 2007a). The design is under the responsibility of the PWD but it could be under the private designers if the PWD appoints them as consultants. The contractors are responsible for the quality of the works undertaken (Murdoch & Hughes, 2007).

4.2.2 Design and build (PWD DB)

The PWD DB is a fixed lump sum contract without quantities. The contract sum analysis[11] shall form part of the contract (Public Works Department, 2007b). The contractors are responsible for the design and quality of the works. It means the contractor will be penalised directly by the government if he fail to perform either one or both responsibilities. This contract allows single point responsibility (Murdoch & Hughes, 2007). This is because most of the risks shift from a client to a contractor.

4.3 Basis of Selection

A client could select bidders for his tender by using open tendering, selective and direct negotiation. Basis of selection is important because the competitiveness of tender influences the price. In the low bid method, the bidders who enter the contract with low bid value are considered to be more competitive than those with high bid value (Drew & Skitmore, 1992). The PWD uses open tendering for most of its projects. This literature

[11] estimated value of the works.

review focuses on three (3) methods of tendering only. These are open tender, selective tender and direct negotiation.

4.3.1 Open tendering

The bidders enter the tender at their own initiative. Open tender means most bidders can bid. A client is not concern who the potential bidders are. There is no control over the size of bidders and the selection is based on competitive selection method (Drew & Skitmore, 1992). The bidders affect the intensity of tender prices, as this creates competition. Open tendering has one major advantage if the bidding process is independent of political, social and economic pressure (Herbsman & Ellis, 2006). The price is the most important criteria for evaluation. Clients are more inclined towards the lowest bid due to the cheap contract. Elements like time and quality are secondary. Nevertheless, the weaknesses of open tendering are the unreasonable low bids, bid rigging and unqualified bidders.

4.3.2 Selective tendering

A client invites the bidders to bid. The number of bidders is limited. According to Drew and Skitmore (1992), the selective tendering could achieve the same competitiveness as the open tendering if there are a sufficient number of tenderers competing. The selective tendering reduces bidding from unqualified bidders. It ensures those bidders who are not qualified to stay out. But, some bidders who are qualified may put 'cover price[12]' because they did not want to win the project (Raftery, 1991). They have decided not to

[12] An expensive bid for tender that they have no intention of winning.

take part because of the risks from his current projects. Nevertheless, they do not want to damage business relationship with the client.

4.3.3 Direct negotiation

Direct negotiation tendering is an uncompetitive tender. It means only one supplier is contracted by a client for the provision of goods and services due to his expertise in one-off project (Government of South Australia, 2008; Public Works Department, 1995). This tendering allows uncompetitive price to be offered by only one bidder. It removes the competition, as no other bidders can make an offer. Pegg (1984) analysed 1372 competitive contract and 65 negotiated contract to clarify the price competitiveness of these contracts. He shows the negotiated contracts are significantly 13% higher than competitive contracts. Refer to Number of bidders (page 79) for further review.

4.4 Project value

Flanagan and Norman, (1985) point out that there is no relationship between the accuracy of estimates and the contract values[13]. Harvey (1979) reveals the bigger the value of the projects, the less bias is the estimates. This is contrary to Wilson et al., (1987). They found that the increase of the project value would decrease the bias. In Australia and Nigeria, estimates of smaller project value tended to be biased but more consistent than the expensive projects (Aibinu & Pasco, 2008; Oladokun, Oladokun, & Odesola, 2009). A study by Kiew (2009) using cost data from QS consultants in

[13] It definitely worsens with project value if it is a straight dollar difference between estimate and bid.

Sarawak[14] found the trend is reversed. Positive bias increases as the project value increases.

Skitmore (2002) found the estimates for expensive contracts were underestimated for up to 7% than the cheap contracts. Skitmore and Cheung (2007) explain that there is evidence from previous researches which show that the expensive projects are forecasted accurately. Gunner and Skitmore (1999b) said this phenomenon is simply inexplicable. They envisage that expensive projects inclined to be more complicated than small projects. QS estimates are predicted to be overestimated. In theory, there is one possible explanation; expensive contracts are more significant in the opinion of the clients therefore, it influences the QS forecasting trends. Aibinu and Pasco (2008) agree with this theory. Estimating works for small buildings are usually assigned to junior quantity surveyors, while the large projects are assigned to senior member of QS consultants. Refer to Table 4.3 for evidence on contract size, which affect accuracy of estimates.

[14] State in east of Malaysia (Borneo Island).

Table 4.3: Empirical evidence on contract size affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Contract size	McCaffer (1992)	No bias trend
	Harvey (1979)	Bias reduces with size
	Morrison & Stevens (1980)	Modulus error reduces with size. Consistency improves with size
	Flanagan & Norman (1983)	Bias trend reversed between samples
	Wilson et al. (1987)	No linear bias trend
	Skitmore & Tan (1988)	Bias reduces and consistency improves with size
	Skitmore (1988)	No consistency trend
	Ogunlana and Thorpe (1991)	Consistency reduce with larger contract size
	Cheong (1991; 106)	No consistency trend
	Thng (1989)	No consistency trend
	Gunner and Skitmore (1999)	Bias reduces and consistency improves with size
	Skitmore (2002)	No bias or consistency trend

4.5 Price intensity theory (PI)

Gunner and Skitmore (1999b) offer a new theory to explain the accuracy of estimates. This theory is called as “Price Intensity Theory (PI)”. It could explain the systematic bias, which occurs during estimation. PI is the cost estimates of the building divided by GFAm^2. This theory states that the building with low cost/m^2 gross floor area tends to be overestimated while the higher cost/m^2 tends to be underestimated. The following is the formula for PI (cost/m^2):

$$Price\ intensity = \frac{\$(x)}{\$(Y)GFAm^2}$$

$X =$ *estimates*

$Y =$ *Area of the building*

$GFA =$ *Gross Floor Area*

This explains why the contracts with high PI are expensive contracts and contracts with low PI are cheap ones. This theory states the QS's bias of is when he chooses his cost data (usually in cost/m^2GFA). This results in a systematic bias in the estimates (Gunner & Skitmore, 1999b). PI theory is significant and sufficient to explain systematic bias of estimates because the variable is predicted to be significant in the final model. Nevertheless, a research made in Australia could not prove the certainty of this theory (Aibinu & Pasco, 2008). Refer to Table 4.4 for evidence on PI which affect the accuracy of estimates.

Table 4.4: Empirical evidence on PI affecting quality of estimate (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Price Intensity	Skitmore et al. (1990; 191)	High value contract were underestimated and low value contracts were overestimated
	Gunner and Skitmore (1999)	High value contract were underestimated and low value contracts were overestimated

4.6 Contract period

In theory, if the period of construction is longer, there might be some changes made by the client and projects take a long time to complete. In addition, preliminaries items with a large amount of overheads will increase (Akintoye, 2000). Skitmore and Ng (2003) found that the actual construction period for industrial projects are the longest to complete if compared to residential, education and recreational ones. Study on the data of 51 projects by Chan (2001) in Malaysia found that the time to complete a RM1.0 million project is about 269 days (almost 38 weeks). He shows there is a direct relationship between time and cost. Therefore, QS needs to adjust the historical cost data for a new contract period. This means construction costs could increase or decrease according to construction period for example if a project needs to be completed under a normal construction period, it increases the construction costs (Stoy & Schalcher, 2008). QS must ensure the estimates represent the actual time taken. Refer to Table 4.5 for evidence on the contract period, which affect the accuracy of estimates.

Table 4.5: Empirical evidence on contract period affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Contract period	Skitmore (1988)	No difference between groups of contract period
	Gunner and Skitmore (1999)	No conclusion due to different results obtained from using contract sum as the base measurement of bias against contract sum minus provisional sums as the same

4.7 Number of bidders

Number of bidders affects the competitiveness of contracts bidding. McCaffer, (1976) and Flanagan, (1980) show estimates are more bias when the number of bidders increases. Number of bidders depends on economic conditions (Skitmore, 1988). In good times, when there are plenty of works for contractors, fewer bidders would be interested to bid. This ultimately increases the bid prices. It also depends on the nature of works. Bigger contractors are more competitive on large contracts. The small and medium bidders are obligated to small and medium contracts respectively (Drew & Skitmore, 1997).

There is a connection between a large number of bidders and the competiveness of price. A large number of bidders means a price reduction (Carr, 2005; Pegg, 1984). In theory, if selective tendering is done according to merit it gives competitive bids (Drew & Skitmore, 1992). These merits are firm capacity, experience on similar project and type of expertise. Skitmore (1988) explains the selective tendering is acceptable for competitive prices when reasonable number of bidders enters the bid. A study by Skitmore (2002) on 10 data sets from different countries found that an additional bidder to contract bidding reduces the bias. Most bid prices stay more or less the same when more than eight bidders enter the contracts. This study could not decide any clear relationship between consistency and number of bidders. Dell'Isola (2002) says that bid price is 15% more expensive if only two bidders enter the bid. A 10% bid price reduction when a large number of bidders are involved.

A study made in the United States on 84 projects shows that a reduced number of bidders increase the project bid price. When only one bidder enters the bid, the price is roughly 15% more expensive. There is a four percent reduction if one new bidder enters the bid. It reduces to 27% when eight bidders enter the bid. The bid price is more the less stagnant when more than eight bidders enter the bid (Carr, 2005). According to this study, competitiveness of bid could be maximised if at least eight bidders enter the bid. After that, the competitiveness is not improved. Refer to Table 4.6 for evidence on nature of competition which affect the accuracy of estimates.

Table 4.6: Empirical evidence on nature of competition affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Nature of competition	Harvey (1979)	Estimates higher with more bidders
	McCaffer (1975)	Estimates higher with more bidders
	Harvey (1979)	Ditto. Inverse number of bidders gives best model
	Flanagan & Norman (1983)	Estimates higher with more bidders
	Runeson & Bennett (1983)	Estimates higher with more bidders
	Hanscomb Association (1984)	Estimates higher with more bidders. No-linear relationship
	Wilson et al. (1987)	Estimates higher with more bidders. No-linear relationship
	Tan (1988)	Ditto but not with UK Data
	Ogunlana and Thorpe (1991)	No bias and consistency trend

4.8 Good / bad years

Market condition may change from good to bad. It leads to overestimate (Gunner & Skitmore, 1999a). This validates the Cheung et al. (2008) finding as they found the mean acceptable error increases when the market condition changes from good, moderate to bad condition. This is because of the uncertainty of market, especially when the market condition gets worse. As a result, the QS tend to overestimate in worse market conditions. Refer to Table 4.7 for evidence on economic climate, which affect the accuracy of estimates.

Table 4.7: Empirical evidence on economic climate affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Prevailing economic climate	Neufviller et al. (1977)	Estimates higher in 'bad' years with lagged response rate
	Harvey (1979)	Estimates higher in 'bad' years with lagged response rate
	Flanagan & Norman (1983)	Estimates higher in 'bad' years with lagged response rate
	Morrison & Stevens (1980)	Estimates higher in 'bad' years with lagged response rate
	Ogunlana and Thorpe (1991)	No significant relationship
	Gunner and Skitmore (1999)	Estimates higher in 'bad' years with lagged response rate

4.9 Project sector

There are two categories i.e. private and public projects. Overestimate is perceived to be higher in commercial and residential buildings except for industrial building. Public projects e.g. school is not prone to overestimate (Cheung, et al., 2008). It happens because commercial buildings are more rewarding but with more risks. In addition, Gunner and Skitmore (1999a) found consistency is better for private sector than the public sector. The contractors are more willing to venture into commercial projects, and they put a higher risk premium and let go the other project opportunities. In fact, clients are less tolerance to cost overrun for residential and commercial buildings because of the commercial nature of those developments during good market (Cheung, et al., 2008). Study made in Hong Kong found out the QS overestimates private sector projects more than the public projects (Skitmore & Drew, 2003).

4.10 Location

Location plays a part in determining construction cost. This comes about because of different wage structure and material prices at different location (Pegg, 1984). Study made in Australia found the estimates prepared for Central Business District is accurate but not consistent. In metropolitan areas, QS tends to overestimate but more consistent than others. Cost estimates for rural areas tends to be overestimated but inconsistent (Aibinu & Pasco, 2008). Harvey (1979), shows there is a significant regional effect to estimates prepared in different Canadian regions. In Malaysia, the PWD publishes the locality index according to state grouping (Refer to Table 4.9). It allows adjustment of locality factors during estimation. Refer to Table 4.8 for evidence on project location, which affect the accuracy of estimates.

Table 4.8: Empirical evidence on project location affecting quality of estimates (abstracted from: Skitmore, et al., 1990)

Factor	Researcher	Evidence
Geographical location	Harvey (1979)	Bias differences between Canadian regions
	Wilson et al. (1987)	No bias trend between Australian regions
	Ogunlana and Thorpe (1991)	No conclusion although bias and consistency difference between regions of the United Kingdom

Table 4.9: The locality factor grouping for index adjustments (abstracted from: Public Works Department, 2009b)

Group	A	B	C	D	E	F
States	Perlis, Kedah and Pulau Pinang	Perak	Selangor, Wilayah Persekutuan, Negeri Sembilan and Melaka	Johor	Pahang	Terengganu and Kelantan
	1.0816	1.0466	1.0000	1.0567	1.0438	1.0417

4.11 Other factors

In Singapore, Gunner and Skitmore (1999a) said the bias and consistency of estimates is better if the foreign contractors constructed the projects. In addition, bias of estimates is found different between foreign and local architects. This shows the firms' locality also plays an important role in influencing the accuracy of estimates.

4.12 Chapter summary

Most researchers suggest the use of project characteristics as the measureable target to measure the accuracy because most of it can be quantified and interpreted from the use of project data. Most importantly, most of the factors have obvious cost implication. This is important for empirical research that is based on evidences. However, there is no consensus among authors, which of the approaches could deal with every aspect of cost estimating research. QS prepare their estimates based on project characteristics as these are the nature of target. The outcome of estimates relies on these factors. Some of these factors could have correlation with other factors and some are very subjective. Using project data could give more results that are reliable because data are originated from specific institution which prepare the estimates. The literature review reveals some of the project characteristics, which are unavailable for data analysis. It is because some of these factors are very subjective or unavailable. They include project constraints, scheme priorities, building space / arrangement, plan shape, perimeter to floor area ratio, specifications and contract type.

The larger the project values the more accurate the estimation. Some authors found the inexpensive projects are more likely to be overestimated if compared to expensive ones.

It is because inexpensive projects are estimated by junior QS, while expensive ones are prepared by senior QS. It contradicts the notion of big and expensive projects will result in an overestimate if compared to inexpensive and smaller projects. Nevertheless, some authors found out the estimates are biased in expensive and large projects. Other authors found no relationship. In the case of standard design projects, cost estimates are expected to be more accurate than customized projects. The standard designs are alike and thus cost data and design information are more or less consistent. Previous studies show that most QS are overestimating in both public and private sector. The type of project also affects the accuracy. School buildings are expected to have less bias estimates than commercial projects. Commercial buildings are more likely to be overestimated because the risks are more than public buildings.

Some results show estimates are more likely to be overestimated when more bidders enter the bidding. This could bring down the value of tender prices because of the intense competition. However, others found no correlation between number of bidders and accuracy. The more the number of storeys, the more accurate are the estimates. It reveals that the estimate bias depends on regional factors. This affects the QS pricing because of the different wages, material prices and machinery costs. This literature review reveals the error trend that occurred for each project characteristics are not identical. The bias and consistency depends on the location of studies. A new theory by Gunner and Skitmore (1999b) called the PI alone which can explain the systematic bias in the cost estimates. This theory specifies a low cost/m^2 is overestimated and high cost/m^2 is underestimated. The data analysis will further examine the theory.

CHAPTER 5: FACTORS WHICH AFFECT THE ACCURACY OF ESTIMATES

The previous part of literature review explains how the project characteristics influenced the cost and accuracy of estimates. This part of review explains the factors, which affect the accuracy of estimates. Some of these factors could be related with project characteristics i.e. through design scope. However, this part would explain more about ability of forecaster, estimating methods, cost data and procedures. In calculating the cost estimates, physical characteristics are not the only consideration (Harding, et al., 1999). There is a need to represent the other complex and little-understood interrelationships that exist between all the cost variables. Other researchers have defined it as “soft” factors (Stoy, Pollalis, & Schalcher, 2008).

5.1 Factor which affect the accuracy of estimates

The primary factors, which decide the quality of forecast is nature of target, level of information, forecasting method, feedback mechanism and estimator (Skitmore, 1991). According to Serpell (2004), accuracy of early estimates depends on scope quality, information quality, uncertainty level, estimator performance and quality of estimating procedure. According to Li Liu and Kai Zhu (2007), factors which influence the accuracy of early cost estimates can be represented by three major factors:

Table 5.1: Factors influence early cost estimate (Li Liu & Kai Zhu, 2007)

Input control factors	Behaviour control factors	Output control factors
Project information	Estimating process	Expected accuracy
Team experience	Team alignment	Review of estimate
Cost information	Estimating design	benchmarking

Dell'Isola (2002) says the validity of cost estimates depend on the following factors:

a) The clarity of estimates' documentations

b) Promoting understanding among all parties involved using anticipated level of format.

c) Designers' commitment to achieve common objective during estimation.

d) A proper consideration on market factors, contingencies, and major risks.

e) Allowing adequate time and effort required to prepare an estimate.

These authors have the same idea about factors, which affect QS accurate estimates. Refer to Table 5.2 for the model, which affects the accuracy of estimates by Serpell (2004). These are as follows:

a) Scope quality represents:

  i. Design and experience of the project team to ensure the completeness and stability of scope.

  ii. Consistent project needs.

b) Information quality represents:

  i. Reliability and availability of current information from vendors.

ii. Reliability and availability of historical information from previous projects.

c) Uncertainty level represents:

i. Environmental changes which are related to market conditions include the material supply and financial uncertainty.

ii. The uncertainty factors are labour productivity, project technology and complexity of the design.

d) Estimator performance depends on his experience, effort and the estimator personal traits. Beeston (1974) says direct improvement of QS performance could improve the coefficient of variation of estimates by 6%

e) Quality of estimating procedure is the expected level of errors and time taken to prepare estimates.

Table 5.2: The model for accuracy of estimates (abstracted from: Serpell, 2004)

Design / Estimating team experience	Completeness of scope	Scope quality
Consistency of scope with project demands		
Owner's commitment	Expected stability of scope	
Project technology		
Project complexity		
Applicability of historical information	Quality of historical information	Information Quality
Reliability of historical information		
Availability of current information	Quality of current information	
Reliability of current information		
Changes in market conditions	Environmental uncertainty	Uncertainty level
Major changes in escalation rates		
Labour productivity changes	Project uncertainty	
Project technology		
Project complexity		
Field	Experience	Estimator performance
Estimating		
Perception of estimating importance	Effort applied	
Common sense	Personal characteristics	
Self confidence		
-	Errors and omissions	Quality of estimating procedure
-	Timetable	

5.2 Other factors which affect the accuracy of estimates

In addition, according to many authors there are other factors, which affect the accuracy of estimates. These factors are as follows:

5.2.1 Familiarity of Quantity Surveyor on type of projects

Morrison and Stevens, (1981) found that the familiarity of QS towards a particular building contributed around 40% of improvement in accuracy. It describes the QS's specific experience could improve the accuracy of cost estimates (Lowe & Skitmore, 1994). This is because senior QS gain experience through direct involvement with the projects, while young practitioners earn their experience through observation. Experience from previous similar projects might contribute significantly toward the quality of estimates (Skitmore, Stradling, & Tuohy, 1994). QS must recognise the trend in estimating in order to improve his assumptions especially when there is no monitoring system available to quantify the QS estimating performance (Lowe & Skitmore, 1994). Experience in estimating is specific rather than general (Ashworth & Skitmore, 1982). QS makes inaccurate estimates when he has to estimate a project which is different from his previous experience.

5.2.2 Communication barrier

The communication barrier is caused by misunderstanding of the cost messages communicated between clients and cost consultants (Bowen & Edwards, 1996). Realistic estimating can be achieved if there is a full co-operation and effective communication between consultants and client during the pre-contract stage (Seeley, 1996). New Scottish Parliament (1997-2004) is a high profile public project associated with miscommunication problems (Dainty, Moore, & Murray, 2006). It happens partly because this is a complex and large project. As the result, the initial estimated cost increased substantially. The communication problem arises when the client made an informal decision-making. A preliminary cost estimate is provided earlier, before the site selection and design concept are completed. There is also unclear line of responsibilities and miscommunication among project teams and the builder despite high-quality personnel involved in this project. The designers and the client failed to communicate effectively. It has resulted in an extra allocation to compensate this underestimated project.

5.2.3 Unclear documentation

Documentation is a client or designers supply documents, specifications, drawings and schedules (Smith & Jaggar, 2007). These include bills of quantities or contractors' supplied documents as it depends on the method of procurement. Most estimates are prepared with limited documents and incomplete details. It could increase the risks of wrong assumptions. An estimate with too little documentation will lead to confusion and arguments because they make different assumption when making the estimate (Dell'Isola, 2002). The accuracy of estimates depends on the completeness of data. This is because a more rigorous estimating method will be used when more information is available. At each design stage, the accuracy level will improve (AACE International, 2005). It happens because conventional estimating methods depend on the magnitude of information received. The area method is usually used for preliminary estimates while the approximate estimate is used when designers supplied more detail drawings. During cost planning, QS should update the information provided by designers. This is made sure through cross checking of estimates at the early stage of design (Smith & Jaggar, 2007). It provides the QS with information and specification for materials and other details, which are important for construction. It also ensures all changes are tracked and, thus reduce the possibility of budget exceeding the target.

5.2.4 Limited time to prepare estimate

Lack of project information at early design stage happens because of the limited time provided by the client. It happens especially to projects which use sophisticated technology (Karlsen & Lereim, 2005). Moreover, a large project is likely to have a huge risk because it involves large and complicated designs. This leads to incomplete estimation because some of the items are not included or excessively assumed (Magnussen & Olsson, 2006). Lack of information increases the chance of high price margin by QS. This happens because QS needs to assume unknown circumstances of the project. A bidder who knew a fair amount of information about a project decreases their price margin if compared to those bidders who were given partial information (Soo & Oo, 2007). QS are suspected to increase his pricing if little information is obtained. Oberlender and Trost (2001) found out if enough time is allocated for preparation of cost estimates the accuracy could improve. It happens because a number of cost drivers have not been resolved. Accuracy of estimates will be better if enough time and personnel are available (Sinclair, et al., 2002). Nevertheless, the cost to prepare the estimates is uneconomic if it takes a longer period of time (Fellows, et al., 2002). The use of more rigorous methods takes more time to complete. They suggest the use of estimating methods should comply with the nature of the project. A finding in South

Korea reveals time allocation for estimating tasks is the most important factor in order to improve the accuracy of estimates (An, et al., 2011).

5.2.5 Quantity Surveyor experience in estimating

Competency of QS in estimating is determined by understanding the cost-determinants (Elhag et al, 2005). Oberlender and Trost (2001) consider competency as the experience of QS to determine and influence the quality of cost information. The more experience the QS the more accurate the estimates (Ashworth, 2002; Skitmore, et al., 1994). QS's instinct to forecast the estimates may improve up to 6% of estimating consistency (Beeston, 1987). QS should be knowledgeable, careful and confident (Skitmore, et al., 1994). In addition, specific traits contribute greatly to QS's judgements are differential perception, sensitivity and attitude towards uncertainty. Differential perception defines the QS ability to identify the aspects of a contract. Sensitivity is the ability of QS understands the clients' needs. The right attitude to uncertainty is needed so QS could cope with inadequate information. There is a growing concern among cost estimators in the United States about the shortage of competent cost estimators over the next decade (Alroomi, Jeong, Chong, & Oberlender, 2010). Most experience estimators are on the verge of retiring. This is because some scope of knowledge, skills and experience are not easy to transfer to a young practitioner. One of the competencies that could not be transferred is soft skills. However, technical skills could be learnt through time.

5.2.6 Quantity surveyor mark-up bias

QS's bias lead to overestimation (Skitmore, et al., 1990). This is agreed by Magnussen and Olsson (2006). They said no QS want to prepare underestimated estimates. This is because they want to avoid unpleasant surprise to the clients if his estimates are the lowest. It may put QS at risk of being sued by his client and also has to return the consultation fee to client (Chappell, et al., 2001). According to Shane et al. (2009), contractors' bias estimates is a tendency to be overoptimistic about the significance of cost factors which results in the bid to be underestimated. QS always aims to be on the safe side when preparing the estimates. They are more concerned about clients rejecting the underestimated estimates. They suspect the cost overrun will occur with underestimated estimates. This view has encouraged QS to put some extra mark-up. QS simply add on the 'raw'[15] estimates with the amount they felt suitable (Skitmore & Cheung, 2007). This assumption may not always be true as some findings revealed that the trend of overestimating reduces if the project value is getting higher[16].

5.2.7 Application of alternative estimating methods

Some of the alternative estimating methods are recent to practice, and it gives little information to QS (Karlsen & Lereim, 2005). These methods such as regression and probabilistic equation are used widely in academic only (Raftery, 1991). It could replace the current traditional methods because some considered the alternative methods are more accurate (Butts, 2006; Cheung & Skitmore, 2006; Li, et al., 2005; Lowe, et al., 2006; Skitmore & Patchell, 1990). However, the inclusion of these methods into the

[15] Predetermined estimate.

[16] It depends on how the accuracy is measured.

current practice may not likely because QS consider the traditional methods as acceptably accurate to justify their rejection (Harding, et al., 1999). The use of alternative estimating methods is also not well-accepted by QS in Malaysia (Nor Azmi, et al., 2008; Nurul Azam, et al., 2006).

5.2.8 Ability of QS to cope with stress

The estimates need to be completed during a limited time at the tendering stage. QS needs to work as a team for a short period of time to overcome this lengthily and tedious estimating process (Leung, Skitmore, & Yee, 2010; Leung, Zhang, & Skitmore, 2008). Cost estimation is a highly stressful task for QS. Stress is divided into three (3) categories:

a) Objective stress (external factor): QS perception towards jobs loading e.g. deadline and number of projects.

b) Subjective stress (internal factor): It relates to QS level of satisfaction in the working environment.

c) Emotional exhaustion: It relates to job burnout due to prolonged exposure to stressful work. Committed and productive QS may lose his concentration overtime.

It was found that QS in contracting firms is subjected to objective stress due to high analytical tasks such as calculating, planning and organizing. They recommended that QS should be given more autonomy, good feedback, fair reward and treatment to reduce the stress level (Leung, et al., 2010; Leung, et al., 2008). In addition, emotional support and feedback could enhance communication process between QS and their employers. Emotional supports include effective communication, recognition and understanding (Leung, et al., 2008).

5.2.9 Contingencies and variation of price (VOP)

PWD classifies risks in pricing as contingencies and Variation of Price (VOP). A certain percentage is added to the preliminary cost estimates (Public Works Department, 1992). Contingencies' allocation for estimates must be sufficient (Karlsen & Lereim, 2005; Mak, et al., 1998). Smith, Merna and Jobling (2006) point out estimates are realistic if there are proper consideration of expected risks and uncertainties. These considerations are cost, time and quality as these are the primary targets for a project. But more often, contingencies' estimation relies on expert judgement which is based on the percentage described in various cost estimates standard (Rothwell, 2004).

Rothwell (2004) points out contingencies for estimates could pose a major problem on bidder's tender offer. This is because the allocation by clients through designers is different from bidders' allocation. Allocation depends on the level of risks, uncertainties and confidence level. The PWD states that its QS determines the contingencies for conventional projects separately for both preliminary cost estimates and accepted tenders (Public Works Department, 1992). However, in design and build projects, bidders include the contingencies allocation in construction cost. According to report from National Audit Department (2006), contingencies percentage allocated were insufficient, as some projects needed an additional allocation for local government requirement. It was found that contingencies allocation could not cover this figure. They suggest a comprehensive guideline should be prepared to overcome this problem. Allocation should cover changes in market condition, financial, project management, labour productivity, project technology and complexity of design (Serpell, 2004). Smith and Jaggar (2007) describe the contingencies are needed to cover planning, design, contract and project risks. Australian Institute of Quantity Surveyors recommends the risks pricing as in the following (Cost Control Manual, 2000; 2-17):

a) Planning risks are to cover the risks for design. It ensures the design is according to the spatial relationships of the required functional area. It also allows additional travel and other engineering allowances.

b) Design risks are to cover the risk of the designers if they fail to predict the accurate design and its complexity.

c) Contract risks are to cover the risks of variations and unforeseen items encountered during construction.

d) Project risks are to cover delays and/or inflation, major changes required by the client or authorities, fee negotiations and others.

Rothwell (2004) describes contingencies allocations rely on expert judgement based on cost-engineering standard. The percentage of contingencies is allocated according to design stages. The percentage of contingencies as suggested by AACE and Electric Power Research Institute (EPRI) is at +/- 10% to +/- 15% expected accuracy. The allocations are 5% and 5% to 10% respectively. The VOP is an amount allocated based on the projected increase and decrease of the building cost index issued by the department of statistics. It allows not more than 5% of builder's work (Public Works Department, 1991). Table 5.3 shows the materials covered by VOP are as follows:

Table 5.3: Materials covered by variation of prices (Ministry of Finance, 2008a)

Building and infrastructure works	**Electrical and Mechanical Works**
Cement, steel bar reinforcement, premix, sand, aggregates, water pipe, corrugated steel beam guardrail, steel fabric reinforcement, diesoline, fuel oil (Light and Medium), bitumen,	Cables, switchgears, transformers, generators, lighting protection system & earthing system, air-conditioning system and motor (pump set)

The percentage of contingencies and VOP provided in estimates are more related to final cost. It emphasizes towards cost escalation in the contract. However, this research focuses on bidding price prediction and not the final cost. Nevertheless, it is important to determine the sums of contingencies and VOP in the preparation of estimates. Skitmore and Cheung (2007) suggest the easiest way to estimate cost contingencies is by using percentage variance of contract prices and future final accounted costs. Meanwhile, Karlsen and Lereim (2005) and Picken and Mak (2001) suggest the use of breakdown structure in estimation on each construction risk (Refer to Figure 5.1). Both the above methods are using probabilistic approach to determine the cost contingencies. The contingencies' percentage suggested by AACE and EPRI is for estimates with 80% confidence level (Rothwell, 2004). Whereas, PWD standard guideline suggests the contingencies should not exceed 10% of item 1 to 8 in PDA form. Refer to Appendix 1. This allocation does not consider the confidence level or the expected accuracy of estimates. PWD depends on its QS officers' expert judgements rather than the scientifically proven method.

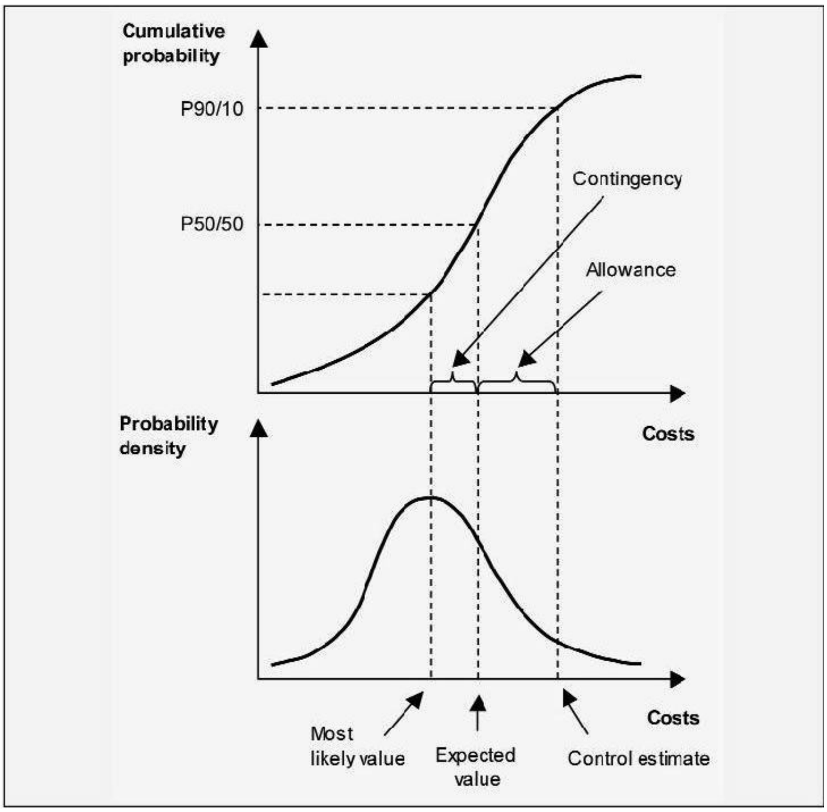


Figure 5.1: Estimation using probabilistic approach for cost contingencies

QS has to differentiate the accuracy percentage before and after the contingencies' mark-up (Dysert, 2006). It is important because the closeness to bid amount changes after the allocation is added to the estimate (Refer to Figure 5.2 and Table 5.4). However, the practice in PWD only allows the contingencies for conventional contract. The government absorbs the risks if there are additional design changes and fluctuation of prices. The bidders should not overprice these risks, as this will be allocated by PWD. Contingencies and VOP are not considered in the evaluation of tender. In design and build projects, the VOP and contingencies are priced inclusively with building items. The VOP is priced by bidders for design and build because these risks are under their contractual obligation. From 2008 onwards, the government compensates design and build projects at 50:50 profit and loss sharing (Ministry of Finance, 2008b). Both contractor and government share this allocation. It is because the sharp increase in price of building materials in 2008. The contingencies are high at preliminary stage. As design progress to a more detailed design the contingencies reduce into a smaller amount than previously allocated (Dell'Isola, 2002; Loosemore & Uher, 2003). Smith and Jagger (2007) recommended at the early design stage, the percentage is about 5% but will fall to 1% to 2% at the tender stage. They suggest the contingencies for planning and design risks could be zero when the tender design is completed.

Figure 5.2 (i): Estimate accuracy range affected by contingencies (abstracted from: Dysert, 2006)

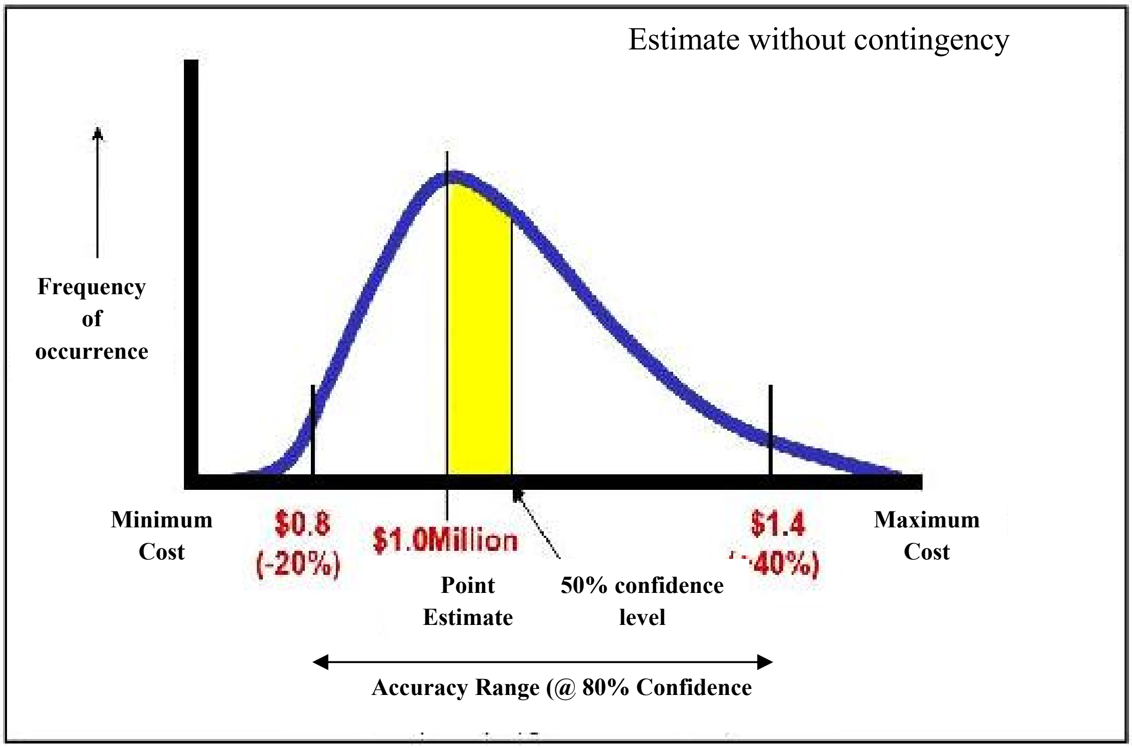


Figure 5.2 (ii): Estimate accuracy range affected by contingencies (abstracted from: Dysert, 2006)

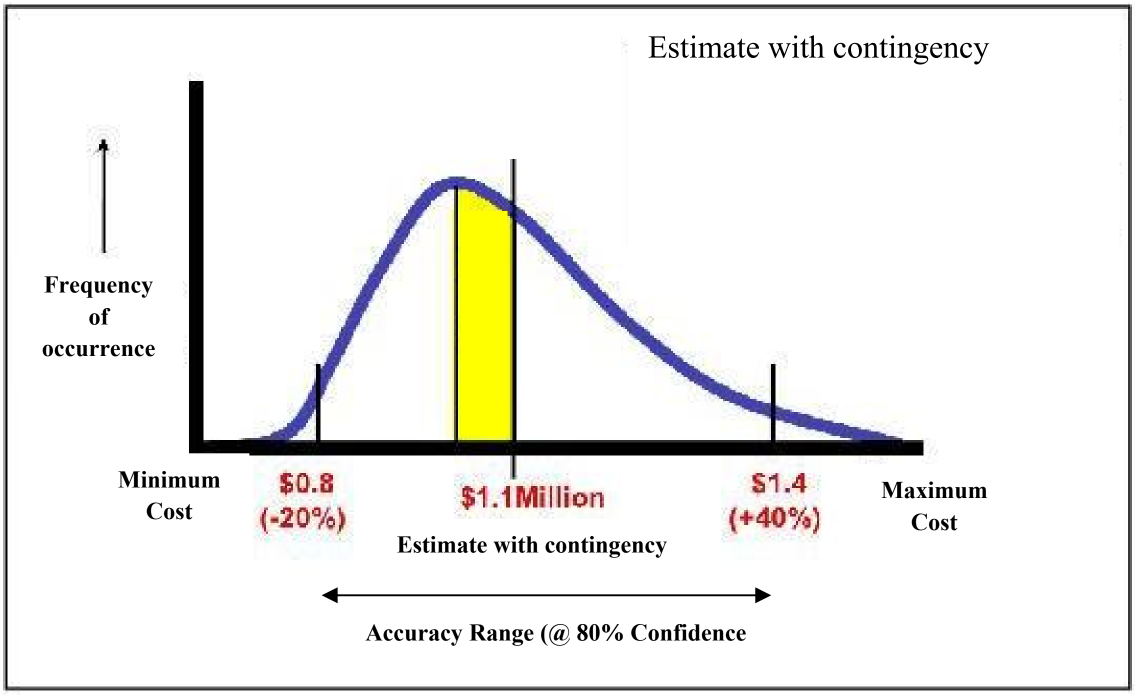


Table 5.4: The accuracy of cost estimates affected by Contingencies (abstracted from: Dysert, 2006)

Point Estimate	$1.0M
Estimate with contingencies	$1.1M
Low Range (80% Confidence)	$0.8M
High Range (80% Confidence)	$1.4M
Estimate Range (before contingencies) -20% to +40%	
Estimate Range (after contingencies) -27% to +27%	

5.2.10 All other factors mentioned in this literature

These factors are as follows:

a) Design scopes – it refers to Building functions in project characteristics (page 63).

b) Commitment of client to project – Most of the times, Malaysian government will go ahead with extra budget or reduced scopes.

c) Design team experience – similar to QS expertise and experience.

d) Location - refer to location in project characteristics (page 83).

e) Type and condition of contract – refer to type and condition of contract in project characteristics (page 71).

f) Basis of selection - refer to basis of selection in project characteristics (page 73).

g) Project technology and complexity – project complexity is related to project size (Doyle & Hughes, 2000) (page 68).

h) Cost data – refer to cost data (page 51).

i) Market conditions - refer to good and bad year in project characteristics (page 81).

j) Perception of estimating importance – a smaller project is carried out by junior QS (Aibinu & Pasco, 2008).

k) Expected level of error in estimate – the accuracy of estimate is better when design progressing (page 40).

l) Estimating method – more rigorous estimating method increases the accuracy. Refer to estimating methods (page 43).

m) Availability of estimating procedure in organization – refer to PWD estimating procedure (page 27).

5.3 Chapter summary

Factors, which affect the accuracy of estimates, may involve other factors, which are not explained by project characteristics such as uncertainty level, information level, QS experience and quality of procedure. These factors are very subjective, as it could not be measured through project characteristics. Some authors prefer to use the expert view of QS and other designers for e.g. the use of questionnaire survey to explain in general the accuracy of cost estimates for e.g. Elhag et al. (2005), Enshassi, Mohamed & Madi (2005) and Oberlender and Trost (2001). Expert opinion looks into the generalization of factors, which affect the accuracy of estimates and it may not be comprehensive because QS are not aware of persistent trend due to lack of feedback mechanism especially on measurement of their estimating performance. However, it could provide more explanation on factors, which are very subjective.

QS could prepare more accurate estimate if he had a similar previous experience for the same type of building. In addition, QS with good technical knowledge could give results that are more reliable. It is also influenced by QS who performs the task. Attitude and stress are also known factors, which can affect the QS performance during estimation. Soft skills e.g. communication are hard to learn if compared to technical skill. This proves the specific experience of QS in estimating is very important. Systematic biases did occur due to numerous reasons. One of them is that QS is biased while performing their estimating task. QS make more assumptions that are correct if he had more information and this will result in estimates that are more accurate. Less information could lead to more bias estimate. It could happen unconsciously or deliberately because data from previous studies show overestimation bias happened more often.

The VOP and contingencies could influence the accuracy of estimates if bidders price both of these estimating components but this happens only in design and build projects. The accuracy changes according to the percentage allocations from contingencies and VOP. In conventional project, contingencies and VOP are not priced by the bidders but by the designers. As usual, both contingencies and VOP are added to both PDA and ATDA. Some suggest the percentage should be allocated based on the confidence level, estimate accuracy and design stage. Most authors agree contingencies should be reduced when project phase is progressing.

As summary, the factors which affect the accuracy of estimates are divided into 5 (five) categories. These could be used to discover which ones of them are considered important to QS in PWD and QS in private consultants. These factors are as follows (Table 5.5).

Table 5.5: The known factors affecting accuracy of estimates

Scope quality	• Design scope (Plan shape, size m^2, height, specification and performance) • Design team experience (architect, engineers and etc) • Unclear documentation (project brief / drawings) • Location of the project (site and soil conditions and extent of services) • Type and condition of contract • Basis of selection (open, selective and direct negotiation) • Commitment of client to project
Information quality	• Cost data (historical and current information)
Uncertainty level	• Project technology and complexity level • Market conditions and sentiments
Estimator performance	• QS' experience • Ability of QS to cope with stress (work pressure) • Communication barrier • Familiarity of QS with the type of projects • Perception of estimating importance
Quality of estimating procedure	• Expected level of error in estimates • Limited time to prepare estimate due to dateline • Estimating method used in the preparation of estimates • Application of alternative methods by organisation • Organization's estimating procedure

CHAPTER 6: APPROACHES TO IMPROVE ACCURACY IN ESTIMATING

The accuracy of preliminary cost estimates must improve as the construction industry becomes more complicated. This is because the introduction of new technology and procurement options into the industry. The QS in PWD and hired QS consultants need to improve, so that they can enhance their estimating policies and procedures. This ensures the estimates are more accurate and more acceptable to clients. The improvements needed are as follows:

a) Improvement to current estimating process.
b) Introduction of new approaches in existing policies.

6.1 Improvement to current estimating process

A number of authors have discussed their concerns about the estimates' reliability for many years. There are a number of researches on the factors, which influence the estimating accuracy and the steps to improve it. However, these researches are based on the procurement and working systems of their respective countries. Ling and Boo (2001) and Aibinu and Pasco (2008) analyzed the current estimating processes to prepare cost estimates in order to improve accuracy in Singapore and Australia. Perhaps, in a different location like Malaysia, the results might be different. The most important methods to improve the current estimating process according to them are in the following table:

Table 6.1: Findings by Lin Boo (2001) and Aibinu and Pasco (2008)

Ling and Boo (2001) in Singapore	**Aibinu and Pasco (2008) in Australia**
a) Proper design documentation and information management b) QS to check all estimating assumptions **c)** Client to provide a realistic estimating period	a) Sufficient design information b) QS to check all estimating assumptions c) The use of cost control and cost planning

The methods are explained as in the following:

6.1.1 Design documentation and information management

Better design documentation and information management could be understood easily by all designers (Ling & Boo, 2001). BRB[17] and NRC[18] (1990) of the United States concluded that the standard formats, and terminology should be developed and used by both private practices and government agencies. They believe the problem persists because there are different terminologies used by different parties responsible for federal projects. It leads to flaw contextual understanding and it creates different assumptions. This is acknowledged by QS consultants hired by PWD (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004).

6.1.2 Effective communication and coordination

There is a need to establish an effective communication and coordination among all parties which include architects, engineers and QS (Ling & Boo, 2001). Sound communication is very important because of the enormous information flow in every

[17]Building Research Board, Committee on Budget Estimating Techniques, United States of America.

[18]National Research Committee, Committee on Budget Estimating Techniques, United States of America.

stages of the project design. QS are expected to make assumptions to cover some of the aspects of design insufficiency. QS needs to get responses from the designers in order to make acceptable assumptions (Smith & Jaggar, 2007). It is confirmed by Seeley (1996), who said realistic estimating can be achieved if there are full co-operation and good communication between consultants and clients. It could be done by having design coordination meetings and feedbacks from the designers and clients. Refer to Communication barrier (page 90).

6.1.3 Sufficient design information

Sufficient design information is required before the estimating process commences (Ling & Boo, 2001). It ensures the contextual requirements of cost data are confirmed. The cost data is very subjective in its classification due to different type of work (Kiziltas & Akinci, 2009). Boussabaine (2007) describes the design information could be incomplete, inaccurate or late in delivery. Critical cost information such as high-cost items should be available to QS sooner as it contributes enormously to the project value (Smith & Jaggar, 2007). The estimating method is based on the availability of design information. Hence, QS should not employed unsuitable estimating methods that use unsupported design information. The communication of design information manually takes a lot of time to convey from one party to the others. Introduction of Building Information Modelling (BIM) could improve this because the incorporation of collaborative working environment through effective communication can be done in real time through online mechanism (Grilo & Jardim-Goncalves, 2010).

6.1.4 Feedback systems and ascertained assumptions

QS need to double-check all assumptions with clients, architects and engineers. Those assumptions' feedbacks should be arranged formally (Ling & Boo, 2001). Study by Lowe and Skitmore et al. (1994) shows different QS make different assumptions on the same type of building. It concludes that QS needs feedbacks from other designers and clients in order to ensure the reliability of his assumptions. Boussabaine (2007) explains cost plan without proper assumptions could lead to inappropriate decisions and loss of value. All the assumptions and its objectives should be listed and approved by all parties involved. Incorrect assumptions lead to erroneous cost estimation.

6.1.5 Tender documents used in estimates

It is not a normal practice to prepare cost estimates based on tender drawings. Most of the time, QS uses preliminary design drawings (Ling & Boo, 2001). The tender drawings are the contract drawings before the construction proceeds but they are a complete design. However, the problem of having tender drawings used as an estimate is that it could not be completed in time. A client would ask for cost estimates at the early stage because decision on cost limit is decided during that time. Tender drawings could be used to prepare the estimate if standard pre-design drawings are used for the project. Tender drawings are used for final estimates in tender evaluation rather than the preliminary cost estimates, which are rather inaccurate. The tender drawings are considered as a complete design because it complies with client needs, and all design details were finalised. This reduces uncertainties and increases the confidence of QS in terms of pricing. The QS will use the bills of quantities as estimates as they ensure more definite items are included according to the rules of measurement.

6.1.6 Quantification of risks

The percentage figure should not be applied to contingencies but they should be clearly identified, classified and priced (Dysert, 2006; Karlsen & Lereim, 2005; Ling & Boo, 2001; Mak, et al., 1998; Picken & Mak, 2001). The contingencies should be priced according to expected accuracy and the confidence level of the estimates (Rothwell, 2004). These risks include market condition, financial, project management, labour productivity, project technology and complexity of design (Serpell, 2004). Refer to Contingencies and variation of price (VOP) at page 96.

6.1.7 Cost planning and cost control

Ling and Boo (2001) believe QS should implement the cost planning and cost control activities during design stages. It ensures more accurate estimates as any changes are tracked closely. The aims and objectives of cost planning as summarized by Seeley (1996; 13):

> *"Cost planning aims at ascertaining costs before many of the decisions are made relating to the design of a building. It provides a statement of the main issues, identifies the various courses of action, determines the cost implications of each course and provides a comprehensive economic picture of the whole. The architect and the quantity surveyor should be continually questioning whether a specific item of cost is really necessary, whether it is giving value for money or whether there is not a better way of performing a particular function".*

The cost planning is undertaken during the pre-tender stage, while cost control is implemented at all stages of building life cycle, according to Smith and Jaggar (2007; 85) :

> "*Methods of controlling the cost of a building from the inception stage through to the completion and preparation of the final account, handover and into occupation of the building through life cycle costing and facilities management. Cost control is relevant at all these stages in the development and use of buildings".*

The following are the methods of cost controlling:

a) Frame of reference (cost limit): the sum of all elements in cost plan
b) Method of checking (cost target): It divides the elements of a project and can be adjusted according to design, quality and area as the design progresses.
c) Means of remedial action (cost check): It ensures the cost targets will not exceed the cost limit.

Ferry et al. (2007) explain that QS who does not undertake the cost planning and control during preparation of estimates, may see his estimates having a large gap when compared to the tender price submitted. Cost management systems could help clients to make decision based on the cost that he can commit and this will reduce abortive design works.

6.1.8 Cost data selection and updates

Selection of cost data should not solely based on the lowest bidder. This was suggested by Drew and Skitmore (1992). They found the bidders who made the most mistakes would win the most number of jobs. The tendency of QS using the winning tender bids could lead to more errors for their future estimating works. QS should update cost data with new cost analyses and obtain necessary feedback from designers (Ling & Boo, 2001). Refer to Cost Data (page 51).

6.1.9 Subdivided large item

Langston (2002) says the large items with expensive value should be reduced into small items rather than the other way round. Usually, the larger the item the more the error, as larger item is complicated. He proposes each part of an item should not exceed 1.5% of total project cost. A fewer number of sub-estimate items reduce the chances of one error to be cancelled by other errors (Morrison, 1984). This happens because QS may price an item incorrectly and this increases the chances of estimates to be less accurate. However, due to estimating method constraint, only some of them are applicable. When preparing elemental estimate for large projects, most QS consultants in the UK priced the detailed level of element, when more information is available (Soutos & Lowe, 2011). Area method may not be able to appreciate the large item reduction because the area of a building is the basis for measurement. It is more applicable to approximate quantities and elemental estimate.

6.1.10 Others

The other improvement is to provide more acceptable time allocation for estimating task as a detail one could be produced. The many types of estimating methods have their own reliability. Using methods that are more rigorous may increase the chances of getting estimates that are more accurate. The cost of buildings is influenced by market sentiment and economic conditions so it is advisable for QS to include these changes in their estimates. All procedures are mentioned in the previous part of the literature review.

6.2 Introduction of new approaches into the policies

The Building Research Board (BRB) was asked by Federal Construction Council of the United States to review the current estimating practices of federal projects so that the existing procedure could be improved. The committee found that faulty estimating methods and procedures are not the primary reasons for budgets related problems. They concluded that the early estimate procedures used by the federal government is in fact comparable to private estimators. Nevertheless, they suggested a number of new approaches to be used by both federal government and private practices (BRB & NRC, 1990). The Royal Institution of Chartered Surveyors (RICS) has also introduced standardize guideline in order to reduce practice inconsistency. There are as follows

6.2.1 Investment and collaboration in cost estimate research

Government agencies and private practices should invest and collaborate in cost estimating research (BRB & NRC, 1990). Research on estimating should be conducted jointly, and the results should be shared together among participants and they could be used on a larger scale. Thus, the feeling of "not invented here" is avoided. Collaboration between government and private sectors in solving the estimating problem should be rewarding because the government as a client makes the policy whereas private practices undertake the consultancy services. If only one party decides to carry out the improvement in estimate procedure, it could create a setback because one party may not be able to know all the other party's needs. Therefore, the objective of the research is not attainable.

6.2.2 Sharing cost data

The sharing of cost data could be done on similar constructed facilities (BRB & NRC, 1990). Many government institutions are constructed with the same facilities, and this gives plenty of cost databases. It should be shared among various departments, institutions and private practices. Large pool of cost data could result in the improvement of estimating performance especially amongst similar projects with less variance in project specification and cost (Yeung, 2009). The system of cost data sharing could include BIM to provide integrated solution to cost estimate. It can be calculated from model quantities during the phase of development as the data depends on the level of information provided by designers (Grilo & Jardim-Goncalves, 2010) (refer to Figure 6.1). Procurement agencies in Taiwan are using a system of data mining algorithm for public construction projects in order to improve the government procurement effectiveness (Refer to Figure 6.2 and Figure 6.3). The system uses a large pool of cost data to estimate the range of bidding prices (Perng & Chang, 2004). This is calculated from an annual awarded price during past fiscal year. It gives the procuring agency historical information regarding construction market. This helps the agency to improve the accuracy of estimation for future projects.

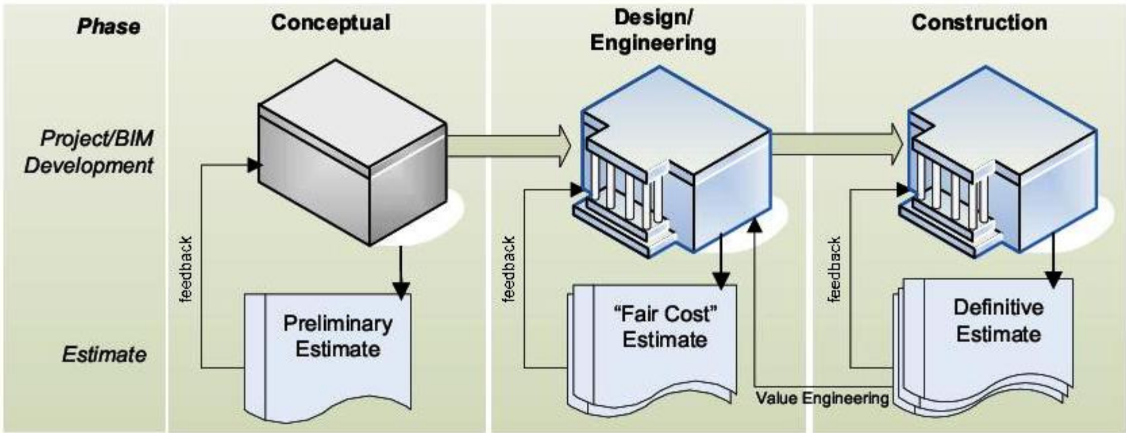


Figure 6.1: Project phases and cost estimating method (abstracted from: Sabol, 2008)

Figure 6.2: Unified Modeling Language (UML)[19] use-case diagram for Taiwan government construction procurement data mining (abstracted from: Perng & Chang, 2004)

[19] Standard diagramming notation to illustrate analysis and design models.

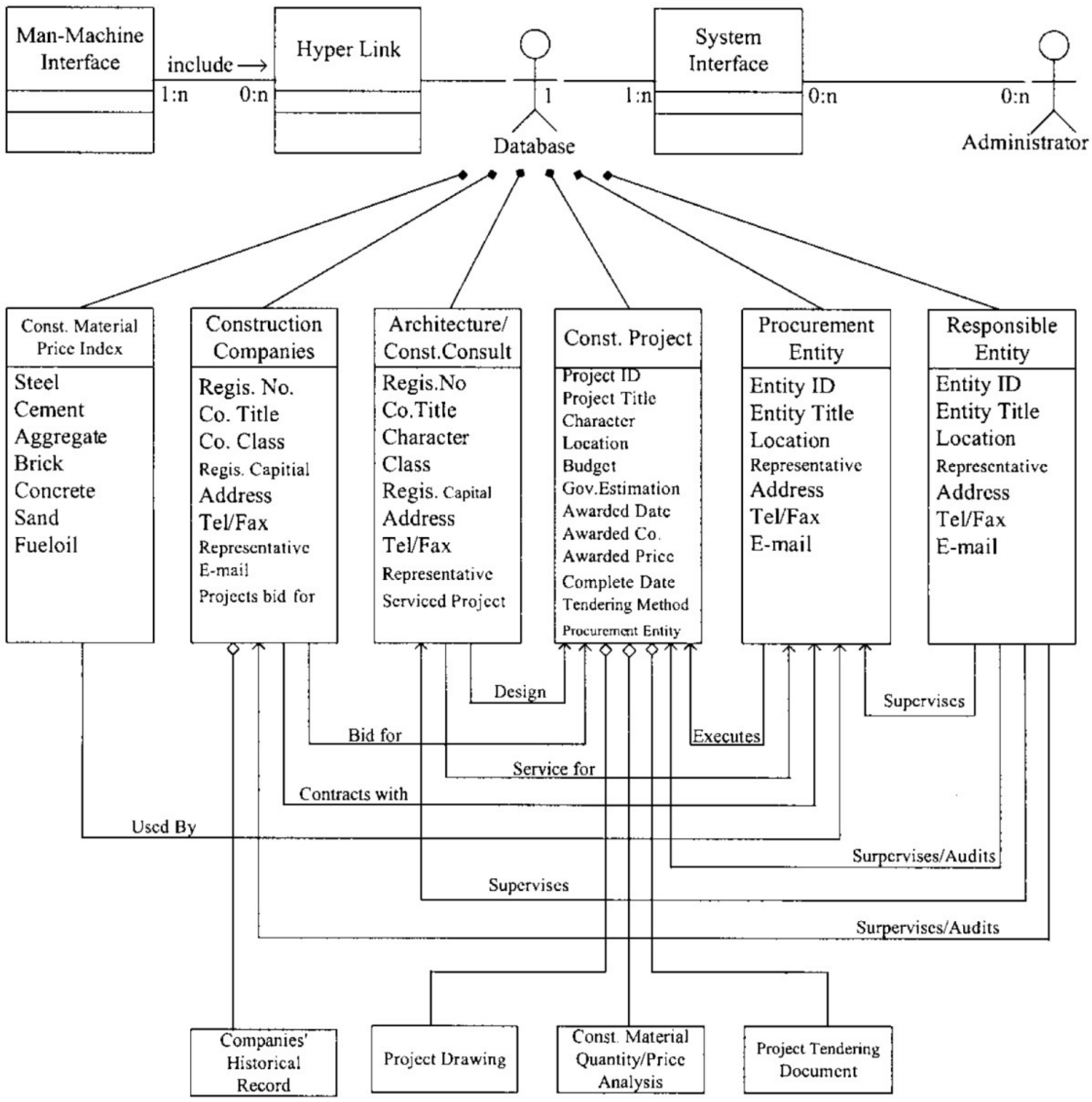


Figure 6.3: UML conceptual model for Taiwan government construction procurement data mining (abstracted from: Perng & Chang, 2004)

6.2.3 Alternative estimating methods

The use of alternative estimating methods such as mathematical modelling for e.g. parametric modelling and others should be used during the early stages of a project (BRB & NRC, 1990). The traditional methods are prone to error, as every possible cost item must be priced and the likelihood of an item being missed is high. On the other hand, the mathematical model start with a complete estimate before it can be adjusted according to new project requirements. The Kennedy Space Centre has decided to use the parametric estimating method for early cost estimates, as this method is accurate within +/- 5%. However, it takes time to build the system as it involves the collection of vast data. The cost modelling developed can be adjusted according to building size, number of bidders, number of storeys and etc and it reflects the project characteristics (Butts, 2006). Yet, Fortune (2006) has criticised the use of alternative estimating methods because many practitioners failed to use it effectively. It could be improved if these methods include the construction process. Nevertheless, it remains unpopular to many practices even though most academics have urged the industry to use these methods. They should be aided with a standardised process and decision aid simulator to encourage a more probabilistic based approach. According to Prince (2002), the aided decision tool for alternative cost models should include:

a) Programme of the work and construction variables
b) Predict the type of question or queries that may be asked by designers and clients
c) Able to explain the logic on how the estimating model will run

According to him (Prince), the second and third characteristics of a model are the one that hold back the progress of using the alternative cost model. It is because effective management decision is based on the understanding of designers about the model.

6.2.4 Value Management

The value management attempts to minimize direct costs and eliminate over-designed. This is to ensure the facilities are serviceable, safe, and favourable to occupants. BRB and NRC (1990) recommend value management to ensure the estimate procedure is well coordinated and comprehensive. Firm project brief and unnecessary costs could be reduced without losing its functions. Smith and Jaggar (2007; 70) explained the value engineering as:

> *"The concept encourages a questioning approach to design decisions and continually prompts the client and the designer to consider alternatives that may still provide the same level of quality and performance for a much lower cost. That is, better value".*

The unnecessary costs can be eliminated by persistent search of waste through the use of value analysis without impairing the quality of the estimates (AACE International, 2005). The problems in eliminating unnecessary costs are as follows:

a) Lack of information: the QS are unfamiliar with the knowledge of materials and methods. It happens due to the unavailability of accurate, detailed and understandable cost data.

b) Lack of original ideas: the QS are only familiar with a few inherited ideas to resolve design problem.

c) Honest wrong belief: the incorrect belief continues to dictate QS estimating habits. It leads to unnecessary costs to be included in the estimates.

d) Temporary circumstances and time pressure: the condition that put the QS into unnecessary circumstances. He might prepare the estimates with wrong assumptions but has to make changes later.

e) Habits and attitudes: Some QS have certain habit of resisting to changes.

f) Overdesigning: QS should recognise the clients' needs. Unnecessary costs should not be included in the estimates.

Malaysian Airport Berhad[20] and Tenaga Nasional Berhad[21] are the earliest organisation that implemented Value Management, (Mohd Mazlan, 2010). They required projects, which were more than RM 300,000 and more than RM 10million respectively to implement value management. In 2009, the government introduced Value Management as compulsory requirement to all public procurement for projects which are more than RM 50million (Economic Planning Unit, 2011). This ensures projects could achieve its required targets. These targets are as follows:

a) Increasing the level of accuracy on assumptions used during the planning.
b) Identifying the real needs in order to achieve the set functions.
c) Promoting and generating creative ideas.
d) Optimizing resource utilization.
e) Accelerating the process of making a decision.
f) Ensuing and improving the standards, rules, procedures and criteria for projects to be consistent with the development and current needs.
g) Enhancing performance and synergy of participants which involved in the work group.
h) Minimizing the "gold plating"[22] .
i) Taking into account the use of Life Cycle Costs (Life-Cycle Cost - LCC).

[20] Government-linked company entrusted for operation, management and maintenance of airports in Malaysia.

[21] Government-linked company entrusted for generation, transmission & distribution of electricity in Malaysia.

[22] gold-plating is when implementation goes beyond the minimum necessary requirements set by the organization.

6.2.5 Estimating training

The government and private practices should invest in estimating training programs in order to improve the technical knowledge. Technical skills can be improved if more training time is available (Alroomi, et al., 2010). This could increase QS knowledge with new information and techniques. It ensures QS to be well prepared with the current changes for project estimation (BRB & NRC, 1990). Quantity Surveying course is focused less on estimating as most of the subjects are focused on tendering i.e. the preparation of the bills of quantities (Hackett & Hicks, 2007). It results in a limited supply of high-level performers in the industry especially for estimating tasks. They suggested QS to take a specific estimating course and qualification so they could become highly skilled personnel.

6.2.6 Introduction of standardized rules of measurement

In 2007, Royal Institute of Chartered Surveyors (RICS) released a Standardized Rules of Measurement. This is to ensure a uniform cost advice for estimating and cost planning by the QS. Previously, there is no specific standard procedure on the measurement of estimating (Lee & Smith, 2010). As a result, QS had to adopt the principles described in Standard Method of Measurement for quantities (SMM), Elemental Cost Analysis (ECA) guidelines or company procedure. These give inconsistencies to QS practices. The SMM provides the guideline for Bills of Quantities but not the preliminary cost estimates and cost plan. The introduction of this guideline could reduce the inconsistencies especially on items that are priced. Some issues had been brought up by private QS consultants, which were engaged by PWD. These are incomplete drawings, poor communication and lack of of knowledge on PWD procedures. In addition, some terminologies used by PWD are not well understood by QS consultants. Hence, these problems could be overcome by having a standardize procedure (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004).

6.3 Chapter summary and conceptual framework

The accuracy of preliminary cost estimates could be enhanced with improved methods to current estimating process. These methods are as follows:

a) Proper design documentation and information management.
b) Effective communication and coordination between designers.
c) Sufficient design information from the designers.
d) Ascertained assumptions from designers and client.
e) Establish formal feedback for design and estimating activities.
f) Realistic time for estimating activity.
g) Use more rigorous estimating method
h) Incorporate market sentiments and economic conditions into estimate.
i) Tender documents used as estimate.
j) Quantification of design and construction risks.
k) Cost planning and cost control during design stage.
l) Subdivided the large item into small items to reduce pricing errors.
m) Improve methods of selection, adjustments and application of cost data.
n) Update cost data with new cost and create feedback system.

Introduction of approaches in existing policies is recommended. Some suggested that the government and private practices should invest more in cost estimate research, sharing cost data, value management and alternative estimating methods for more accurate estimates. It is suggested that both government and private QS should invest on training courses and new standardized rules for estimating which are acceptable to both are found. Cost data sharing could be incorporated with BIM and data mining algorithm. A number of researches show that these two systems significantly improved the accuracy of estimates.

As a summary, the literature review provides this research with ideas and the information needed to define the problems, variables, limitations and their relationships these are used to construct the conceptual framework (Refer to Figure 6.4). The theories and empirical evidences guide the aspect of this research and they help to design the research methodology. Observation from this study will be discussed to provide critical views, assumptions and suggestions.

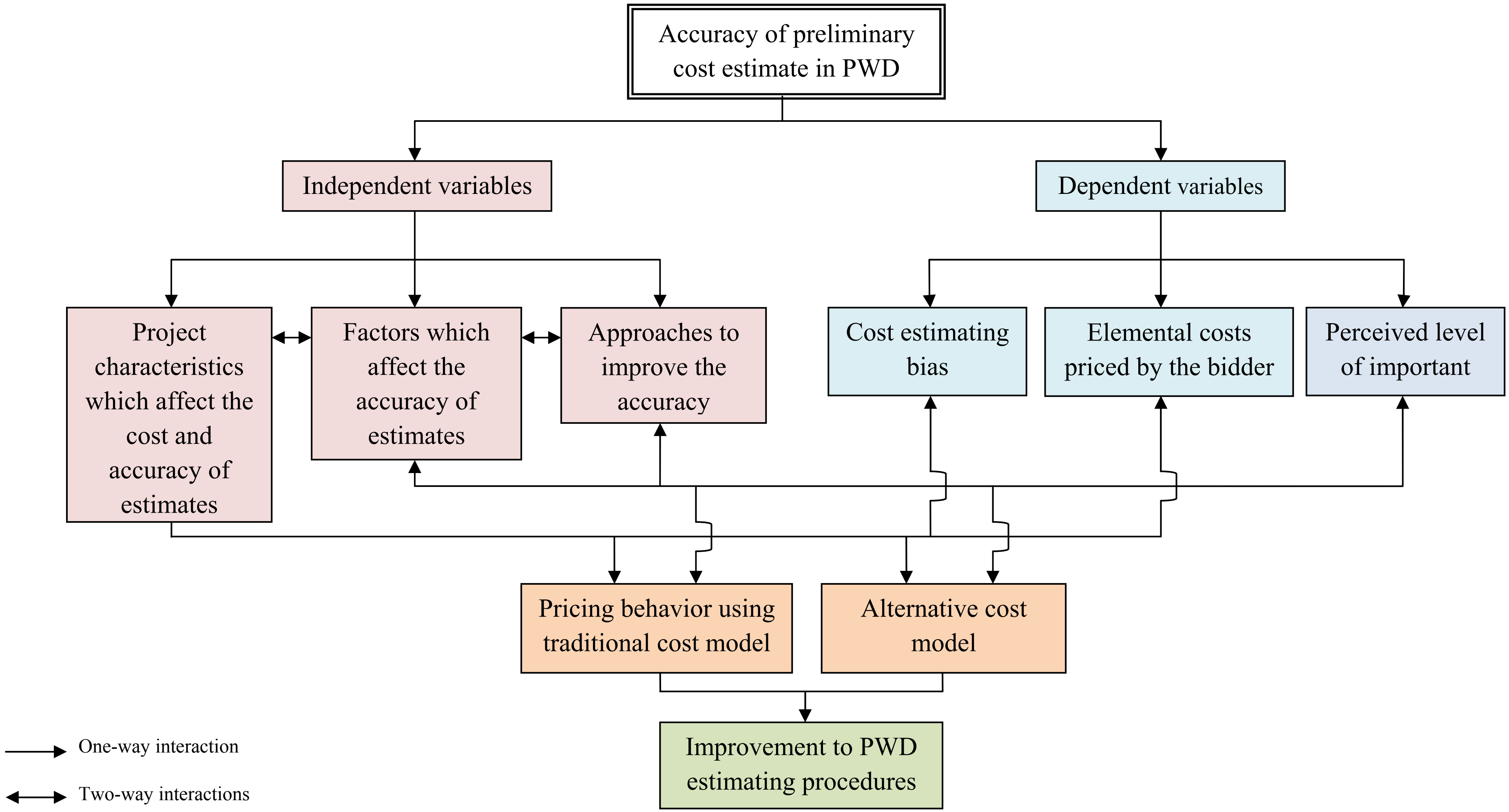


Figure 6.4: Conceptual framework for this research

CHAPTER 7: METHODOLOGY

The literature review provides this research with theories and empirical findings from previous research. It identifies the research variables and conceptual knowledge as it dictates the experimental design. The methodology is designed according to research objectives. Objective one (1) is to identify factors, which affect the accuracy of estimates, and objective two (2) is to identify approaches, which can improve the accuracy of preliminary cost estimates. These are taken from questionnaire survey. Objective three (3) is to investigate the significance of estimating components. Objective four (4) is to explore the reliability of alternative estimating method using MRM. Objective five (5) is to measure accuracy of estimates. These are taken from PWD i.e. the data on project estimates and from bidders' submitted bids (PDA and ATDA forms).

7.1 Research design

The following are the research design phases (Refer to Figure 7.1):

1. The research proposal is prepared by identifying and defining the key issues and problems. This establishes the research objectives.

2. The literature review includes the estimating methods, procedures, variable of project characteristics and other factors. The ways to improve the accuracy of estimates have also been studied. This creates the conceptual framework.

3. The Preliminary Cost Estimates (PDA) and Submitted Tender Bids (ATDA) from PWD will measure the accuracy of estimates. These data are used to build a MRM for alternative estimating method. Other components of estimates such as elemental costs, contingencies and variation of price will be examined using these data.

4. The research questionnaires were distributed to respondents. They are QS from PWD and private sectors who provide the quantity surveying services to PWD. Before the questionnaires were distributed, a pilot study was prepared in order to ensure the reliability of the questions.

5. Both data from projects and questionnaires were analyzed for discussion.

6. This research includes conclusions and recommendations.

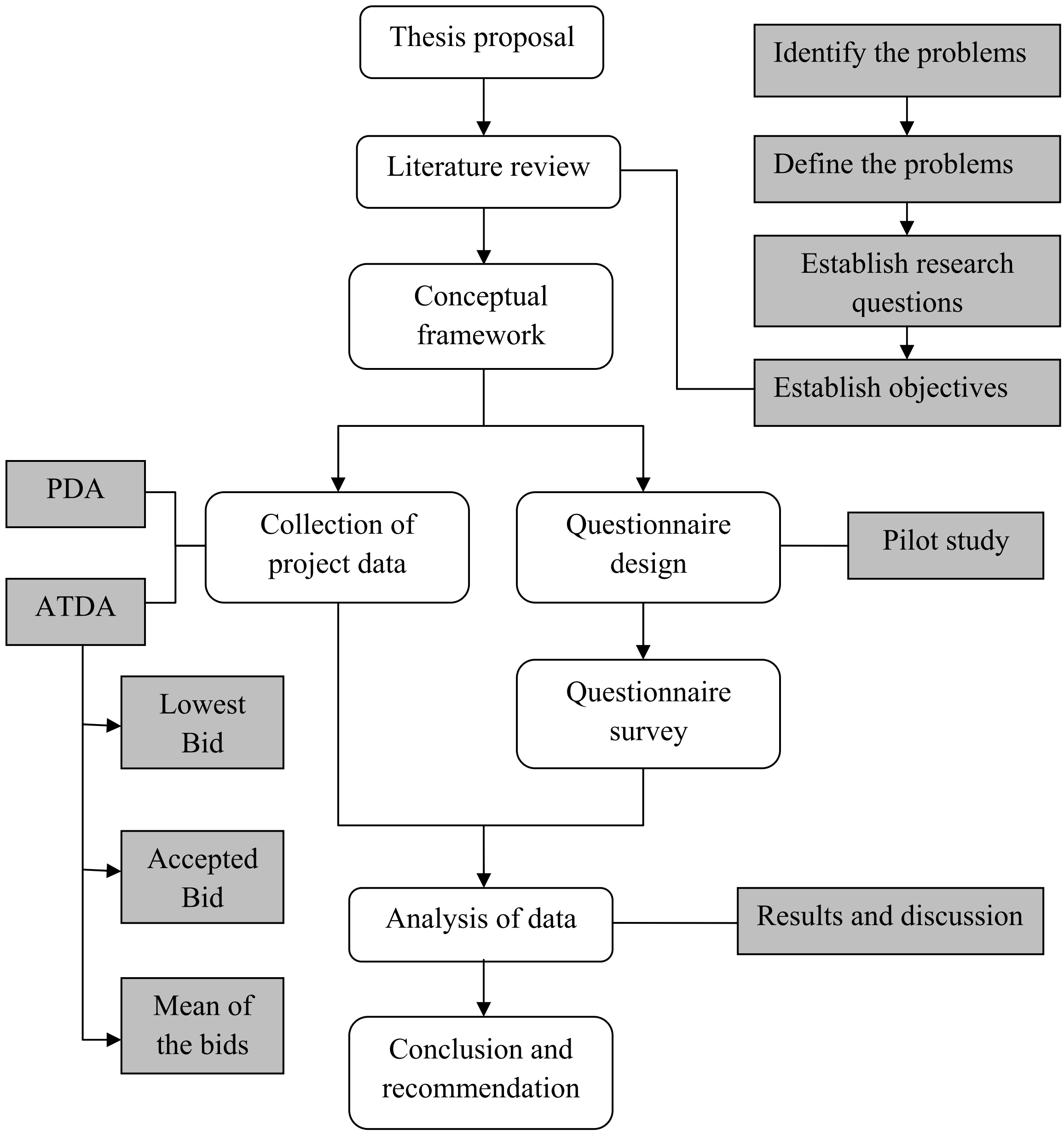


Figure 7.1: Research methodology flowchart

7.1.1 Research approach

This research uses quantitative method. It involves the measurement of data collected from construction projects (estimates and submitted bids) and questionnaires. These types of data are measureable and realistic to research objectives.

7.2 Quantitative data collection

The research methodology provides the approach on how the quantitative data are collected.

7.2.1 Questionnaire survey

Questionnaire survey addresses research objective no.1 i.e. factors which affect the accuracy of estimates and objective no.2 i.e. approaches to improve the accuracy of preliminary cost estimates. They are based according to the experience of respondents. These are more or less based on the methodology used by Akintoye (2000), Oberlender and Trost (2001), Elhag et al. (2005), Cheung et al. (2008), Odusami and Onukwube (2008) and Enshassi et al. (2005).

7.2.1.1 Instrumentation

The questionnaire surveys were sent to respondents by post. This method is selected because respondents come from diverse location and they take time to respond. In addition, this method allows enough sample size to be analyzed by using quantitative data analysis.

A) Targeted respondents

The respondents chosen for this research are senior officers in CKUB, PWD preferably J44[23] and above (Refer to Table 7.1). Questionnaires are also sent to senior QS, which are working in private QS consultants (assuming that only one-experienced QS are working in one firm). They are providing quantity-surveying services for the PWD as preliminary cost estimates are not prepared entirely by PWD. Respondents with such background could give convincing responses as they have considerable experiences in estimating. The feedbacks from private consultant QS (Refer to Table 7.2) can be used as comparative research. They have to abide by the policies and procedures of PWD in dealing with public projects. Thus, any changes in policy will affect them too.

Table 7.1: PWD's QS officers in PWD, J44 to J54 (Source: Public Works Department, 2011b; Public Works Department, 2011c)

Rank	No.	Minimum service required (years)
Senior Principal Assistant Director (J54) and above	29	21 - 26
Principal Assistant Director (J52)	33	16 – 20
Senior Assistant Director (J48)	89	11- 15
Assistant Director (J44)	74	6 – 10
Total	225	-

Table 7.2: QS Consultants in Peninsula Malaysia (Source: Public Works Department, 2011a)

Group	A	B	C	D	E	F	Total
States	Perlis, Kedah and Pulau Pinang	Perak	Selangor, Wilayah Persekutuan, Negeri Sembilan and Melaka	Johor	Pahang	Terengganu and Kelantan	
Number	8	1	98	4	1	7	119

[23] J44 – A position for officers who have more than 5 years of experience.

B) Questionnaire structure

The questionnaire survey structures are divided into three (3) sections:

Section A : Information on respondents' experience and backgrounds

Section B : Factors which affect the accuracy of preliminary cost estimates

Section C : Approaches which can improve the accuracy of preliminary cost estimates

Refer to Appendix 5 for Questionnaire.

C) Scales of measurement

The questionnaires are made up of closed and scaled questions. They are as follows:

Section A : Nominal scale

Section B : Ordinal scales of 5-point scale

Section C : Ordinal scales of 5-point scale

D) Pilot test

The author has to improve the questionnaire by having a pilot study. It removes any ambiguity in the survey form by rephrasing and restructuring the question before they were circulated to respondents. Two (2) questionnaires are used for the pilot test. The respondents answered the questions in the author's presence. Thus, respondents could raise questions if they wanted any clarification. During pilot test, two (2) respondents were selected to answer the model questionnaire. One respondent is from PWD and the other one is from private consultant. They are very experience because they are working for more than 20 years in their respective organisations.

7.2.1.2 Sample Size

There are 225 QS Officers of grade J44 and above registered in PWD. Due to a large number of respondents, a minimum sample size is needed in order to achieve the expected responses. According to Krejcie and Morgan (1970), a population of 225 needs a minimum of 144 sample size. Therefore, 63% response rate is needed. This was not achievable due to the time constraint on the part of respondents to respond. Fellows and Liu (2008) suggest 32 or more responses are sufficient if the population size is over a hundred. Elhag et al. (2005) suggest that an ideal rate of responses for an accepted sample size is about 20% to 30% of the population. Therefore, 45 to 68 responses from PWD QS officers and 24 to 36 responses from QS practices respectively should be sufficient.

7.2.2 Data from project

The data from projects' PDA and ATDA were collected from CKUB, PWD files. The author was given the approval to collect the data by PWD officers in charge. These data are considered confidential and have not been published by PWD. They were collected and tabulated into schedule (Refer to Appendix 6).

7.2.2.1 Instrumentation

The data from PDA and ATDA were prepared in the first half of the year 2007. They were obtained from the office of CKUB, PWD. This unit (CKUB) provides consultancy on cost and contract administration to the government (Refer to Appendix 1 and Appendix 2 for sample of PDA and ATDA forms). Projects involved were pre-design standard additional school building in Peninsular Malaysia.

A) Variables for project characteristics

This research investigates the significant relationship between accuracy of estimate and project characteristics. The lowest tender, accepted tender and mean of the returned tenders (mean of the bids) are used as measures of target. This addresses objectives no. 3, 4 and 5. The following are the project characteristics available for analysis:

a) Building function – Value and size of project (contract value and area m^2GFA) and Storey Height
b) PI (cost/m^2GFA)
c) Contract period (weeks)
d) Number of bidders
e) Location (state)
f) Types of schools (secondary and primary)
g) Classes of projects (main-building, ancillary, mix) development

Some project characteristics are very subjective. Moreover, not all data were available from PDA and ATDA forms. As a result not all project characteristics mentioned in the literature review could be analysed (Refer to Table 7.3).

Table 7.3: Availability of data of project characteristics from PDA and ATDA forms

Project characteristic	**Availability**
Building function	-
• Constraints	×
• Priorities of the scheme	×
• Space, arrangement and form of the building	×
• Plan shape	×
• Size of building	√
• Perimeter / floor area ratios	×
• Circulation space	×
• Storey height and total height of buildings	√
• Level of Specification and principal material	√
Type and condition of contract	-
• Traditional / general contracting (PWD 203a)	√
• Design and build (PWD DB)	×
Basis of selection	-
• Open tendering	√
• Selective tendering	×
• Direct negotiation	×
Contract sum	√
Contract period	√
Number of bidders	√

Table 7.3: Availability of data of project characteristics from PDA and ATDA form (cont'd)

Economic condition	-
• Good year	×
• Bad year	×
Sector	-
• Public	√
• Private	×

Note:

√ = data which are available

× = no data is available

Two (2) more project characteristics' variables were added. These are types of schools (primary and secondary school) and types of buildings (main building, small ancillary building and mixed). This is because there are two different types of schools and three different types of buildings. It is necessary to include these two (2) variables because different types of designs could influence the accuracy of estimates. This is to ensure the design variables are sufficient for data analysis. Construction elemental costs from the PDA and ATDA are also collected. These costs determine the accuracy of each elemental cost priced by the QS. It is important because QS prices his cost estimates according to cost plan, which is tabulated in the PDA form. A large difference in elemental cost will likely influence the total accuracy of estimates. It is assumed that the tendency of "front and back loading'' or unbalanced bid by the bidders would not affect the results because the bid prices transferred to ATDA form usually have been rationalized to ensure the prices are acceptable. It is assumed that any improper pricing from accepted bidders to gain extra revenue from the cash flow is not presented here. The elemental costs in PDA/ATDA are as follows:

a) Preliminaries
b) Piling and foundation
c) Buildings
d) Internal services
e) External Works

B) Scope of project

The scope of this research is pre-design additional school projects (Refer to Chapter 1 for scope of research). The data are from primary and secondary schools. Only school projects are available for analysis because the author has a limited number of other types of projects.

7.2.2.2 Sample size

The sample size is important in order to avoid systematic error such as over or under measurement of the sample size (Fellows & Liu, 2008). The sample size is made by selecting a set of element from the population. This sample represents accurate characteristics of the population with minimum variance (Dattalo, 2008). Sample size from previous studies were conducted by Skitmore and Drew (2003) based on 89 projects in Hong Kong, Aibinu and Pasco (2008) based on 56 projects in Australia. and Ling and Boo (2001) based on 42 projects in Singapore. Nevertheless, they did not show the minimum sample size was calculated. Dattalo (2008) suggests the use of

*G*Power software* to determine the sample size needed. In parametric test, statistical inference about a population could only be made through a sample size. It needs *a priori*[24] knowledge of the model sample size to determine how many cases would be needed to achieve acceptable power for detecting the interaction between predictors that are statistically significant (Kelley & Maxwell, 2003). This allows a sufficient sample size because the population is large. Thus, the time taken for data collection is reduced and, it will enable the author to decide when the data collection should end. The estimate of sample size calculation using G*Power software is as follows:

Assumption:

Thirty-three (33) groups of nine (9) project characteristics (variables) on average have four (4) groups per variable in factorial ANOVA (main effects only). Due to limited data available from PWD, it was assumed the effect size is large ($f = 0.4$). It means it could only observe a large degree of deviation of the null hypothesis. According to Chua (2006), medium effect size ($f=0.25$) is more appropriate for social science studies. However, the access to data depends on the permission of the owner; the author decides to limit the sample to a minimum. Noncentrality parameter is set at a minimum power of 80% or 0.80 (Dattalo, 2008). Numerator df = $(k - 1)$, k = number of groups. The following is the calculation use G*Power to determine the sample size (Faul, Erdfelder, Lang, & Buchner, 2007):

$$\lambda = f^2 N$$

$$11.68 = (0.4)^2 \times N$$

$$\text{Estimated total sample size (N)} = 73$$

[24] Prospective power analysis.

Output of G*Power:

F tests - ANOVA: Fixed effects, special, main effects and interactions

Analysis:	A priori: Compute required sample size		
Input:	Effect size f [25]	=	0.40
	α err prob [26]	=	0.05
	Power (1-β err prob) [27]	=	0.80
	Numerator df [28]	=	3
	Number of groups [29]	=	4
Output:	Noncentrality parameter λ [30]	=	11.6800000
	Critical F [31]	=	2.7374923
	Denominator df [32]	=	69
	Actual power [33]	=	0.8052728
	Estimated total sample size	=	73 (for 4 groups)
	Estimated sample size per group = 73 / 4 = 18 per group		

[25] The larger the effect needs a smaller sample size. Clinical research for medical science needs a smaller effect size because this kind of research requires statistical analysis to detect a smaller change in the sample analyzed. This is determined according to Cohen's effect size conventions. It is assumed for this kind of research, the effect size is large.

[26] P-value requires for statistical analysis.

[27] The power of a test is defined as 1-beta, and beta is the probability of falsely accepting H_0 when in fact H_1 is true. Value of 0.80 is acceptable for social science research.

[28] Assuming the average number of groups required in one factor and minus by one (1).

[29] Assuming the average number of groups required in one factor.

[30] Noncentrality parameters are used in power and sample size calculations and reflect the extent to which the null hypothesis is false.

[31] The critical value is the number that the test statistic must exceed to reject the test.

[32] It refers to the denominator degrees of freedom for F tests (total sample size – number of groups).

[33] It refers to the calculated return of the test actual power.

This gives the minimum number of sample collected from ATDA and PDA for ANOVA test. Field (2009) suggests a sample size of 80 will always be enough with 20 predictors to find a large effect size for multiple regression analysis (MRA). The following calculation use G*Power software in order to determine the sample size for MRA (Faul, et al., 2007):

$$\lambda = f^2 N$$

$$26.95 = (0.35) \text{ x N}$$

$$\text{Estimated total sample size (N)} = 77$$

This is proven using G*Power:

tests - Linear multiple regression: Fixed model, R^2 increase

Analysis:	A priori: Compute required sample size	
Input:	Effect size f^2	= 0.35
	α err prob	= 0.05
	Power (1-β err prob)	= 0.80
	Number of tested predictors [34]	= 20
	Total number of predictors [35]	= 20
Output:	Noncentrality parameter λ	= 26.9500000
	Critical F	= 1.7608613
	Numerator df	= 20
	Denominator df	= 56
	Actual power	= 0.8004214
	Estimated total sample size	= 77

[34] A number of predictors those are required for statistical analysis (assuming the total number is 20 predictors).

[35] A number of predictors retained in the final model (assuming no predictors will be deleted).

7.3 Data Analysis

Microsoft Office Excel and Statistical Package for the Social Sciences (SPSS) provide the tools for data analysis.

7.3.1 Questionnaire

The questionnaire is designed to examine QS attitude based on their experience on the factors, which affect the accuracy of estimates for PWD projects. Then, another set of questions are designed so that the QS can identify approaches to improve the accuracy of estimates.

7.3.1.1 Questionnaire survey analysis

The following are the quantitative data analyses used for questionnaire survey analysis:

a) Frequency and Chi-square test for Section A
b) Cronbach's Alpha (Reliability test) for Section B and C
c) The relative importance index (RII) for Section B and C
d) One sample t-test for Section B and C
e) Mann-Whitney test for Section B and C
f) Kendall's Coefficient of Concordance for Section B

A) Frequency and Chi-square test

The data is analyzed according to frequency value. It reflects the percentage distribution and cross-tabulation. This represents the frequency of answered questions by the respondents. Two (2) groups represent the respondents. These groups are QS working in PWD and QS consultants hired by PWD and they represent two categorical variables. The relationship of these groups can be measured by Chi-square test. It tests whether these groups of respondents' responses are different significantly from the expected frequencies and the observed frequencies (Field, 2009). The Pearson's Chi-square test is as follows:

$$\chi^2 = \sum \frac{(observed\ frequency - expected\ frequency)^2}{expected\ frequency}$$

X^2 is Chi-square

B) Cronbach's Alpha (reliability of the question)

This is for instrument reliability. It means the questionnaire should be consistent and reflect the construct that is being measured. It measures the reliability of a scale. It is based on the idea that individual items or set of items should produce consistent results based on the questionnaires (Field, 2009). Alpha value varies from zero (0) to one (1). The closer the Alpha values to one (1), the greater the internal consistency of items of the instrument being assumed. The acceptable value is 0.60 (Moss, et al., 1998). In social science research, value of more than 0.70 is considered excellent (Nunnally & Bernstein, 1994). The formula for the standardized Cronbach's alpha:

$$\alpha = \frac{N^2\overline{Cov}}{\sum s^2 + Cov_{item}}$$

N is number of items

$\overline{Cov}$ *is average covariance between items*

$\sum s^2 + Cov_{item}$ *is the sum of all the elements in the variance-covariance matrix*

C) Likert's scale and relative importance index (RII)

Likert's scale measures levels of agreement. This scale quantifies degree of influence of each variable. Akintoye (2000) used it to quantify factors, which affect the project cost estimating. Elhag et al. (2005) used it to quantify factors, which affect construction-tendering costs. Enshassi et al. (2005) and Odusami and Onukwube (2008) used it to quantify factors, which affect the accuracy of pre-tender cost estimates in Palestine and Nigeria. The questions in Section B and C are presented with 5-point Likert's scale of 1 to 5. They are as follows:

1 = not important

2 = little important

3 = somewhat important

4 = important

5 = very important

In addition, Odusami and Onukwube (2008) used relative importance index (RII) to rank the levels of agreement scaled by the respondents. The RII is as follows:

$$\frac{\sum w}{AN} = \frac{5n_2 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

W is the weighting given to each factor by the respondent, from 1 to 5

A is the highest weight (5 in the study)

N is the total number of samples

n1 to n5 is the number of respondents which answered each Likert's scale accordingly

D) One sample t – test

This test examines the mean score of a hypothesis value. The value of the mean for 5-point Likert's scale is three (3). It was assumed that the mean score of three (3) or more is the acceptable mean usefulness. The score below this value is not considered important. This test determines the significant difference between expected and the actual score. The following is the formula:

$$t = \frac{\tilde{x}_1 - \mu}{S_{\tilde{x}}}$$

$\tilde{x}$ = sample mean

μ = population mean

$S_{\tilde{x}}$ = standard error of the mean

E) Mann-Whitney test

Mann-Whitney test is a nonparametric statistic used to look for differences in the rank between two independent samples. It tests whether the populations from the two samples are drawn from the same distribution (Field, 2009). This test is equivalent to parametric independent t-test. It determines whether there is a significant difference between the two (2) groups of respondent's agreement (PWD officers and QS consultants). The following is the formula for Mann-Whitney test:

$$U_x = n_1 n_2 + \frac{n_1(n_1+1)}{2} - T_X$$

$$U_y = n_1 n_2 + \frac{n_1(n_1+1)}{2} - T_y$$

$$U = min(U_x, U_y)$$

T_x and T_y = Rank sum of x and y

n_1 is the sample size for sample 1

n_2 is the sample size for sample 2

F) Kendall's coefficient of concordance

Kendall coefficient of concordance (W) is a nonparametric statistic used to evaluate the strength of agreement between QS officers in PWD and QS in Private Sector regarding their opinion on each ranking of groups of factors. It measures the extent of agreement between respondents. In social sciences, the variables are about people who assess different subjects or situations (Legendre, 2010). If the test statistic (W) is one (1), it means all respondents agree unanimously, if W is zero, there is no trend of agreement among respondents. Table 7.4 shows the interpretation of Kendall's W. Kendall's (W) ranges $0 \leq W \leq 1$. One (1) is a perfect concordance (agreement). The formula is as follows:

$$W = \frac{12S}{p^2(n^3 - n) - pT}$$

Where,

$$U = \sum_{i-1}^{n} (\sum R_i - \overline{R})^2$$

S is a sum-of-squares statistic over the row sums of ranks Ri

R is the mean of the Ri values

n is the number of objects,

p is the number of judges (respondents).

T is a correction factor for tied ranking

Table 7.4: The interpretation of Kendall's W score (abstracted from: Schmidt, 1997)

Kendall's W	Interpretation	Confidence in Ranks
0.1	Very week agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very high
1	Complete agreement	Highest

7.3.2 Accuracy of estimates

This analysis examines the accuracy of estimates. The measures of target are using lowest bid, accepted bid and mean of returned bids (mean of the bids). Gunner and Skitmore (1999a) say lowest bid and accepted bid can be used as targets. However, McCaffer (1976) used mean of the returned tenders as the target because it has less intervening variable. This research compares these targets using the same set of data. This is to investigate which estimating target could explain more about systematic bias. Therefore, it could answer which target should be used for future research. Some adjustment has to be made when using mean of the returned tenders for this study. Only eight (8) bidders are used for mean calculation, as they are limited. The eight (8) bidders are assumed sufficient with regard to the strength of competition (Carr, 2005; Dell'Isola, 2002; Skitmore, 2002). If more than eight bidders, chances of uncompetitive tenders remained in the analysis is high. The use of different targets could affect the accuracy levels (Refer to Figure 7.2 for analysis on the estimates and tender bids). The following is the calculation for mean of the returned tenders:

$$Mean\ of\ the\ returned\ tenders = \frac{Total\ Amount\ of\ bid\ (RM)\ from\ 8\ bidders}{Eight\ (8)\ bidders}$$

Mean of the returned tenders = mean of the bids

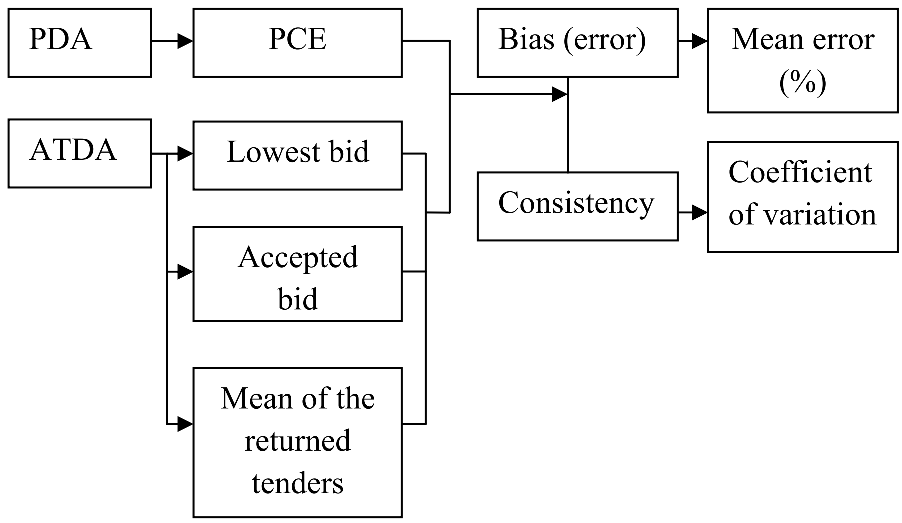


Figure 7.2: Analysis to measure accuracy of projects (with and without contingencies and VOP)

The accuracy of estimates is analysed according to "bias" and "consistency" (Ashworth, 2010; Ashworth & Skitmore, 1982; Skitmore, 1991; Skitmore & Drew, 2003; Skitmore, et al., 1990). The estimates are not converted to recent price figure of "Tender Price Index" published by PWD because they were prepared in the first quarter of the year

2007. This study also examines VOP and Contingencies allocations. (Refer to Figure 7.3 for analysis on VOP and contingencies).

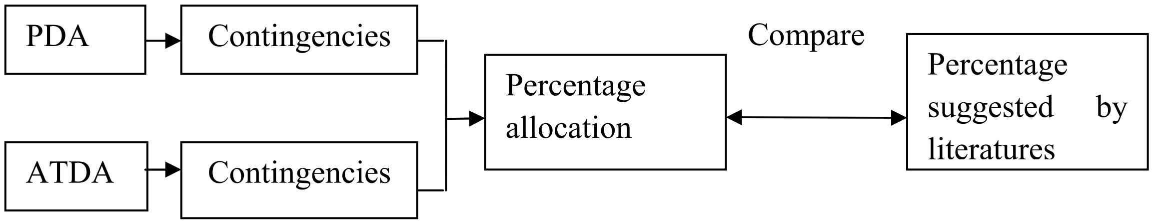


Figure 7.3: Analysis to measure the contribution of VOP and Contingencies

The analysis on cost estimates and tender bids includes the construction costs. It means the analysis includes the prime cost sums and provisional sums. Meanwhile, Morrison (1984) did not include these sums in his research. Some other items were excluded to limit the scope of research. These are as follows:

a) Contribution to local authorities
b) Advertisement
c) Documentation
d) Supervision
e) Professional Fee

7.3.2.1 Measurement of error (bias)

Arithmetic mean of forecast / tender bid ratio measures the bias of the estimate:

$$x = \frac{Prelimary\ cost\ estimate - Tender\ bid}{Tender\ bid} \times 100\%$$

Therefore, mean of estimate bias ($\tilde{x}$) =

$$\sum x/N$$

Where x = estimate bias; N= number of projects

Tender bid = Lowest bid, accepted bid and mean of the bids

7.3.2.2 Measurement of consistency

Standard Deviation (s) measures the variation of the mean error as in the following equation:

$$s = \sqrt{\sum (x - \tilde{x})^2/N}$$

Where x = estimate bias; $\tilde{x}$ = mean estimate bias; N = number of projects

Then, coefficient of variation of ratio forecast / actual (cv) will be used to measure the consistency of the estimate:

$$cv = (s/\tilde{x}) \times 100\%$$

s = standard deviation of ratio forecasts / tender bids

$\tilde{x}$ = mean of ratio forecasts / tender bids

Tender bid = Lowest bid, accepted bid and mean of the bids

The analysis on accuracy and its relationship with project characteristics are prepared according to Figure 7.4. Gunner and Skitmore (1999a), Skitmore and Drew (2003) and Aibinu and Pasco (2008) used almost same design to conduct experiment on accuracy of cost estimate. The bias of estimates is tested by ANOVA and MRA. In addition, consistency is tested by Levene's test. Bias and consistency are the dependent (observed) variables. The independent (predictor) variables of project characteristics are as follows:

a) Building function - Size of building and storey height
b) Contract sum
c) PI - cost/m^{2}GFA
d) Contract period
e) Number of bidders
f) Location
g) Types of schools (secondary and primary)
h) Classes of projects (main-building, ancillary, mixed) development

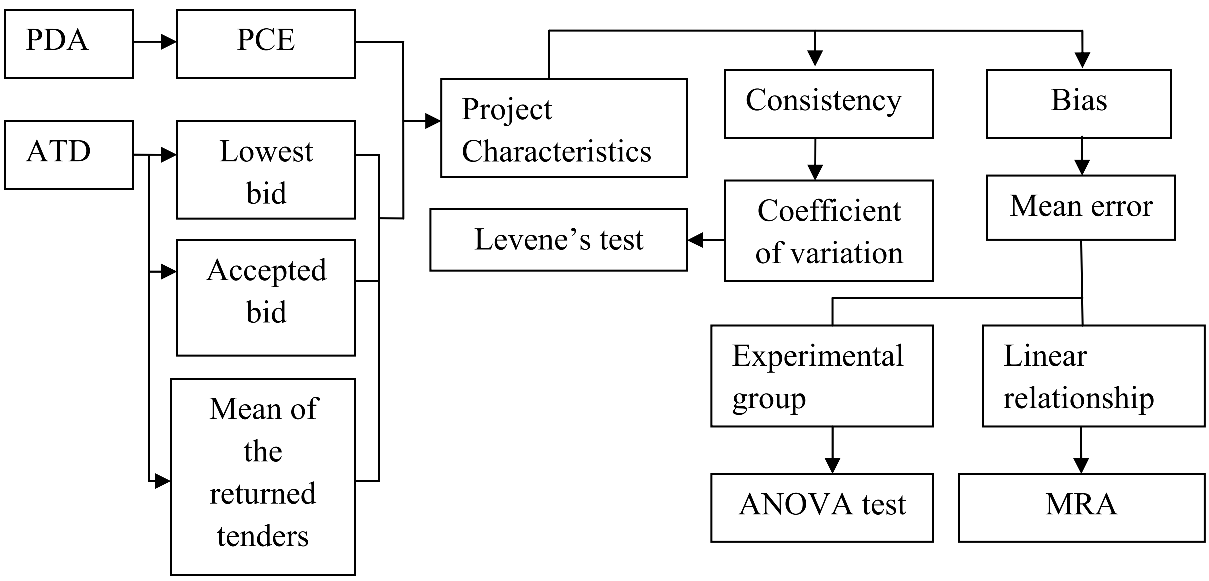


Figure 7.4: The analysis on project characteristics affecting the accuracy of estimates

Figure 7.5 shows the analysis for accuracy of elemental costs. The elements included in this analysis are as follows:

a) Preliminaries

b) Piling and foundation

c) Buildings

d) Internal Services

e) External Works

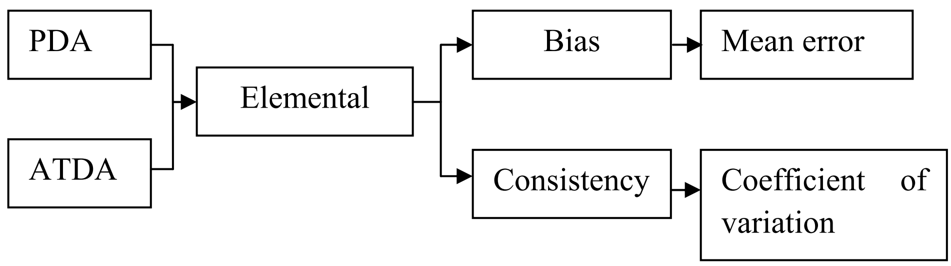


Figure 7.5: The analysis for accuracy of elemental costs

7.3.2.3 ANOVA test on bias

Factorial ANOVA (between group design) test examines the bias (error) of estimates against the project characteristics, which includes the groups of factors. It looks into the main effect of one independent variable on a dependent variable while ignoring the effects of all other independent variables. This test is a parametric statistic that assumes the data must meet certain assumptions on probability distribution. Field (2009) suggests this method is suitable for controlled experiments i.e. experimental group e.g. different groups of building sizes and their effect on estimating bias. It compares mean scores of different groups.

This method is used because it compares more than two (2) treatment conditions unlike the t-test (Burns, 2000; Fellows & Liu, 2008). This determines whether the mean bias in the estimates varies according to each project characteristic. ANOVA uses F-test to compare the means of the group. It measures the ratio of the variance in the data to the amount of unsystematic variance in order to provide the best-fit model. The larger the F value, the more likely the presence of true effects of independent variable in the model rather than the error variance. The F-value determines the significance of factors analyzed (Fellows & Liu, 2008). The statistical significance is set at ($P<0.05$) which is sufficient to indicate the significance level. Field (2009) indicates that the assumptions of this test are:

a) The dependent variable is based on interval scale
b) Distributions within groups are normally distributed
c) Homogeneity of variance

The Shapiro-Wilk test examines the normality of data. It compares a set of measures against the normal distribution. It tests whether the data is normally distributed. Shapiro-Wilk test is appropriate for a small sample size (Hun Myoung Park, 2008). Levene's test measures the homogeneity of variance by accessing the equality of variances of the groups. Multiple comparisons using Tukey's test used to identify which group of factor is different significantly (Fellows & Liu, 2008). F-test ANOVA does not indicate which group is significantly different from the others. It is because project characteristics are divided into different groups; therefore, follow-ups post-hoc tests (pairwise comparison) are necessary.

7.3.2.4 Levene’s test on consistency

Levene’s test investigates whether the consistency varies in each project characteristics. This test enables the analysis on homogeneity of variance. It measures the equality of the variance. The result could be homogeneous or heterogeneous across each group of project characteristics (Field, 2009). This suggests the consistency of project characteristics could be equal or not equal across the groups. Levene’s test is used because it is less sensitive to departure from normality. Median value is used for analysis reading. It provides robustness against non-normal data (Schultz, 1985).

7.3.2.5 Simple regression test on bias

Simple regression test is used to correlate the linear relationship between dependent variables (biases) and independent variables (project characteristics). This test uses scatter plot to represent linear regression of X (independent) and Y (dependent) plot. This gives the linear regression line of dependent variable (error) and independent variable of project characteristics.

7.3.2.6 Multiple regression analysis (MRA) on bias

MRA investigates the relationship between bias of estimates and project characteristics using continuous data. This analysis assumes linear relationship between variables. According to Field (2009), any research which is looking for real-life relationships should adopt MRA. It is important to explain the linear relationship of project characteristics that contribute to error of estimates. “Enter” technique is used for the analysis. Some assumptions for this test are also related to Multiple regression method (MRM) for estimating model (refer 7.3.3).

7.3.3 Multiple regression method (MRM) for estimating model

This analysis explores the reliability of MRM. This cost model can be used as the alternative to traditional cost model (Hammad, et al., 2010; Li, et al., 2005; Lowe, et al., 2006; Skitmore & Patchell, 1990). Currently, only traditional estimating methods are employed by PWD. This provides the multiple variables relationship of project characteristics against the observed value since the cost could not be explained by a single variable. This model is using cost data collected from past projects. It is intended for building works only and it is created using project characteristics as predictor variables and contract prices as observed variables.

The bid price is the target price for quantity surveyors. The budget cost estimate greatly relies on historical cost data to predict the future cost. Therefore, the contract prices are used for budget estimating by quantity surveyors. The contract prices are considered as market prices for the proposed projects. According to Seeley (1996) the purpose of a budget cost model is to predict the likely cost in the future before design for the building is completed. Prediction of price using more rigorous estimating such as resource analysis may not be suitable at this stage. Skitmore and Lo (2002) explained the purpose of cost model is to predict the lowest acceptable tender price. The lowest bid price may not be chosen if it is a suicidal low bid. In addition, the accepted level of prices by client may be biased and ignores the best price in the market. However, for this research it is assumed the contract prices (accepted bids) are the market prices for observed independent variables. The objective of this research is to build a model from project characteristics as predictors and building works' contract prices[36] as observed variables. The model could help officials of the PWD to prepare the budget cost estimates for standard design in the future. All other construction costs were excluded[37]. It assumes the relationship between the predictors and the observed variables are linear. The model is created from SPSS package through MRA. "Step-wise" technique is used for selecting and removing predictors. The variables create a set of equation for cost prediction as follows:

$$Y = a + b_1X_1 + b_2X_2 \ldots\ldots b_nX_n + \varepsilon$$

Y is observation (cost of building)

X_1, X_2 and X_n are for project characteristics

b_1, b_2 and b_n are unknown and will be estimated by regression technique

ε is random error of Y

Next, the observe variable (Y) of cost (RM) will be replaced with cost/m2 and removing the understood linear relationship between cost (RM) and size (m2) from the model. This will focus on others less understood variables that might affect the cost (Emsley, Lowe, Duff, Harding, & Hickson, 2002). The variables create a set of equation for cost prediction as follows:

$$Y = a + b_1X_1 + b_2X_2 \ldots\ldots b_nX_n + \varepsilon$$

Y is observation (cost/m2 of building)

[36] structural and architectural works

[37]Preliminaries, piling works, internal services, external works, contingencies, variation of prices and miscellaneous

X_1, X_2 and X_n are for project characteristics but excluding sizem^2

b_1, b_2 and b_n are unknown and will be estimated by regression technique

$\mathcal{E}$ is random error of Y

Only projects from standard repeated design were collected in accordance to the scope of research. Ninety-one (91) projects were collected and divided into 2 groups. Sample data 1 consist of 83 projects for proposed model building and Sample data 2 consist of eight projects for cross-validation (holdout samples). Figure 7.6 shows the model building.

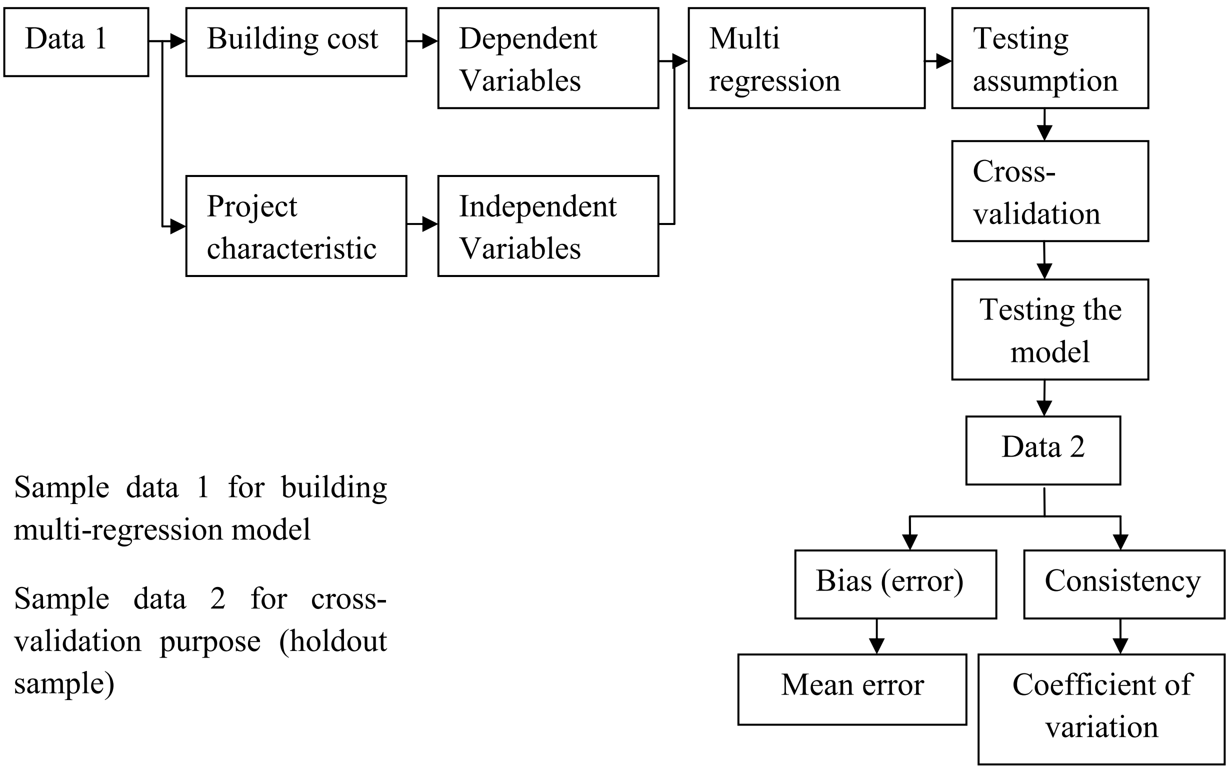


Figure 7.6: The model for MRM

Cross-validation of the proposed model ensures the reliability of the sample accurately represents the entire population. The R^2 value gives how much the variance of dependent variable is accounted by predictors in MRA. The adjusted R^2 represents the loss of predictive power if the model is tested from the population sample. However, it tells nothing about how well it could predict from a different sample taken from the same population. This could be validated by using Stein's formula to cross-validate the adjusted R^2 calculated by the statistical software (Field, 2009). The cross-validation using real data gives the real comparison of the model performance in the real situation. This is tested using project data of holdout samples (Cheung & Skitmore, 2005; Li, et al., 2005). Thus, it gives the real quantification of model reliability.

$$adjusted\ R^2 = 1 - \left\{ \left[\frac{n-1}{n-k-1} \right] \left[\frac{n-2}{n-k-2} \right] \left[\frac{n+1}{n} \right] \right\} (1 - R^2)$$

n is number of sample

k is number of predictors in the model

R^2 is unadjusted value

The model is for exploratory study. Nevertheless, all assumptions must be acceptable in order to draw conclusions about the sample. This model could assume the conclusion for a wider population (unbiased generalization). According to Field (2009) and Skitmore and Patchell (1990):

a) All predictor variables should be quantitative or categorical (with two categories). The outcome variable must be quantitative at interval level, continuous and unbounded.

b) The predictors should have some variation in value.

c) No perfect multicolinearity. This is tested using Variance Inflation Factor (VIF) and collinearity diagnostics. It indicates the value of a predictor relationship with the other predictor. A value greater than one (1) for average VIF suggests the MRA model is biased and if the value is more than 10 it is worrying. In colinearity diagnostics, each predictor variance proportion should be distributed across different dimensions of eigenvalue. The condition index that is more than 15 indicate the problem of multicollinearity exist (Tabachnick & Fidell, 2007).

d) Predictors are uncorrelated with ‘external variables’.

e) Homoscedasticity – the variance of the residual should be constant. The graph (ZRESID against ZPRED) points are randomly and evenly dispersed without patterns of heteroscedasticity and non-linearity. Histogram and P-P plot is normally distributed and almost lie perfectly on the line.

f) Durbin-Watson test detects auto-correlation between consecutive residuals. Error variables are dependent if autocorrelation exist. The values of less than one (1) and more than three (3) are cause for concern.

g) Normal distributed errors – The different value between the model and the observed data are most frequently zero and normally distributed (the mean of standard residual value is closed to zero).

h) The relationship between variables is linear. It can be detected using partial plot.

In addition, casewise diagnostics examine any extreme cases, which affect the model. It was determined 5% of cases have standardized residuals outside the limit or 95% of cases with less than +/- two (2) standard deviation. In addition, Cook's distance value should be less than one (1) and Mahal's distance should not be more than 15. The model created is reliable and not influenced by any subset.

7.4 Chapter summary

There are two types of data collected for this research analysis. The first type of data collected is from questionnaire survey. This addresses the research question no. 1 and 2. QS in PWD and private QS consultants hired by PWD are the respondents. This survey targets the senior management because they are having experience in cost estimate. Two (2) set of questionnaires are used for pilot test in order to improve the clarity of the questions. A minimum of 30% of responses from the targeted population is sufficient.

The second type is the data from PWD projects. This includes PDA (estimates) and ATDA (submitted bids). It is collected from CKUB, PWD files. It will be used to examine the accuracy of estimates, project characteristics (which affect the accuracy of estimates) and this creates the MRM for alternative cost model. It explores the reliability of alternative estimating method. Lowest bid, accepted bid and mean of the returned tenders (mean of the bids) are used as targets to measure the accuracy of estimates. The use of different targets could give different results. These are prepared to address research question no. 3, 4 and 5. The data of additional school building projects were collected. Not all data from project characteristics could be analyzed as some of these data were unavailable. The minimum sample size needed is about 80 from both PDA and ATDA.

Nonparametric tests on questionnaire data were used because they were not normally distributed. The reliability of questionnaire's measurement was tested using Cronbach's Alpha. The acceptable level for reliability of instrument is at least 0.60. The RII is used to rank the answers. One sample t-test examines the score of Likert's scale. It was determined that mean value of score below three (3) was not important. Mann-Whitney test was used to determine the mean difference of the two group of respondents. Kendall's coefficient of concordance was used to evaluate the strength of agreement of the group of factors.

Project data involved two (2) types of tests, which is ANOVA and MRA. These are both parametric tests. ANOVA examines whether bias of estimates varies according to different groups of project characteristics. P-value should be less than the significance level ($P<0.05$). Then, the follow up test (Tukey's test) decides which group of factor is significantly different from others (pairwise comparison). The Levene's test measures the homogeneity of variance on consistency of different factors. It tells whether the consistency in the estimates varies in each factor.

Simple regression test shows the linear relationship of the bias of each project characteristics. Scatter plot provides the relationship between bias and project characteristics. In addition, error bar is used to show the spread of the data. MRA examines the linear relationship of project characteristics against the bias of estimates. Besides, the MRA builds a MRM cost model. It explores the reliability of the alternative cost model. It is cross-validated using holdout samples. The questionnaire is designed to examine factors, which affect the accuracy of estimates, and approaches, which can improve the accuracy. Before the questionnaires are distributed to respondents, a pilot study was performed to improve the questions. The acceptable responses should be at least 30% from the total predetermined number of population.

CHAPTER 8: DATA ANALYSIS

This chapter discusses the data analysis. It is divided into two (2) sections. Section one (1) presents the analysis for research objective one (1) and two (2). Section two (2) presents objective three (3) and four (4) and five (5). Objective one (1) identifies the factors, which affect the accuracy of estimates. Objective two (2) identifies which approaches can improve the accuracy of estimates. Objective three (3) explores the project characteristics and other components, which influence the accuracy of estimates. Objective four (4) explores the reliability of MRM. Objective five (5) evaluates the accuracy of preliminary cost estimates prepared by PWD. Data from section one (1) are collected using questionnaire survey. Data from section two (2) are collected from PDA and ATDA of PWD.

8.1 Section One (1) – Questionnaire Survey

This section discusses the feedback from 157 respondents of PWD QS and private sector QS. Part one (1) presents the QS personal details and experiences. Part two (2) presents the factors, which affect the accuracy of estimates. Part three (3) presents approaches, which can improve the accuracy of estimates.

8.1.1 Part One (1) – Quantity Surveyor personal details and experience

This part explores the respondents' profiles, knowledge on estimating, experiences and organizations' procedures.

8.1.1.1 Personal details

A) Years of experience

Questionnaires were sent to senior executives and senior officers of both QS in PWD and private consultants. All respondents from PWD are senior officers with grade J44 and above while 75.5% of respondents from private consultants are senior executives. Almost 92% of total respondents are considered having experience in estimating because of most of them have been working for more than 5 years in quantity surveying. 40.1% of respondents are working more than 15 years in their respective organization. So, this survey has achieved its target in having experience respondents (Refer to Figure 8.1 and Table 8.1).

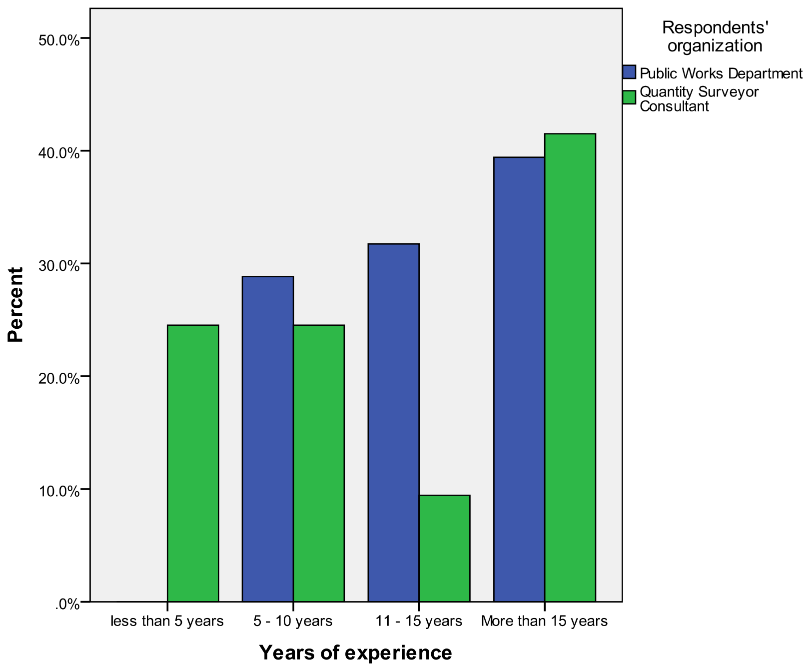


Figure 8.1: Percentage of respondents' years of experience

Table 8.1: Frequency and percentage of respondents' years of experience

Years of experience	Respondents' organizations					
	PWD		Private Consultant		Total	
	Count	N %	Count	N %	Count	N %
less than 5 years	0	0.0%	13	24.5%	13	8.3%
5 - 10 years	30	28.8%	13	24.5%	43	27.4%
11 - 15 years	33	31.7%	5	9.4%	38	24.2%
> 15 years	41	39.4%	22	41.5%	63	40.1%

B) Respondents' organization and returned responses

The percentage of respondents is 66.9% from PWD QS officers and 33.1% from private QS consultants. The total questionnaires returned were encouraging. About half of the questionnaires (46% - 157 responses) were returned out of 344 issued. Thus, the returned questionnaires have already exceeded the 30% targeted return from respondents (Refer to Figure 8.2 and Table 8.2).

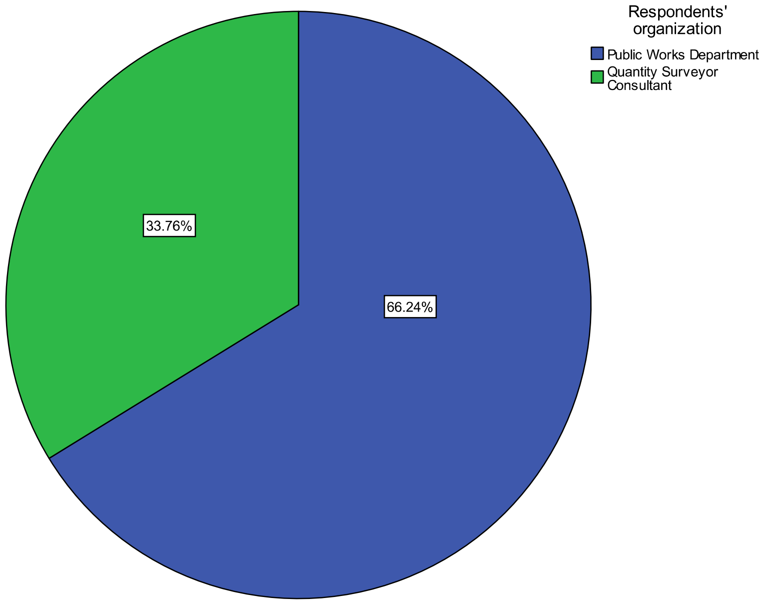


Figure 8.2: Percentage of respondents' organizations

Table 8.2: Frequency and percentage of respondents' organizations

	Respondents' organization					
	PWD		**Private consultant**		**Total**	
	Count	%	Count	%	Count	%
Sent	225	65.0%	119	35.0%	344	100.0%
Returned	104	66.2%	53	33.8%	157	100.0%
% Returned	104 / 225 x 100% = 46%		53 / 119 x 100% = 45%		157 / 344 x 100% = 46%	

8.1.1.2 Acceptable estimated values for public client

Figure 8.3 and Table 8.3 show the bar chart and the summary table of respondents' answers. More than half (59.2%) of respondents from both sides agreed that the overestimated value was the most acceptable value for public client. Underestimated value was the least agreed by respondents (10.2%). More than a quarter of total respondents, (30.6%) did not know about which values were more acceptable. Chi-square test shows there is significant difference between type of respondent's organization and level of tolerances, χ^2 (2) = 7.060, $p<0.05$ (Refer to Table 8.4). This is because even though more than half from both sectors agreed with overestimated value, there were considerable respondents (37.5%) from PWD who did not know which value is more acceptable to government.

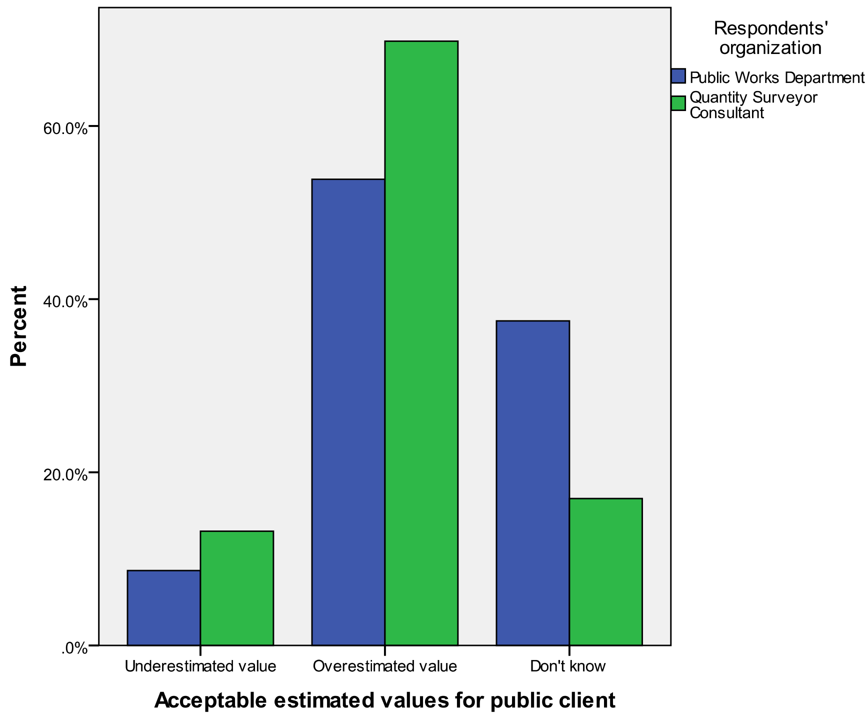


Figure 8.3: Percentage of value tolerable for client in public sector (PWD)

Table 8.3: Frequency and percentage of respondents' views on acceptable estimated values for client in public sector

Response	**Respondents' organization**					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Underestimate	9	8.7%	7	13.2%	16	10.2%
Overestimate	56	53.8%	37	69.8%	93	59.2%
Don't know	39	37.5%	9	17.0%	48	30.6%

Table 8.4 : Chi-square test results of respondents' views on acceptable estimated values for client in public sector

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.060[a]	2	0.029
Likelihood Ratio	7.503	2	0.023
Linear-by-Linear Association	5.990	1	0.014
N of Valid Cases	157	-	-

a. zero cell (.0%) has expected count of less than 5. The minimum expected count is 5.40.

8.1.1.3 Acceptable levels of accuracies

Figure 8.4 and Table 8.5 show the bar chart and the summary table of respondents' answers. Less than half (42.7%) of total respondents agreed that the acceptable level of accuracy was around +/- 10 for preliminary cost estimates, which was the highest. About a third (33.8%) of total respondents believed +/-15 percent was the acceptable level. Less than a quarter (17.2%) of respondents chosen +/-5% was the acceptable target. Only small percentage of respondents (6.4%) accepted other values than mentioned earlier as acceptable level. Chi-square test shows there is no difference between type of respondents' organizations and level of estimating accuracy, χ^2 (5) = 8.952, p>0.05 (Refer to Table 8.6).

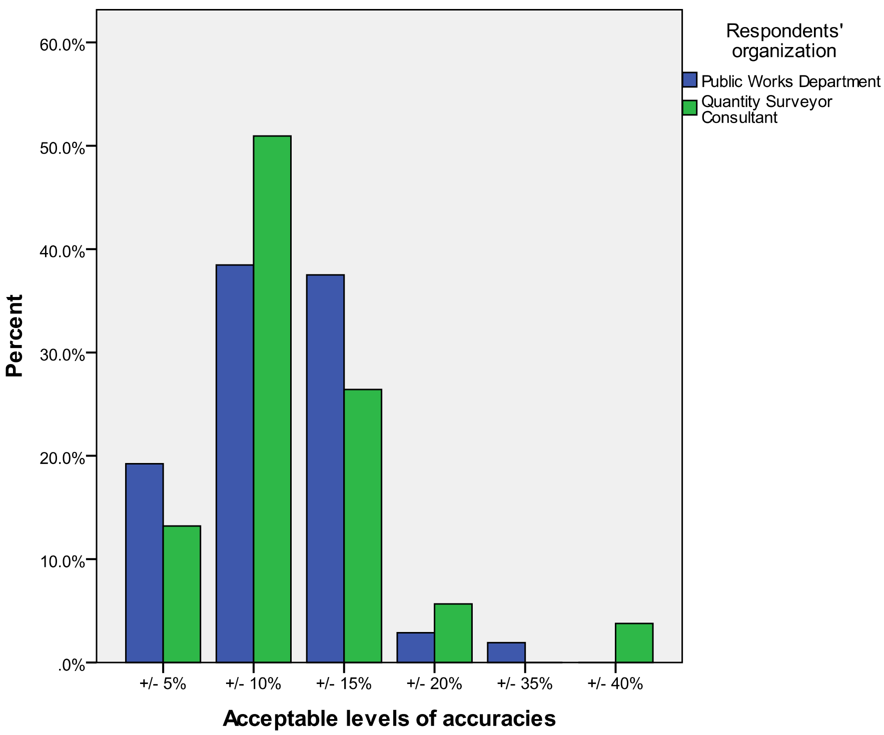


Figure 8.4: Percentage of respondents' acceptable levels of accuracies

Table 8.5 : Frequency and percentage of respondents' acceptable levels of accuracies

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
+/- 5%	20	19.2%	7	13.2%	27	17.2%
+/- 10%	40	38.5%	27	50.9%	67	42.7%
+/- 15%	39	37.5%	14	26.4%	53	33.8%
+/- 20%	3	2.9%	3	5.7%	6	3.8%
+/- 25%	0	0.0%	0	0.0%	0	0.0%
+/- 30%	0	0.0%	0	0.0%	0	0.0%
+/- 35%	2	1.9%	0	0.0%	2	1.3%
+/- 40%	0	.0%	2	3.8%	2	1.3%

Table 8.6: Chi-square test results of respondents' acceptable levels of accuracies

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.952[a]	5	0.111
Likelihood Ratio	10.013	5	0.075
Linear-by-Linear Association	0.493	1	0.483
N of Valid Cases	157	-	-
a. 6 cells (50.0%) have expected count of less than 5. The minimum expected count is .68.			

8.1.1.4 Performance review on estimates in measuring its quality

Figure 8.5 and Table 8.7 show the bar chart and the summary table of respondents' answers. More than half (69.4%) of respondents said they had some kind of procedure on performance review of the estimate. More than a quarter of respondents (26.1%) said they did not measure the performance of estimate. Only a few respondents (4.5%) said they did not know the existence of performance review procedure. Chi-square test reveals there is no difference between respondents from both PWD and private consultants on performance review of estimates. χ^2 (2) = 4.066, p>0.05 (Refer to Table 8.8).

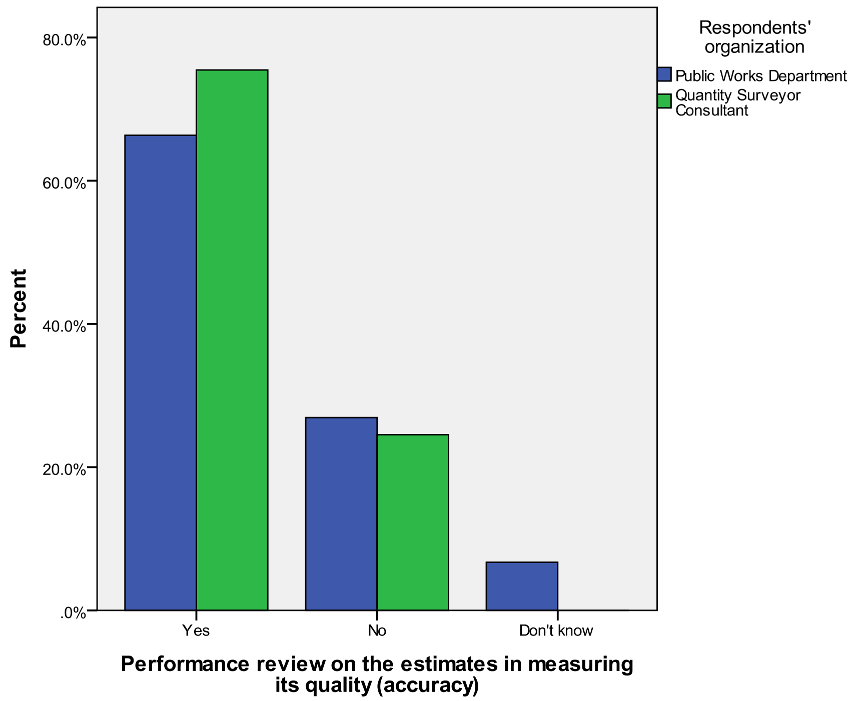


Figure 8.5: Percentage of respondents which implemented performance review on the estimates

Table 8.7: Frequency and percentage of respondents which implemented performance review on the estimates

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	69	66.3%	40	75.5%	109	69.4%
No	28	26.9%	13	24.5%	41	26.1%
Don't know	7	6.7%	0	0.0%	7	4.5%

Table 8.8: Chi-square test results of of respondents which implemented performance review on the estimates

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.066[a]	2	0.131
Likelihood Ratio	6.259	2	0.044
Linear-by-Linear Association	2.769	1	0.096
N of Valid Cases	157	-	-

a. 2 cells (33.3%) have expected count of less than 5. The minimum expected count is 2.36.

8.1.1.5 Implementation of systematic data collection system

Figure 8.6 and Table 8.9 show the bar chart and the summary table of respondents' answers. A significant number of respondents (79.6%) stated there was a systematic data collection implemented in their respective organization. About a quarter of respondents, (17.8%) said they did not implement systematic data collection. Only a few of the respondents (2.5%) did not know whether it was implemented. Chi-square test shows there is a significant difference between responses of different organisations, χ^2 (2) = 9.172, $p<0.05$ (Refer to Table 8.10). This is because a substantial number of respondents from QS consultants (30.2%) said they did not have a systematic data collection system.

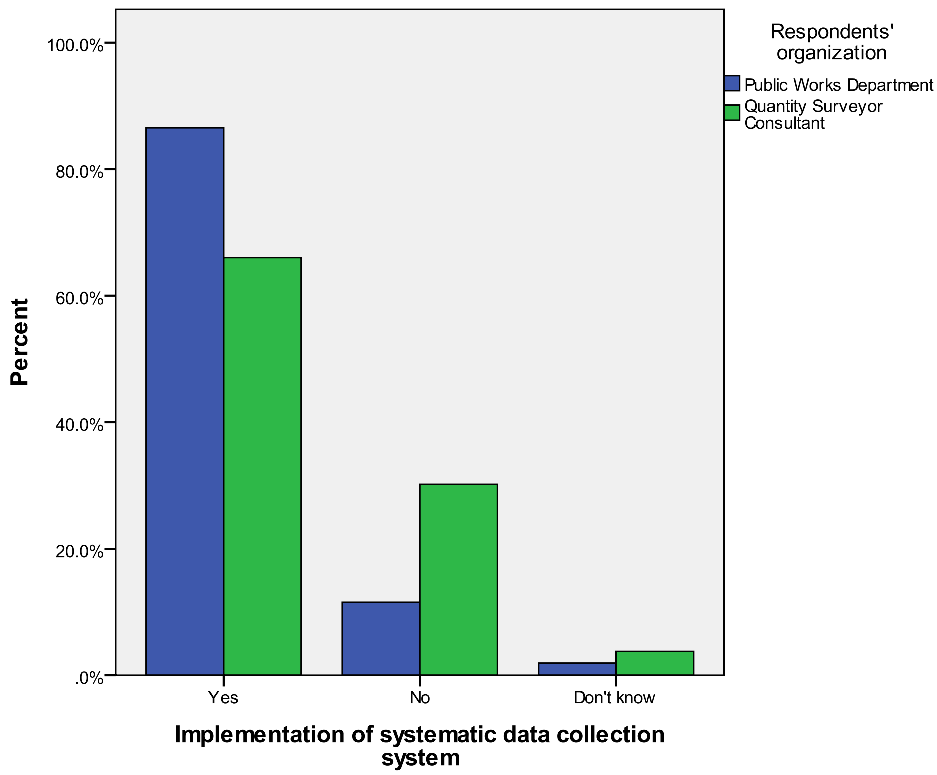


Figure 8.6: Percentage of respondents which implement systematic data collection

Table 8.9: Frequency and percentage of respondents implementing systematic data collection

Respondents' organization						
Response	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	90	86.5%	35	66.0%	125	79.6%
No	12	11.5%	16	30.2%	28	17.8%
Don't know	2	1.9%	2	3.8%	4	2.5%

Table 8.10: Chi-square test results of respondents implementing systematic data collection

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.172[a]	2	0.010
Likelihood Ratio	8.751	2	0.013
Linear-by-Linear Association	7.655	1	0.006
N of Valid Cases	157	-	-

a. 2 cells (33.3%) have expected count of less than 5. The minimum expected count is 1.35.

8.1.1.6 Quantity Surveyors intentionally mark-up the estimates

Figure 8.7 and Table 8.11 show the bar chart and the summary table of respondents' answers. Close to half the number of respondents (48.4%), intentionally mark-up their estimates because they did not want their estimates to be the lowest. Less than half of respondents (43.9%) disapproved the practice. Few respondents (7.6%) said they did not know about the mark-up to the estimates. Chi-square test shows χ^2 (2) = 9.446, p<0.05 (Refer to Table 8.12). There is a significant difference between types of respondents' responses because more than half of private QS (56.6%) consultants said they did not do any mark-up.

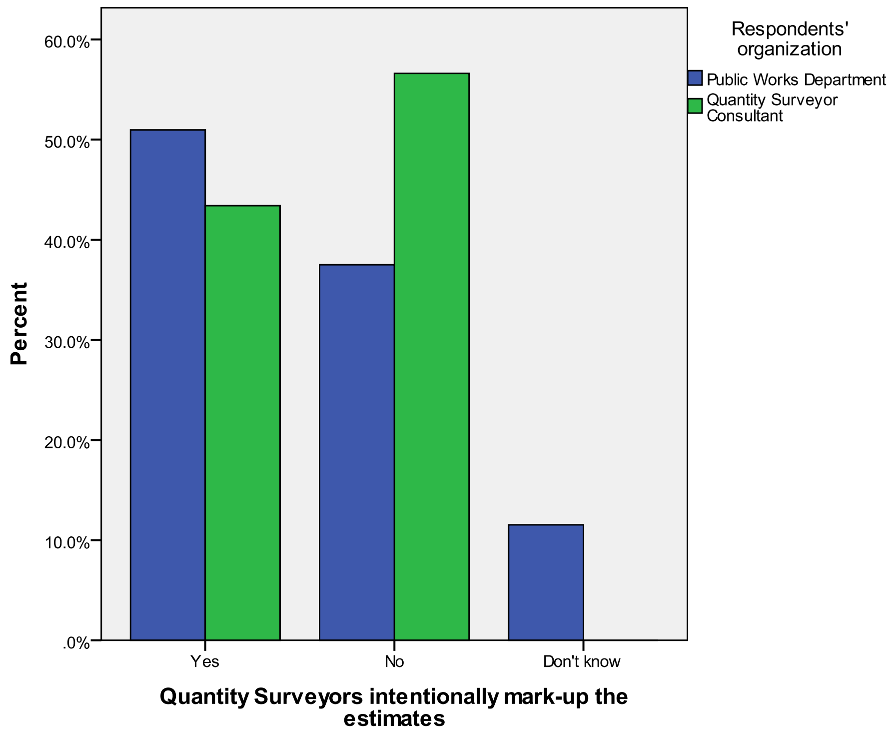


Figure 8.7: Percentage of respondents intentionally mark-up the estimates

Table 8.11: Frequency and percentage of respondents intentionally mark-up the estimates

Response	**Respondents' organization**					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	53	51.0%	23	43.4%	76	48.4%
No	39	37.5%	30	56.6%	69	43.9%
Don't know	12	11.5%	0	0.0%	12	7.6%

Table 8.12: Chi-square test results of respondents intentionally mark-up the estimates

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.446[a]	2	0.009
Likelihood Ratio	13.112	2	0.001
Linear-by-Linear Association	0.140	1	0.709
N of Valid Cases	157	-	-

a. 1 cell (16.7%) has expected count of less than 5. The minimum expected count is 4.05.

8.1.1.7 Satisfaction levels on the accuracy of preliminary cost estimates

Figure 8.8 and Table 8.13 show the bar chart and the summary table of respondents' answers. The majority of respondents (81.5%) were satisfied with the accuracy of preliminary cost estimates prepared in their respective organisations. Only a few respondents (12.1%) were not satisfied. Others (6.4%) said they did not know if they were satisfied with the accuracy of cost estimates prepared. Chi-square test shows χ^2 (2) = 5.638, p>0.05 (Refer to Table 8.14).There is no effect on types of organisations towards the satisfaction on the accuracy of cost estimates.

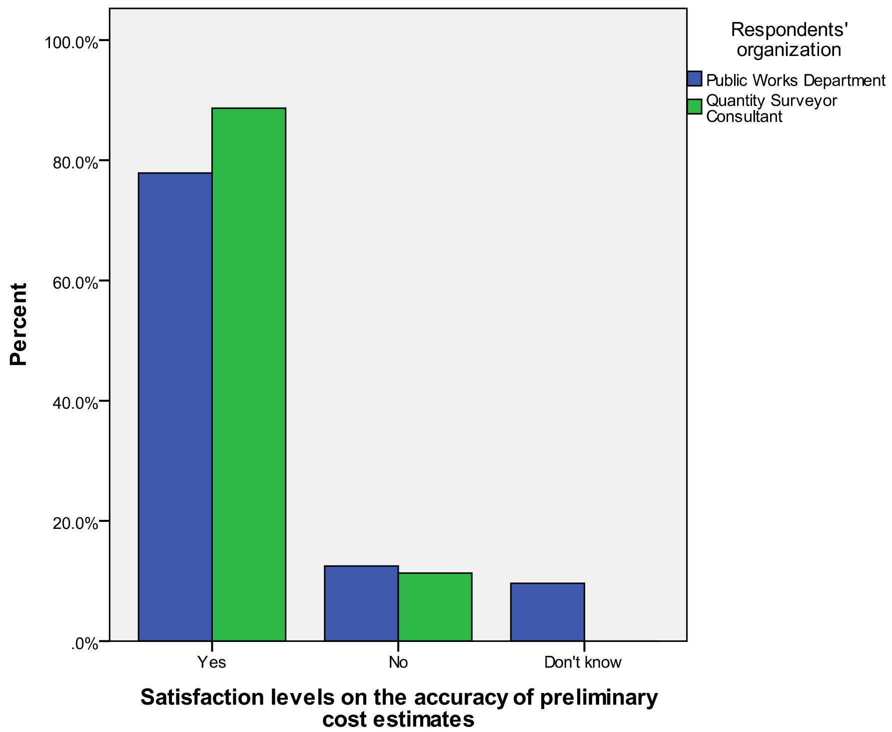


Figure 8.8: Percentage of respondents' satisfaction levels towards the accuracy of preliminary cost estimates

Table 8.13: Frequency and percentage of respondents' satisfaction levels towards accuracy of preliminary cost estimates

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	81	77.9%	47	88.7%	128	81.5%
No	13	12.5%	6	11.3%	19	12.1%
Don't know	10	9.6%	0	0.0%	10	6.4%

Table 8.14: Chi-square test results of respondents' satisfaction levels towards the accuracy of preliminary cost estimates

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.638[a]	2	0.060
Likelihood Ratio	8.773	2	0.012
Linear-by-Linear Association	4.627	1	0.031
N of Valid Cases	157	-	-
a. 1 cell (16.7%) has expected count of less than 5. The minimum expected count is 3.38.			

8.1.1.8 Satisfaction of estimating knowledge taught in local universities

Figure 8.9 and Table 8.15 show the bar chart and the summary table of respondents' answers. About a third of respondents (35.0%) were satisfied with the estimating knowledge of local graduates. More than half of respondents (54.8%) said they did not satisfy. Some of respondents (10.2%) stated they did not know whether they were satisfied or not. Chi-square test shows χ^2 (2) = 0.613, p>0.05 (Refer to Table 8.16). The levels of satisfaction of both sides of respondents were more or less the same.

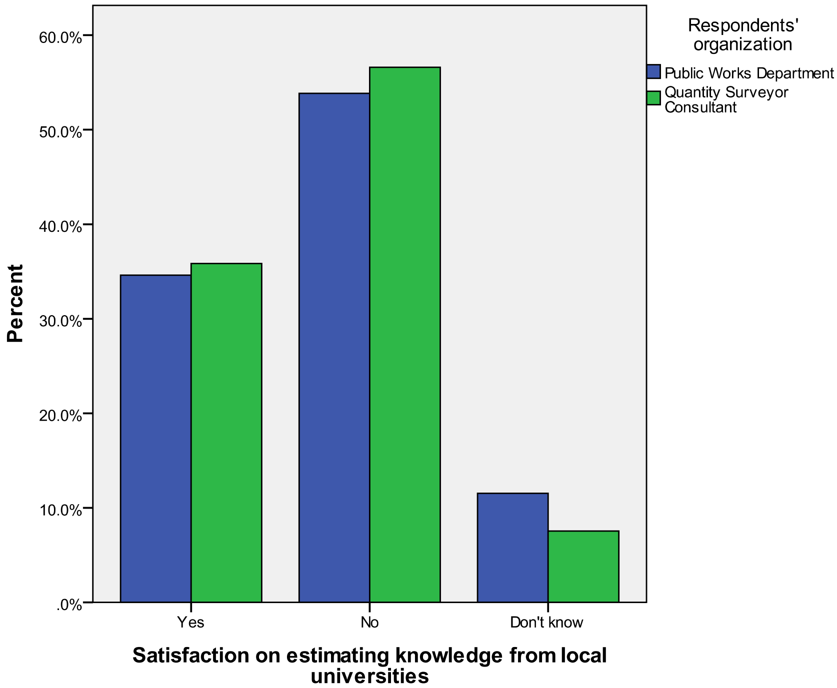


Figure 8.9: Percentage of respondents' satisfaction levels towards local graduates' estimating knowledge

Table 8.15: Frequency and percentage of satisfaction levels towards local graduates estimating knowledge

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	36	34.6%	19	35.8%	55	35.0%
No	56	53.8%	30	56.6%	86	54.8%
Don't know	12	11.5%	4	7.5%	16	10.2%

Table 8.16: Chi-square test results of satisfaction levels towards local graduates estimating knowledge

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	0.613[a]	2	0.736
Likelihood Ratio	0.641	2	0.726
Linear-by-Linear Association	0.244	1	0.621
N of Valid Cases	157	-	-

a. zero cell (.0%) have expected count of less than 5. The minimum expected count is 5.40.

8.1.1.9 Introduction of alternative estimating methods

Figure 8.10 and Table 8.17 show the bar chart and the summary table of respondents' answers. Almost three quarters of respondents, (74.5%) agreed that the alternative estimating methods should be introduced by PWD. A few respondents (9.6%) did not agree and others (15.9%) said they did not know whether the alternative estimating methods should be introduced. Chi-square test shows χ^2 (2) = 1.412, p>0.05. (Refer to Table 8.18) Both sides of respondents were more or less having the same opinion regarding this question.

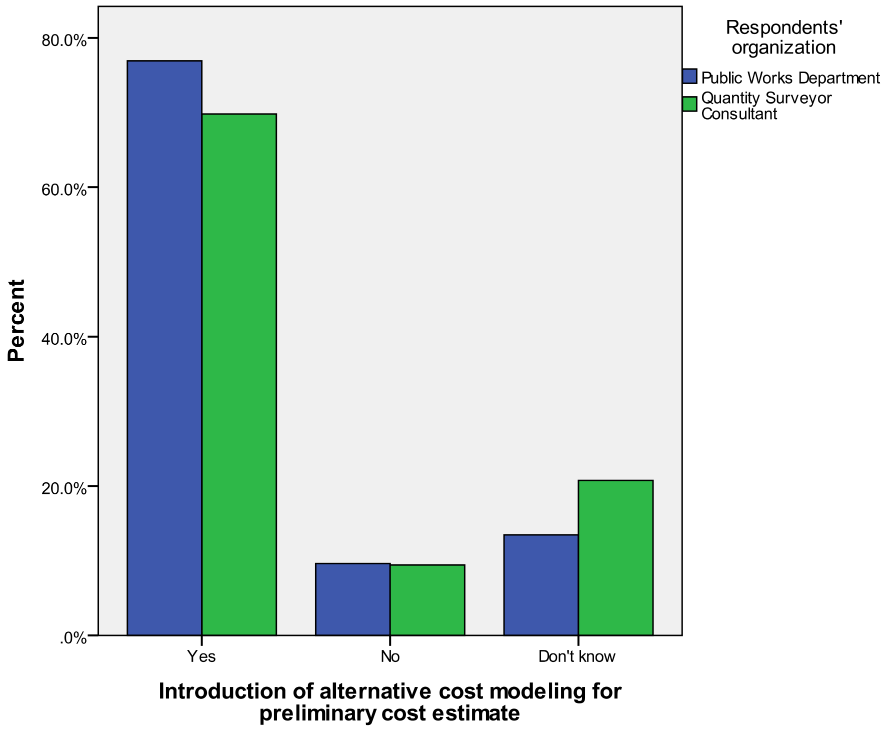


Figure 8.10: Percentage of respondent agreement with the introduction of alternative estimating methods

Table 8.17: Frequency and percentage of respondent's agreement with the introduction of alternative estimating methods

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Yes	80	76.9%	37	69.8%	117	74.5%
No	10	9.6%	5	9.4%	15	9.6%
Don't know	14	13.5%	11	20.8%	25	15.9%

Table 8.18: Chi-square test results of respondents' agreement with the introduction of alternative estimating methods

Chi-Square Tests			
Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.412^a	2	0.494
Likelihood Ratio	1.369	2	0.504
Linear-by-Linear Association	1.290	1	0.256
N of Valid Cases	157	-	-
a. zero cells (.0%) has expected count of less than 5. The minimum expected count is 5.06.			

8.1.1.10 Target to measure the accuracy of estimates

Figure 8.11 and Table 8.20 show the bar chart and the summary table of respondents' answers. Almost half of respondents (47.1%) agreed that the mean of the returned tenders should be the target used to measure the accuracy of the estimates. About a third of respondents (33.8%) agreed the accepted tender bid should be used instead. Less than a quarter of respondents (15.9%), stated that the final contract sum should be the target. A very small number of respondents (1.3%) say the lowest bid should be the target. A few of the respondents (1.9%) said they did not know which target should be used. Chi-square test shows χ^2 (4) = 6.893, p>0.05 (Refer to Table 8.20). Both parties were more or less agreeable on the question.

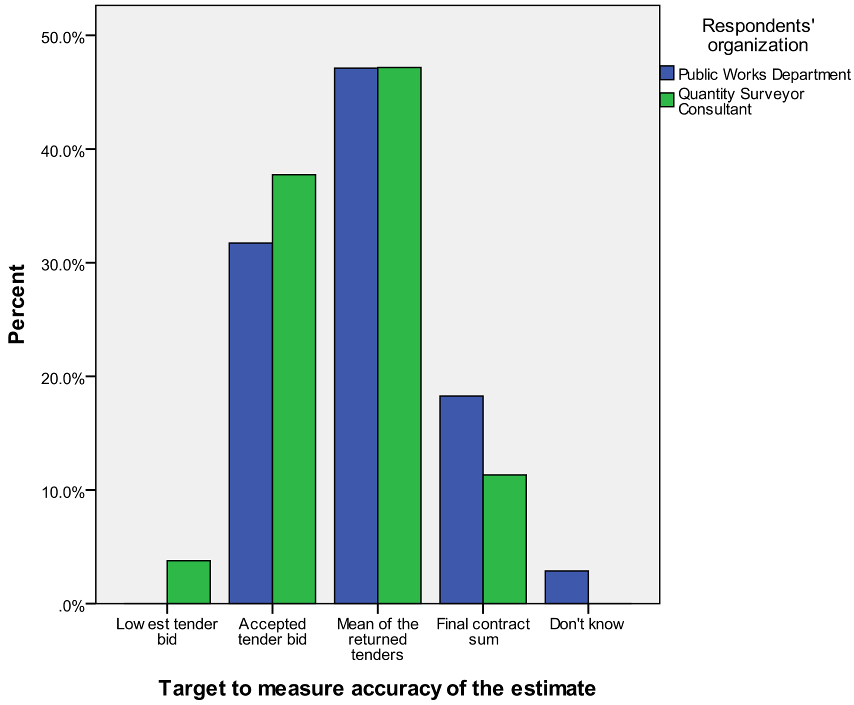


Figure 8.11: Percentage of respondents' opinion on target to be used to measure the accuracy level

Table 8.19: Frequency and percentage of respondents' opinion on target to be used to measure accuracy level

Response	Respondents' organization					
	PWD		Private consultant		Total	
	Count	N %	Count	N %	Count	N %
Lowest tender bid	0	0.0%	2	3.8%	2	1.3%
Accepted tender bid	33	31.7%	20	37.7%	53	33.8%
Mean of the returned tenders	49	47.1%	25	47.2%	74	47.1%
Final contract sum	19	18.3%	6	11.3%	25	15.9%
Don't know	3	2.9%	0	0.0%	3	1.9%

Table 8.20: Chi-square test result of respondents' opinion for target to be used to measure accuracy level

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.893[a]	4	0.142
Likelihood Ratio	8.311	4	0.081
Linear-by-Linear Association	4.034	1	0.045
N of Valid Cases	157	-	-
a. 4 cells (40.0%) have expected count of less than 5. The minimum expected count is .68.			

8.1.2 Part Two (2) – Factors which affect the accuracy of estimates

This part of data analysis studies the perspective of QS in PWD and private consultants on critical factors, which affect the accuracy of preliminary cost estimates. There are 20 factors recognised and they belonged to five (5) groups. These are scope quality, information quality, uncertainty level, estimator performance and quality of estimating procedure. The reliability of items in questionnaires is tested using Cronbach's Alpha. The Cronbach's Alpha is 0.86, which is more than 0.70. This shows that the instrument used for this research is highly reliable. However, uncertainty level subscale has a low reliability (less than 0.6) (Refer to Table 8.21). A two-tailed t-test examined the scores. It was found that only the stress level of QS scores below the mid-point of three (3) out of 5 point Likert's scale ($P<0.05$). Other factors score are more than the mid-point.

Table 8.21: Cronbach's Alpha of factors which affect the accuracy of estimates

Group of factors	No. of items	Cronbach's Alpha
Scope quality	7	0.637
Information quality	1	-
Uncertainty level	2	0.522
Estimator performance	5	0.665
Quality of estimating procedure	5	0.801
Total	20	0.853

8.1.2.1 Scope quality

Table 8.22 shows the RII score for scope quality. In terms of group rank, design scope (Plan shape, size m^2, height, specification and performance of buildings) comes first with RII score of 0.937. It is followed by location of project (0.867), design team experience (0.845), unclear documentation (0.819), basis of selection (0.742) type and condition of contract (0.724) and commitment of client to project is last with RII score of 0.705. Mann-Whitney test (Table 8.23) shows a significant difference in rank between QS in PWD and QS in private sector. QS in PWD ranked the location of project higher (mean rank = 86.06) while QS in private sector ranked it lower (mean rank = 63.81), U = 1951.000, $p<0.05$, r = -0.256. QS in PWD ranked basis of selection higher (mean rank = 84.41) while QS in private sector ranked it lower (mean rank = 67.01), U = 2120.500, $p<0.05$, r = -0.193. Other factors are agreed upon at more or less the same level by both parties ($p>0.05$). The Kendall's W is 0.235 with $P<0.05$ which is less than the significance level. There is a significant but weak degree of agreement among respondents in the group of scope quality.

Table 8.22: RII for scope quality

Factor	PWD QS		Private QS		Group Rank		Total RII Rank
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank	
Design scope	0.939	1	0.932	1	0.937	1	1
Design team experience	0.833	8	0.867	4	0.845	3	5
Unclear documentation	0.828	9	0.800	7	0.819	4	9
Location of the project	0.895	2	0.811	6	0.867	2	3
Type and condition of contract	0.740	13	0.694	15	0.724	6	14
Basis of Selection	0.773	11	0.683	16	0.742	5	12
Commitment of client to project	0.717	15	0.683	17	0.705	7	16

Table 8.23: Mann-Whitney test on scope quality

Factor	PWD QS	Private QS	Test statistic	z-score	P-value		r
	Mean Rank	Mean Rank	Mann-Whitney U				effect of size
Design scope	77.43	79.49	2645.000	-0.289	0.774		-0.023
Design team experience	74.81	84.13	2378.000	-1.325	0.189		-0.106
Unclear documentation	77.08	73.89	2442.500	-0.456	0.651		-0.037
Location of the project	86.06	63.81	1951.000	-3.197	0.001	*	-0.256
Type and condition of contract	81.17	73.30	2454.000	-1.080	0.282		-0.086
Basis of Selection	84.41	67.01	2120.500	-2.410	0.016	*	-0.193
Commitment of client to project	80.54	74.54	2519.500	-0.817	0.416		-0.065

** Statistical significance is set at the 5% level*

8.1.2.2 Information quality

Table 8.24 shows the RII score for information quality. The information quality score is 0.881. There are minor differences between QS in PWD and QS in private sector as the later ranked it higher (0.890) while the former ranked it lower (0.876). Nevertheless, Mann-Whitney test shows these differences are not significant (P>0.05) (Refer to Table 8.25).

Table 8.24: RII for information quality

Factor	PWD QS		Private QS		Group Rank		Total RII Rank
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank	
Cost data (information quality)	0.876	3	0.890	2	0.881	-	2

Table 8.25: Mann-Whitney test on information quality

Factor	PWD QS	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
Cost data	75.39	81.75	2409.500	-.930	0.360	-0.075

8.1.2.3 Uncertainty level

Table 8.26 shows the RII score for uncertainty level. In terms of group rank, market conditions and sentiments comes first with RII score of 0.841. It is followed by project technology and complexity (0.826). Table 8.27 (Mann-Whitney test) shows a significant difference in rank. QS in PWD ranked project technology and complexity higher (mean rank = 84.02) but QS in private sector ranked it lower (mean rank = 66.41), U = 2088.500, $p<0.05$, r = -0.205. The Kendall's W is 0.482 ($P<0.05$) which is less than the significance level. There is a significant but moderate degree of agreement among respondents in the group of uncertainty level.

Table 8.26: RII for uncertainty level

Factor	PWD QS		Private QS		Group Rank		Total RII Rank
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank	
Project technology and complexity level	0.847	5	0.784	11	0.826	2	7
Market conditions and sentiments	0.839	7	0.845	5	0.841	1	6

Table 8.27: Mann-Whitney test on uncertainty level

Factor	PWD QS	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
Project technology and complexity level	84.02	66.41	2088.500	-2.549	0.010 *	-0.205
Market conditions and sentiments	77.74	79.97	2651.500	-.317	0.758	-0.025

* *Statistical significance is set at the 5% level*

8.1.2.4 Estimator performance

Table 8.28 shows the RII score for estimator performance. In terms of group rank, QS experience comes first with RII score of 0.864. It is followed by QS with the type of project (0.826), perception of estimating importance by client (0.735), communication barrier (0.693) and the ability of QS to cope with stress (0.597). Table 8.29 (Mann-Whitney test) shows no difference in rank between groups of respondents (P>0.05). The Kendall's W is 0.344 (P<0.05) which is less than the significance level. There is a significant but weak degree of agreement among respondents in the group of estimator performance.

Table 8.28: RII for estimator performance

Factor	PWD QS		Private QS		Group Rank		Total RII Rank
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank	
QS' experience	0.857	4	0.876	3	0.864	1	4
Ability of QS to cope with stress	0.592	20	0.607	20	0.597	5	20
Communication barrier	0.684	18	0.709	13	0.693	4	17
Familiarity of QS with the type of project	0.841	6	0.796	8	0.826	2	8
Perception of estimating importance	0.731	14	0.743	12	0.735	3	13

Table 8.29: Mann-Whitney test on estimator performance

Factor	PWD QS	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
QS' experience	76.74	79.00	2574.000	-0.326	0.744	-0.026
Ability of QS to cope with stress	76.27	81.32	2527.000	-0.693	0.490	-0.056
Communication barrier	76.81	80.28	2582.000	-0.483	0.632	-0.039
Familiarity of QS with the type of project	82.67	70.39	2299.500	-1.737	0.083	-0.139
Perception of estimating importance	76.60	79.21	2586.000	-0.364	0.716	-0.029

** Statistical significance is set at the 5% level*

8.1.2.5 Quality of estimating procedure

Table 8.30 shows the RII score for quality of estimating procedure. In terms of group ranking, estimating method used comes first with RII score of 0.785. It is followed by limited time to prepare estimates (0.772), availability of estimating procedure (0.715), application of alternative estimating methods (0.696) and expected level of error in estimate (RII score = 0.658). Table 8.31 (Mann-Whitney test) shows no difference in rank between groups of respondents (P>0.05). The Kendall's W is 0.136 (P<0.05) which is less than the significance level. There is a significant but weak degree of agreement among respondents in the group of quality of estimating procedure.

Table 8.30: RII for quality of estimating procedure

Factor	QS PWD		Private QS		Group Rank		Total RII Rank
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank	
Expected level of error in estimate	0.651	19	0.671	19	0.658	5	19
Limited time to prepare estimate	0.759	12	0.796	9	0.772	2	11
Estimating method used	0.778	10	0.796	9	0.785	1	10
Application of alternative estimating methods	0.696	17	0.675	18	0.689	4	18
Availability of estimating procedures	0.715	16	0.698	14	0.709	3	15

Table 8.31: Mann-Whitney test for quality on estimating procedure

Factor	QS PWD	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
Expected level of error in estimate	76.27	81.33	2526.500	-0.707	0.482	-0.057
Limited time to prepare estimate	74.53	84.68	2349.000	-1.416	0.157	-0.114
Estimating method used	75.61	82.66	2459.000	-1.006	0.315	-0.081
Application of alternative estimating methods	79.36	75.38	2564.000	-0.551	0.583	-0.044
Availability of estimating procedures	78.74	78.03	2704.500	-0.100	0.922	-0.008

** Statistical significance is set at the 5% level*

8.1.3 Part Three (3) – Approaches to improve accuracy in estimating

Questionnaires were sent in order to explore the perspective of QS in PWD and QS in private consultants on improving the accuracy of estimates. There are two (2) recognized means of improvement studied. First, the improvement to current (traditional) estimating process and the second is the introduction of new approaches.

8.1.3.1 Improvement to current estimating process

Improving methods to current estimating process has been studied from the perspective of QS in PWD and QS in private consultants. It was found the reliability of the scale is good which is more than 0.70 (Cronbach's Alpha = 0.88). A two-tailed t-test found no methods are below the mid-point of three in the 5 points Likert's scale (P>0.05). Table 8.32 shows the RII score for improvement to current estimating process. Sufficient design from designers comes first with RII score of 0.895. It is followed by proper design documentation and information management (0.893), update cost data with new cost and create feedback system (0.869), effective communication and coordination between designers (0.859), ascertained assumptions from designers and client (0.859), realistic time for estimating activity (0.813), incorporate market sentiments and economic conditions into estimate (0.799), establish formal feedback for design and estimating activities (0.791), cost planning and cost control during design stage (0.787), improve methods of selection, adjustments and application of cost data (0.781), subdivided the large item into small items to reduce pricing errors (0.736), quantification of design and construction risks (0.729), tender documents used as estimates (0.719), use more rigorous estimating method (0.713). Mann-Whitney test (Table 8.33) shows a significant difference in rank between QS in PWD and QS in private sector. QS in PWD ranked the use of cost planning and cost control during design stage lower (mean rank = 71.98) while QS in private sector ranked it higher (mean rank = 88.03), U = 2118.500, p<0.05, r = -0.181. Other methods are agreed more or less at the same level by both parties (p>0.05).

Table 8.32: RII for improvement to current estimating process

Process	PWD QS		Private QS		Total	
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank
Proper design documentation and information management	0.898	1	0.883	2	0.893	2
Effective communication and coordination between designers	0.859	4	0.860	4	0.859	4
Sufficient design information from the designers	0.890	2	0.906	1	0.895	1
Ascertained assumptions from designers and client	0.812	5	0.842	5	0.822	5
Establish formal feedback for design and estimating activities	0.792	8	0.789	9	0.791	8
Realistic time for estimating activity	0.800	7	0.838	6	0.813	6
Use more rigorous estimating method	0.705	14	0.728	12	0.713	14
Incorporate market sentiments and economic conditions into estimate	0.802	6	0.792	8	0.799	7
Tender documents used as estimate	0.725	13	0.709	13	0.719	13
Quantification of design and construction risks	0.744	11	0.702	14	0.729	12
Cost planning and cost control during design stage	0.764	10	0.815	7	0.787	9
Subdivided the large item into small items to reduce pricing errors	0.731	12	0.747	11	0.736	11
Improve methods of selection, adjustments and application of cost data	0.782	9	0.777	10	0.781	10
Update cost data with new cost and create feedback system	0.865	3	0.875	3	0.869	3

Table 8.33: Mann-Whitney test on the improvement to current estimating process

Factor	PWD QS	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
Proper design documentation and information management	76.64	80.62	2564.000	-0.599	0.545	-0.048
Effective communication and coordination between designers	77.39	79.17	2641.000	-0.256	0.808	-0.021
Sufficient design information from the designers	76.37	81.13	2537.000	-0.709	0.485	-0.057
Ascertained assumptions from designers and client	75.09	82.09	2433.000	-1.007	0.318	-0.081
Establish formal feedback for design and estimating activities	77.84	76.85	2642.000	-0.143	0.897	-0.011
Realistic time for estimating activity	73.26	85.58	2248.500	-1.753	0.080	-0.141
Use more rigorous estimating method	74.87	82.52	2410.500	-1.088	0.279	-0.088
Incorporate market sentiments and economic conditions into estimate	78.03	77.93	2699.500	-0.014	0.992	-0.001
Tender documents used as estimate	77.85	76.84	2641.500	-0.142	0.887	-0.011
Quantification of design and construction risks	80.26	70.85	2324.000	-1.349	0.178	-0.109
Cost planning and cost control during design stage	71.98	88.03	2118.500	-2.248	0.024*	-0.181
Subdivided the large item into small items to reduce pricing errors	76.62	79.17	2588.000	-0.356	0.725	-0.029
Improve methods of selection, adjustments and application of cost data	78.44	75.71	2581.500	-0.388	0.705	-0.031
Update cost data with new cost and create feedback system	75.99	80.38	2524.000	-0.640	0.524	-0.052

** Statistical significance is set at the 5% level*

8.1.3.2 Improvement by the introduction of new approaches

Improvement to policies and procedures using new approaches has been studied from the perspective of QS in PWD and QS in private sector. It was found the reliability of the scale is good which is more than 0.70 (Cronbach's Alpha = 0.82). A two-tailed t-test found no approaches are below the mid-point of three in the 5 point Likert's scale (P>0.05). Table 8.34 shows the RII score for introduction of new approaches. Investing in estimating training for QS officers and consultants' executive comes first with RII score of 0.799. It is followed by sharing of cost data among consultants and PWD (0.796), introduction of standardized rules of measurement for estimating and cost planning (0.795), investing and collaborating in cost estimate research between PWD and consultants (0.771), introduction of value engineering in estimating procedure (0.766) and introduction of alternative estimating methods (0.748). Mann-Whitney test (Table 8.35) shows no difference in rank among the groups of respondents (P>0.05).

Table 8.34: RII for introduction of new approaches

Approaches	**PWD QS**		**Private QS**		**Total**	
	RII Score	RII Rank	RII Score	RII Rank	RII Score	RII Rank
Invest and collaborating in cost estimate research between PWD and consultants	0.772	5	0.770	4	0.771	4
Sharing of Cost Data among consultants and PWD	0.788	3	0.811	1	0.796	2
Introduction of alternative estimating methods	0.750	6	0.743	6	0.748	6
Introduction of value engineering for estimate	0.776	4	0.746	5	0.766	5
Investing in estimating training for QS officers / consultants' executives	0.810	1	0.777	2	0.799	1
Introduction of standardized rules of measurement for estimating and cost planning	0.806	2	0.774	3	0.795	3

Table 8.35: Mann-Whitney test on the introduction of approaches

Approaches	PWD QS	Private QS	Test statistic	z-score	P-value	r
	Mean rank	Mean rank	Mann-Whitney U			effect of size
Invest and collaborating in cost estimate research between PWD and consultants	77.57	77.36	2669.000	-0.030	0.982	0.00
Sharing of Cost Data among consultants and PWD	75.14	82.00	2438.000	-0.957	0.341	-0.08
Introduction of untraditional based estimating methods	78.27	76.03	2598.500	-0.315	0.752	-0.03
Introduction of value engineering for estimate	79.55	72.05	2368.500	-1.071	0.285	-0.09
Investing in estimating training for QS officers / consultants' executives	80.00	72.75	2424.500	-1.028	0.306	-0.08
Introduction of standardized rules of measurement for estimating and cost planning	79.18	74.30	2507.000	-0.685	0.497	-0.06

** Statistical significance is set at the 5% level*

8.2 Section Two (2) – Project data

This section is divided into three (3) parts. Part one (1) discusses about the accuracy of project estimates. Part two (2) discusses about project characteristics and other estimating components, which influence the accuracy of preliminary cost estimates, and Part three (3) discusses the reliability of MRM cost model.

The analyses are performed to examine the following:

a) Comparison between estimate and lowest bid.

b) Comparison between estimate and accepted bid with and without contingencies and VOP.

c) Comparison between estimate and mean of the bids (mean of the returned tenders).

d) Comparison betweenVOP and contingencies at early estimate and at tender stage.

e) Comparison between elemental estimate in cost estimate and bidding.

8.2.1 Part One (1) – Accuracy of cost estimates

This part of analysis presents the accuracy of estimates using lowest bid, mean of the bids and accepted bid. The analysis on contingencies and VOP is presented in order to point out how much the percentage of these sums were allocated by PWD officers. Then, the analysis on accuracy of elemental costs estimates could show the estimating accuracy against these costs. Data in PDA and ATDA forms were collected from CKUB, PWD. All the data are related to primary and secondary school projects. These are data of pre-design additional school buildings. The projects were designed and estimated by PWD. None of the estimates were prepared by private QS consultants. The total approved Preliminary Cost Estimates were RM 280,740,476.45. The total approved contract prices were RM 250,539,830.40. All projects are located in the west coast of Peninsular Malaysia. There are Kedah, Perak, Negeri Sembilan (N9), Melaka and Johor (Refer to Appendix 6 for: Schedule of original project data collection). Note: the consistency of estimates is denoted without the percentage (%) of coefficient of variation in order to differentiate with the bias percentage.

8.2.1.1 Accuracy of estimates using different estimating targets

Table 8.36, Figure 8.12 and Figure 8.13 show the estimating accuracy of using different estimating targets. From the data analyzed, it was found that the bias of estimate / lowest bid is 25.05%, while its cv is 11.13. Only 10 projects were accepted through lowest bid prices with bias of 17.51% and cv of 10.25. Bias of estimate / accepted bid (with VOP and Contingencies) is 10.82% and its cv is 9.23. Bias of estimate / accepted bid (without VOP and Contingencies) is 11.18% and its cv is 9.63. Mean of the bid's bias is 10.88% and its cv is 9.54.

Table 8.36: Accuracy using different estimating targets

Comparison	N	Bias (Error) (%)	Consistency (cv)
Estimates and lowest bid	83	25.05	11.13
Estimates and lowest bid (accepted)	10	17.51	10.25
Estimates and accepted tender bids (with VOP and contingencies)	83	10.82	9.23
Estimates and accepted tender bids (without VOP and contingencies)	83	11.18	9.63
Estimates and mean of the bids	83	10.88	9.54

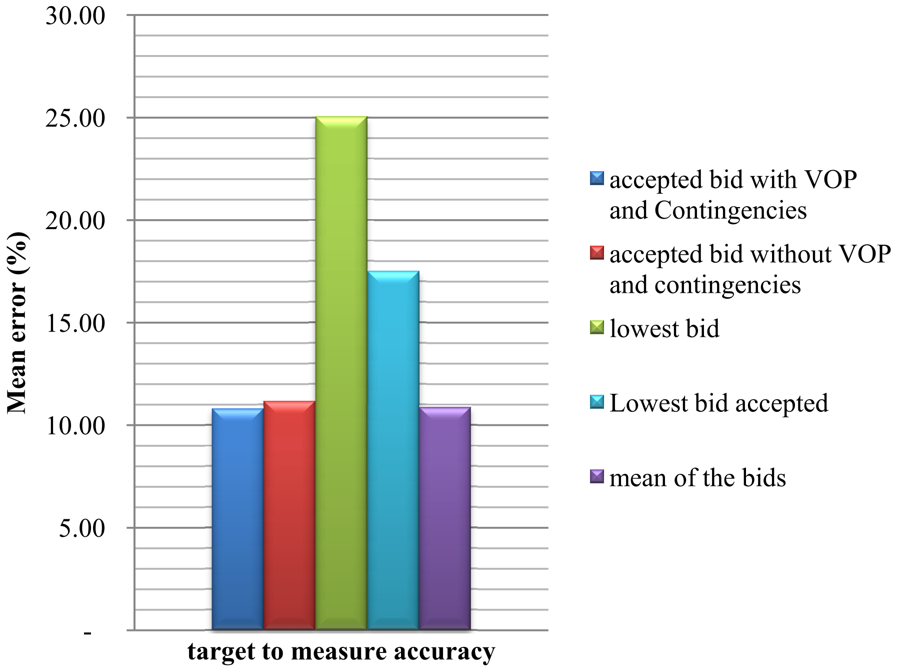


Figure 8.12: Bar chart represents the mean bias of the estimate using different targets

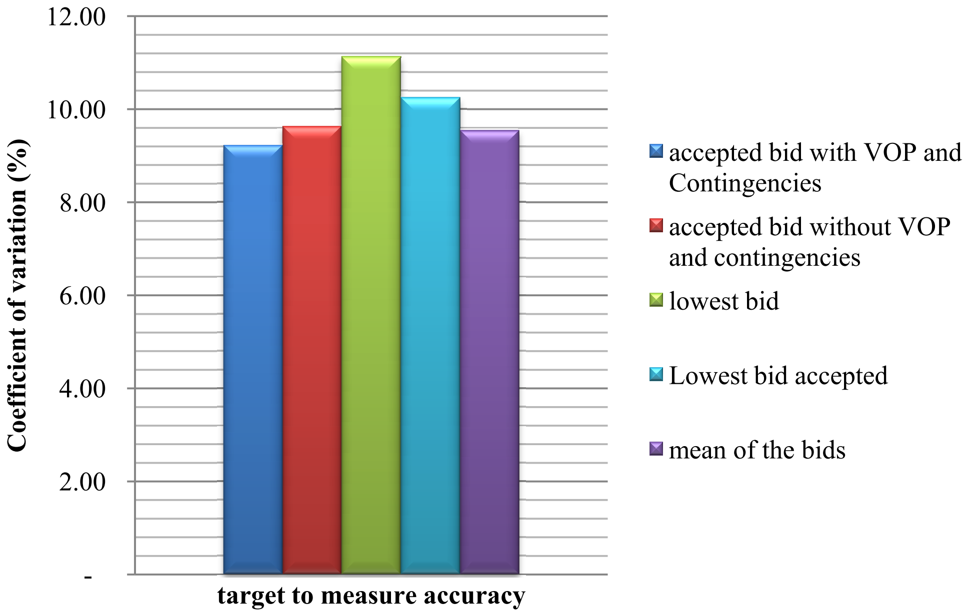


Figure 8.13: Bar chart represents the consistency of the estimate using different targets

8.2.1.2 Parameter of estimating bias using different targets

Table 8.37 shows parameter of estimating bias in the estimates. It shows the use of accepted bid and mean of the bids give similar parameter values. According to paired-samples t-test, there is no significant mean difference between the mean of the bids' errors and accepted bids' errors (P>0.05) but there is a significant mean difference between lowest bids' errors and errors of other targets (mean of the bids and accepted bids) (P<0.05).

Table 8.37: Error parameter with different targets

Target	95% confidence interval	Percentile 25th , 50th and 75th	Refer to
Lowest bid	22.01 (L) 28.09 (U)	16.43 25.48 33.57	Table 8.38 and Figure 8.14
Accepted bid with contingencies and VOP	8.58(L) 13.05 (U)	3.98 10.42 17.27	Table 8.39 and Figure 8.15
Accepted bid without contingencies and VOP	8.84 (L) 13.52 (U)	4.88 11.28 18.54	Table 8.40 and Figure 8.16
Mean of the bids	8.57 (L) 13.19 (U)	3.57 11.86 19.10	Table 8.41 and Figure 8.17

Note: L = Lower value, U = Upper value

Table 8.38 : Distribution of errors using lowest bid

Error (%)	*Frequency*	*Cumulative %*
-8.56	1	1.22%
-0.61	2	3.66%
7.34	5	9.76%
15.29	8	19.51%
23.24	16	39.02%
31.19	25	69.51%
39.15	16	89.02%
47.10	3	92.68%
55.05	3	96.34%
More	3	100.00%

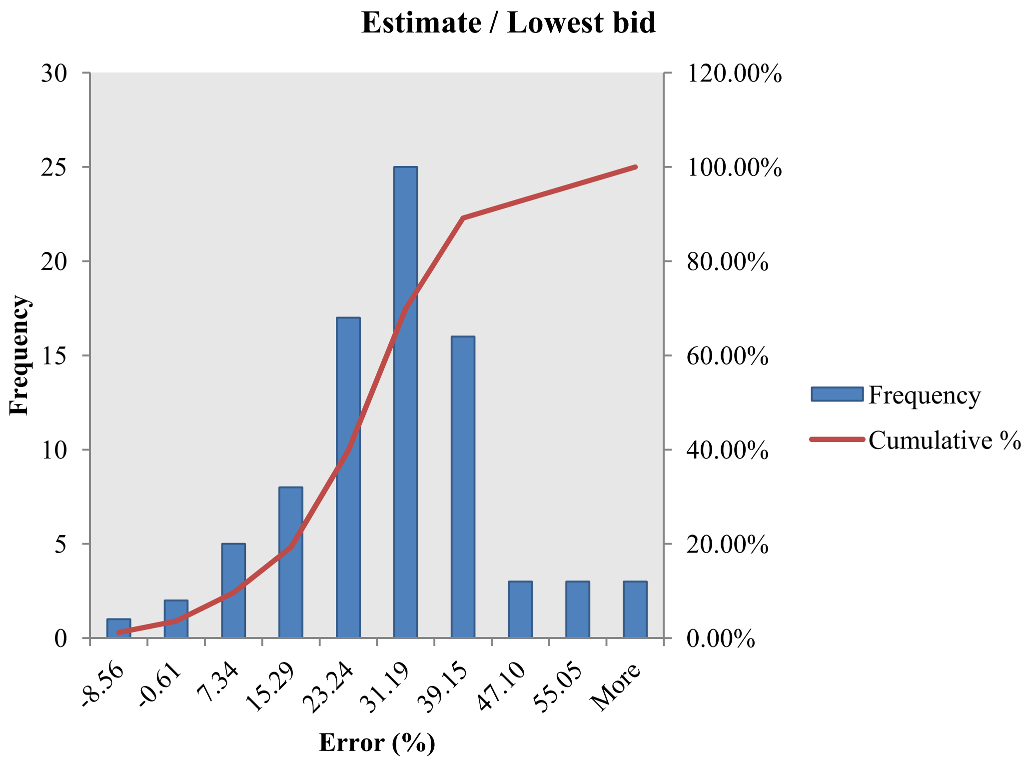


Figure 8.14: Histogram of errors using lowest bid

Table 8.39: Distribution of errors using accepted bid with both VOP and Contingencies included

Error (%)	*Frequency*	*Cumulative %*
-14.46	1	1.22%
-8.47	2	3.66%
-2.48	5	9.76%
3.51	11	23.17%
9.50	18	45.12%
15.49	19	68.29%
21.48	16	87.80%
27.48	6	95.12%
33.47	3	98.78%
More	1	100.00%

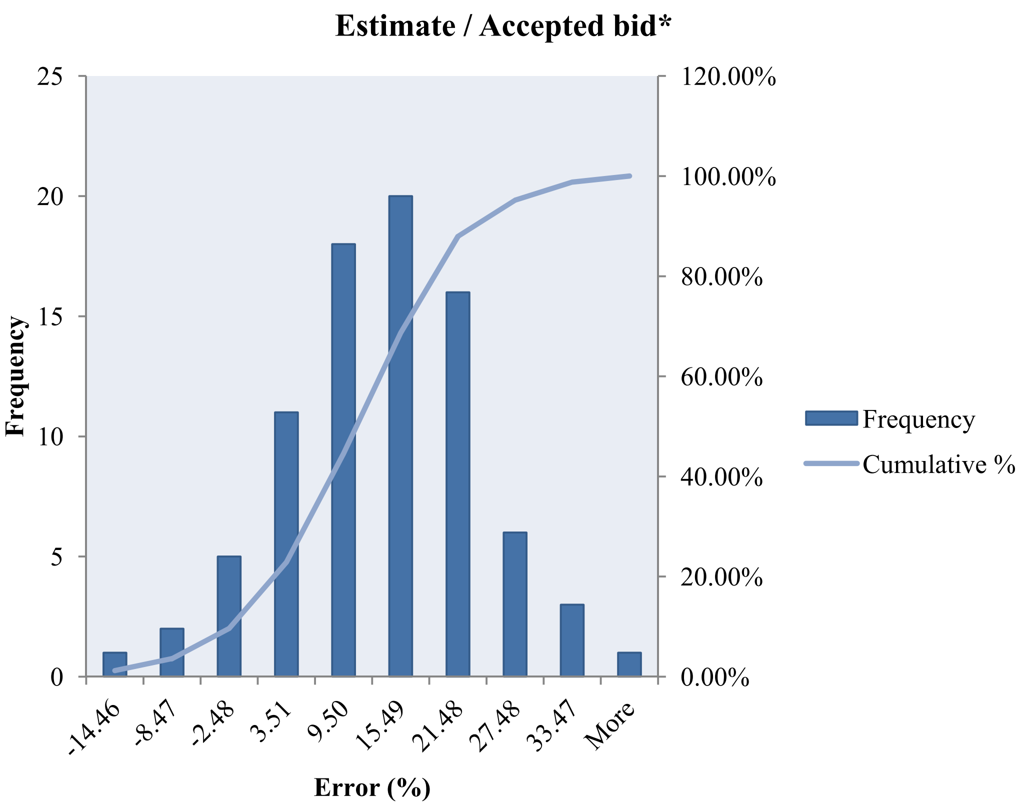


Figure 8.15: Histogram of errors using accepted bid with both VOP and Contingencies included*

Table 8.40: Distribution of errors using accepted bid without both VOP and Contingencies

Error (%)	***Frequency***	***Cumulative %***
-15.90	1	1.22%
-10.35	4	6.10%
-4.80	3	9.76%
0.75	4	14.63%
6.30	12	29.27%
11.85	19	52.44%
17.40	13	68.29%
22.95	16	87.80%
28.50	7	96.34%
More	3	100.00%

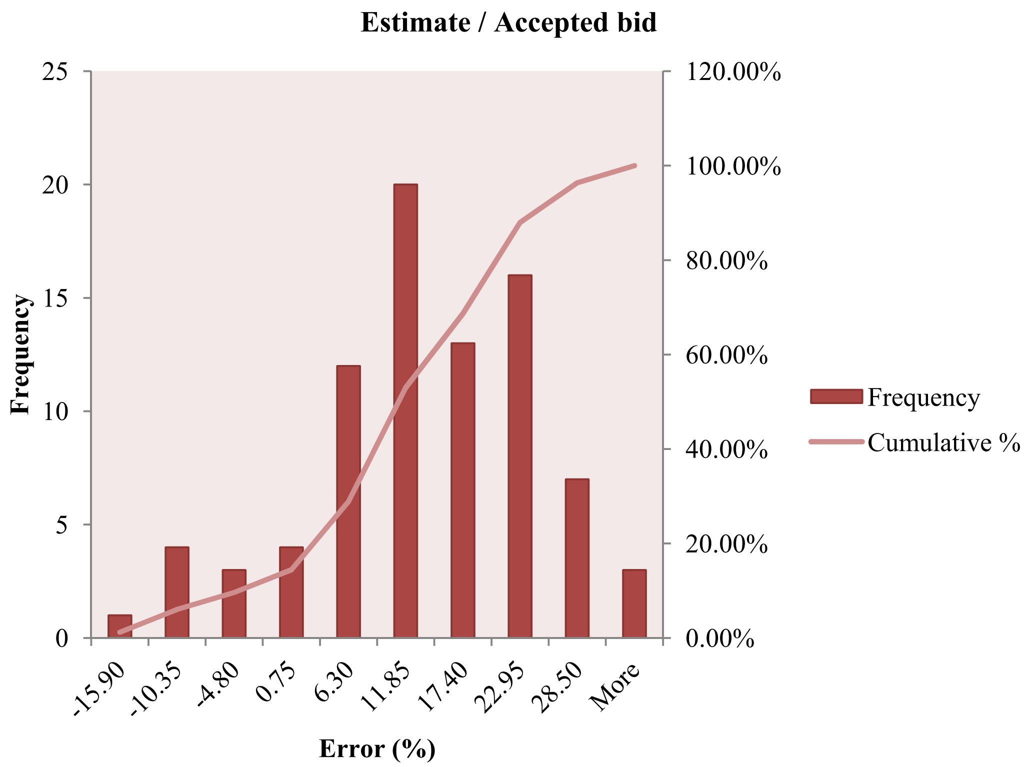


Figure 8.16: Histogram of errors using accepted bid without both VOP and Contingencies

Table 8.41: Distribution of errors using mean of the bids

Error (%)	*Frequency*	*Cumulative %*
-13.93	1	1.20%
-8.82	3	4.82%
-3.70	6	12.05%
1.41	2	14.46%
6.52	19	37.35%
11.64	9	48.19%
16.75	15	66.27%
21.87	16	85.54%
26.98	9	96.39%
More	3	100.00%

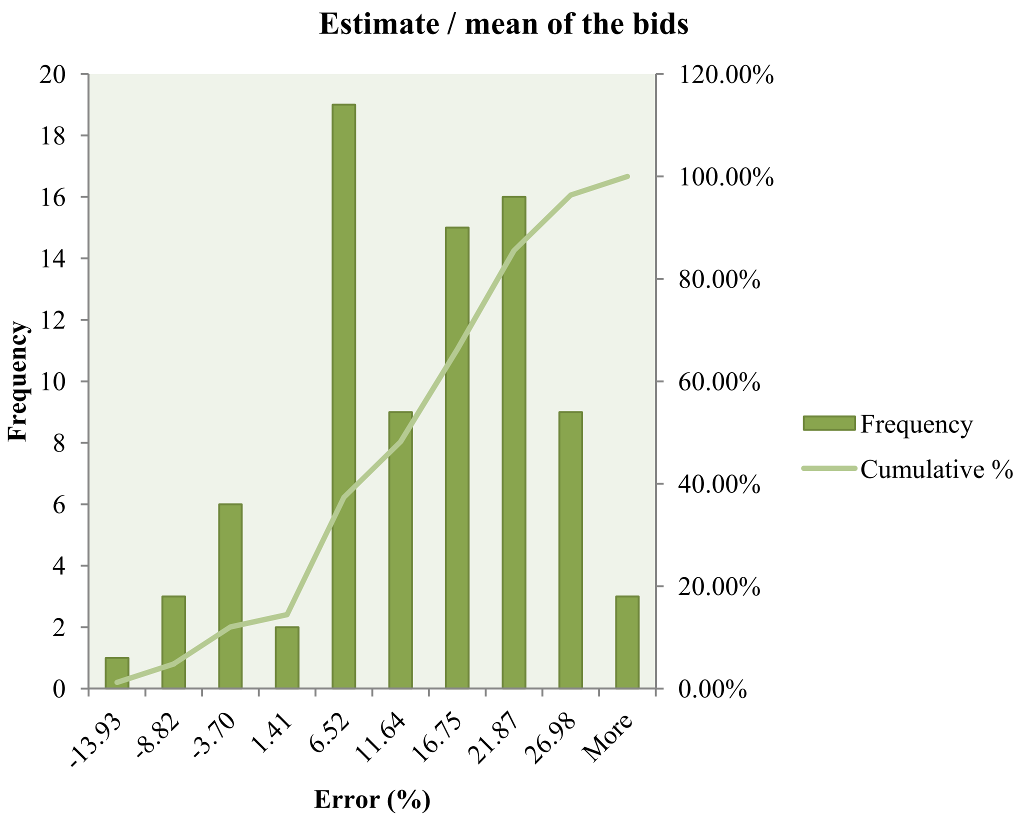


Figure 8.17: Histogram of errors using mean of the bids

Figure 8.18 shows box plot of error (%). In lowest bid, two (2) estimates are extremely inaccurate. The box plot follows a normal distribution. In accepted bid with VOP and contingencies, only one (1) estimate is extremely overestimated. The box plot follows normal distribution. In accepted bid without VOP and contingencies, only one (1) estimate was extremely underestimated. The box plot follows normal distribution. Finally, in the mean of the bids, it has no outliers. The box plot follows normal distribution.

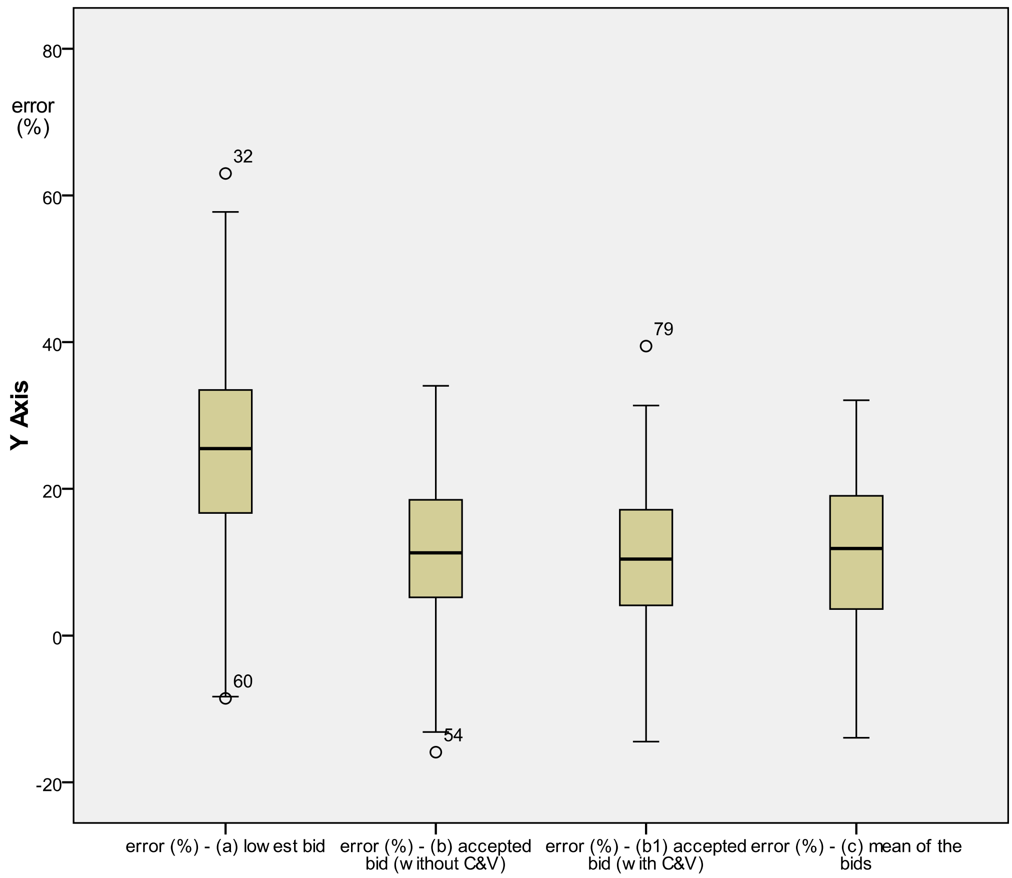


Figure 8.18: Box-plot of error (%) using lowest bid, accepted bid (with and without contingencies and VOP) and mean of the bids

8.2.1.3 Analysis on accuracy of estimates

It was assumed that estimating error of +/-20% is considered accurate due to substantial design is already completed. Morrison (1984) stated that +/-26% is accurate for preliminary cost estimates if preliminary design is used. If it is more or less than this value it is inaccurate. It shows only 34% of estimates is accurate when using lowest bid as the target. The use of accepted bids and mean of the bids shows more than 77% of estimates are accurate. Independent t-test on each group shows the error estimates of +/-20% is not the same as the error in inaccurate estimates ($p<0.05$). This shows accurate estimates and inaccurate estimates are statistically different.

8.2.1.4 Contingencies and VOP allocations

Table 8.42 shows the contingencies and VOP allocation. The amount of contingencies for PDA during estimate is 4.20% and for ATDA at contract stage is 3.52%. For PDA, it is RM 10,335,545.93 and for ATDA, it is RM 7,825,992.53. Less than 5% allocation is allocated to 73% of contingencies during estimate. More than 2% allocation is allocated to 96% of contingencies at tender stage. The percentage of VOP is 3.20% and ATDA 4.10%. The amount is RM 7,158,700.78 for PDA to RM 10,145,450.81 for ATDA. According to Figure 8.19, the building material price index increased gradually from January to December 2007 but it decreased dramatically from first half of 2007 to December 2008.

Table 8.42: Contingencies and VOP at estimate and contract stage

Stage	Mean Contingencies (RM)	%	Mean VOP (RM)	%
Estimate	10,335,545.93	4.20	7,158,700.78	3.20
Contract stage	7,825,992.53	3.52	10,145,450.81	4.10

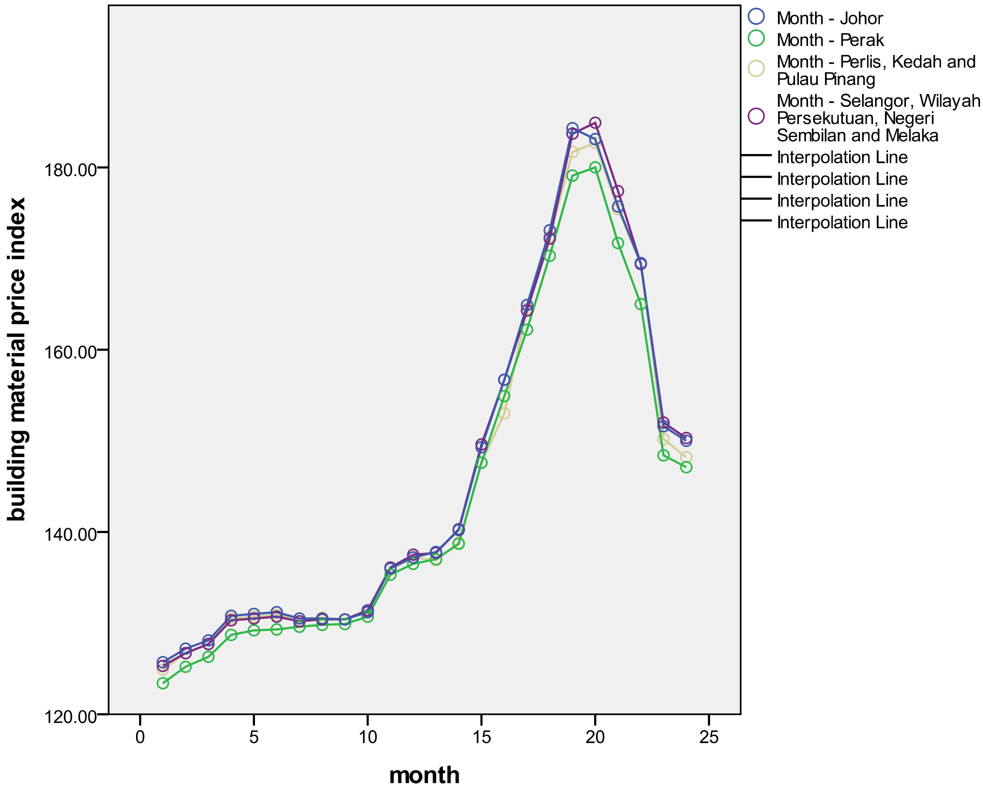


Figure 8.19: Scatter plot for building material price index in year 2007 and 2008 (source: Construction Industry Development Board, 2007, 2008)

8.2.1.5 Accuracy of elemental estimates

Table 8.43 and Figure 8.20 show accuracy of estimates according to elemental costs. Most of the time, area method is used to estimate the building costs. For other elements, various methods such as approximate quantities and percentage allowances were used.

From the analysis, it was found that the highest mean error is piling and foundation at 44.52%. It was found that two (2) projects were estimated without piling works and four (4) projects were not required to erect piling during tender design stage. It is followed by external works at 42.86%, building works at 24.26% and internal services at 3.63%. The least mean error is found in preliminaries, which is at 0.58%. Internal services are the most consistent estimates at 20.61cv. It is followed by building works at 49.26cv, preliminaries at 59.61cv and external works at 69.20cv. Piling and foundation is the most inconsistent estimates at 198.25cv. Building works contributed 48.33% of the total construction cost, which is the highest. It is followed by internal services at 24.67%, piling and foundation at 11.66% and external works at 9.99%. The lowest is preliminaries, which is at 5.35% respectively.

Table 8.43: Accuracy of elemental costs

Element	**Amount (RM)**	**% of element**	**Error (%)**	**sd**	**cv**
Total	232,508,387.06	100.00	11.18	10.71	9.63
Preliminaries	12,446,277.61	5.35	0.58	59.95	59.61
Piling & foundation	27,101,527.60	11.66	44.52	286.52	198.25
Building works	112,370,446.99	48.33	24.26	61.22	49.26
Internal services	57,356,052.02	24.67	3.63	21.36	20.61
External works	23,234,082.84	9.99	42.86	98.87	69.20

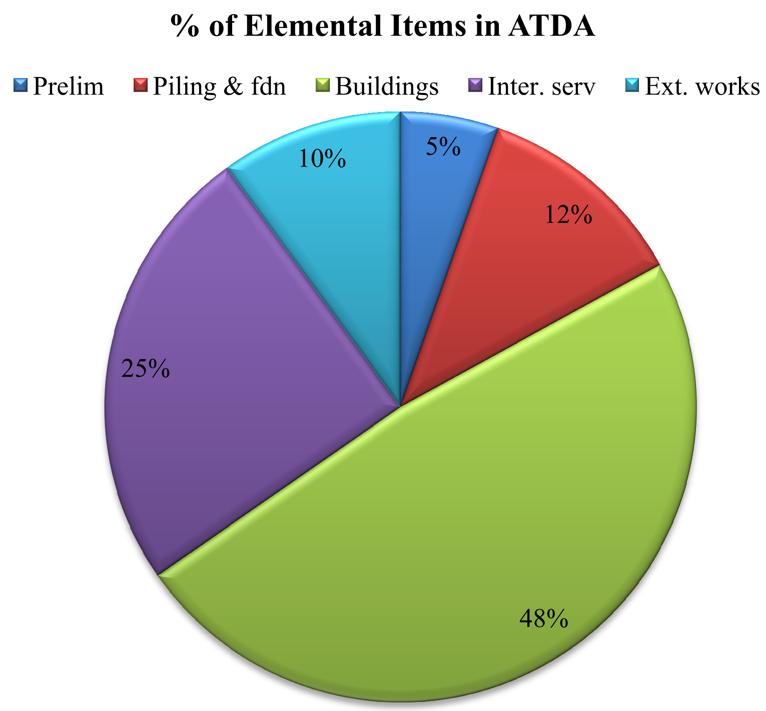


Figure 8.20: Pie chart distribution (percentage) of elements in ATDA

8.2.2 Part Two (2) – Project characteristics' tests and results

Each of project characteristics are tested using selected analysis tools. These tests include ANOVA, Levene's test, and MRA.

8.2.2.1 Preliminary analysis on project characteristics

There are nine (9) project characteristics analyzed. This analysis is limited to school projects, which are valued from RM1 to RM 7,720,120. The smaller the mean error the more accurate are the estimates or less bias. The smaller the coefficient of variation the more consistent are the estimates. This analysis examines lowest bid, accepted bid and mean of the bids. There are three (3) separate analyses prepared and these can be used as targets in order to measure estimating accuracy. Scatter plot is used to investigate the linear relationship between continuous variables while a bar chart (mean value) is used for categorical variables. These are used to observe the relationship between the estimate bias and project characteristics. Error bar (mean value) is used to observe the spread of data in terms of consistency of the estimate. The variables are as follows (Refer to Table 8.44):

Table 8.44: Project characteristics' variables and accuracy of estimates

Variable	N	Lowest bid		Accepted bid		Mean of the Bids	
		Bias	CV	Bias	CV	Bias	CV
Total	*83*	*25.05*	*11.13*	*11.18*	*9.63*	*10.88*	*9.54*
Project Value (RM)							
1 - 1,000,000	16	17.39	14.96	3.62	12.08	2.61	12.43
1,000,001 - 3,000,000	33	26.20	10.56	12.43	8.93	13.18	8.55
3,000,001 - 5,000,000	22	26.81	9.92	11.09	8.62	10.38	8.28
>5,000,000	12	28.88	7.63	18.01	5.24	16.52	4.47
Project Size (m^2)							
1 – 1500	31	19.84	12.49	5.85	10.95	5.23	10.79
1501 – 2500	23	27.26	11.39	13.78	7.95	14.02	8.27
2501 – 3500	21	28.30	8.20	15.45	8.14	14.07	7.62
>3500	8	30.38	9.03	13.19	6.31	15.39	4.86
PI (cost/m^2GFA)							
Lowest bid							
1 – 1000	13	40.25	10.50				
1001 – 1500	39	23.65	7.60				
1501- 2000	18	23.21	9.52				
>2000	13	16.63	14.81				
Accepted bid							
1 – 1200	16			16.22	7.54		
1201 – 1700	40			11.85	8.33		
1701 – 2200	14			10.79	9.15		
>2200	13			3.37	13.49		
Mean of the bids							
1 – 1200	16					18.96	6.45
1201 – 1700	38					11.07	7.93
1701 – 2200	15					8.62	8.05
>2200	14					3.55	13.21
No. of storeys							
1 storey	20	20.96	13.78	6.29	11.79	6.46	12.22
2 storey	9	23.20	9.63	10.48	9.09	6.52	8.14
3 storey	20	22.41	7.95	11.10	9.68	10.87	8.50
4 storey	34	29.51	10.85	14.30	7.80	14.64	7.76

Table 8.44: Project characteristics' variables and accuracy of estimates (cont'd)

Variable	N	Lowest bid		Accepted bid		Mean of the Bids	
		Bias	CV	Bias	CV	Bias	CV
Contract Period (weeks)							
1 -35	18	19.15	14.54	5.91	12.93	4.96	13.26
36 - 52	43	25.66	10.23	13.65	9.12	11.99	8.74
>52	22	28.70	9.25	10.69	6.14	13.57	5.99
Number of Tenders							
1 - 7	13	21.04	10.97	14.15	8.25	8.45	10.05
8 - 15	33	23.63	11.21	9.75	10.90	7.93	9.45
16 - 23	26	27.60	11.17	11.44	9.91	13.83	9.57
>23	11	28.02	11.28	11.37	6.69	15.62	6.59
State							
A - Kedah	36	26.64	10.30	12.28	8.08	13.55	8.10
B - Perak	7	21.93	10.90	8.66	7.24	7.48	5.26
C - Negeri Sembilan (N9)	5	35.49	1.99	14.31	8.67	19.29	5.76
C1 - Melaka	11	13.69	17.02	-4.34	9.25	-2.84	9.68
D - Johor	24	26.62	8.95	16.74	7.03	12.41	8.55
Types of schools							
Primary	28	19.10	12.57	5.87	10.66	6.33	10.73
Secondary	55	28.08	9.73	13.89	8.28	13.20	8.29
Classes of projects							
Main building	33	26.64	11.43	13.57	8.49	13.67	8.76
Secondary building	23	20.96	13.48	5.99	11.03	5.85	11.66
Mix building	27	26.60	8.28	12.69	8.84	11.75	7.41

A) Project value (RM)

Figure 8.21 and Figure 8.22 show scatter plot and error bar for project value. It is the value of the project in terms of RM. Bias increases when the project value increases. Estimates of inexpensive project are more accurate than expensive project but it is inconsistent.

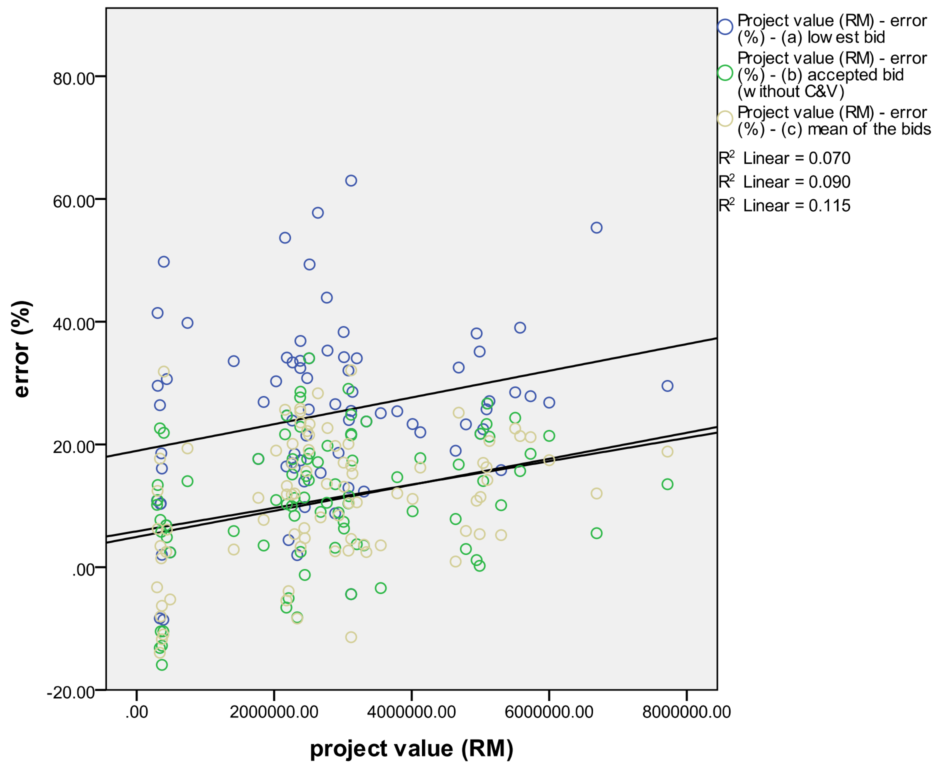


Figure 8.21: Scatter plot shows error (%) against project value (RM)

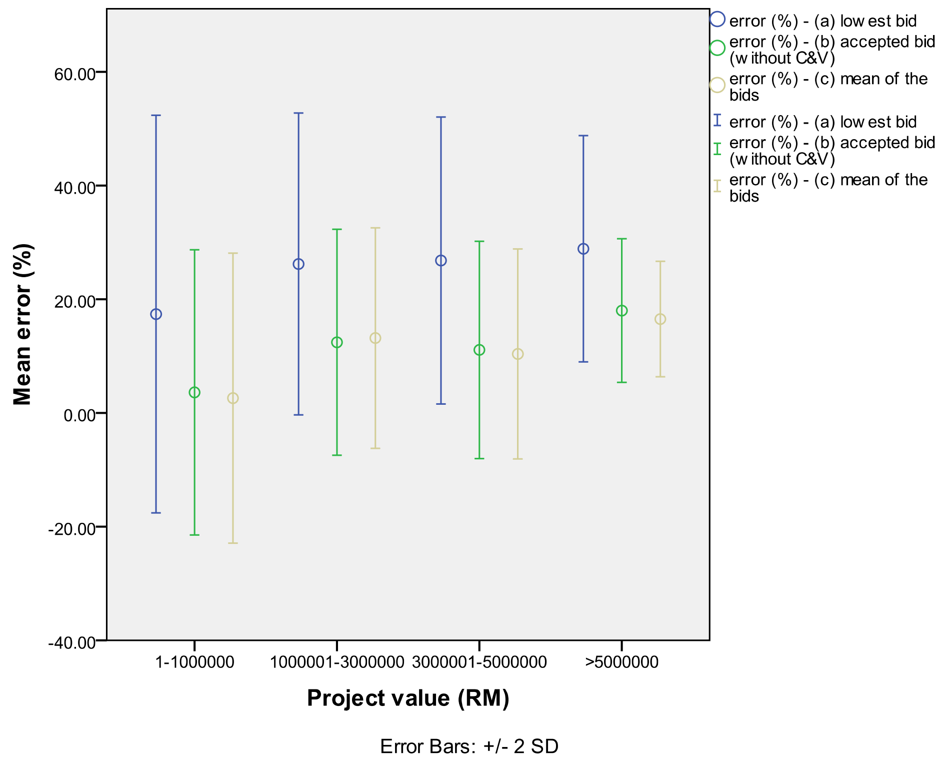


Figure 8.22: Error bar shows mean error (%) against project value (RM)

B) Project size (m^2GFA)

Figure 8.23 and Figure 8.24 show scatter plot and error bar for project size. The Gross Floor Area (GFA) of the project is in terms of m^2GFA. Bias increases when project size increases. The larger the project size the larger the bias increase. The consistency also improves when the project size increases.

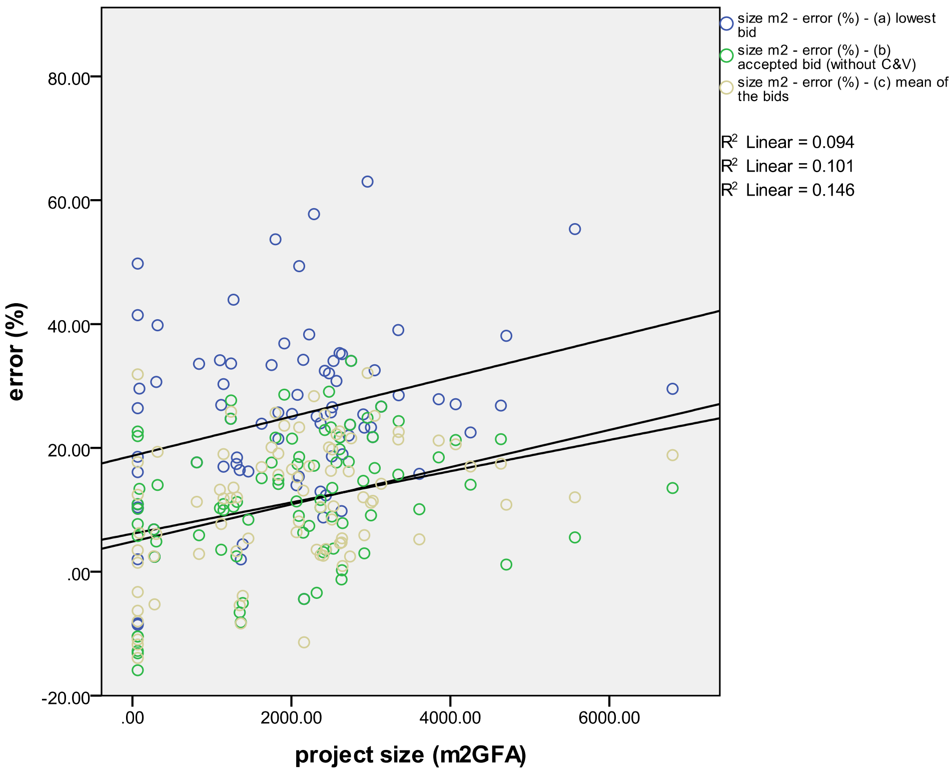


Figure 8.23: Scatter plot shows error (%) against size (m^2GFA)

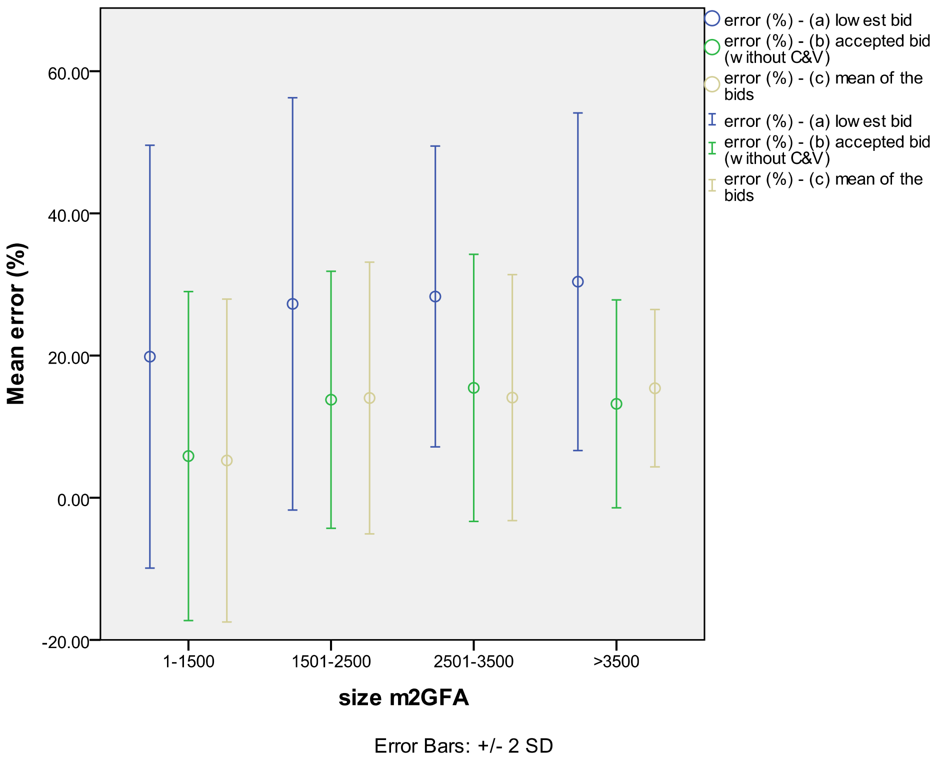


Figure 8.24: Error bar shows mean error (%) and project size (m^2GFA)

C) Price intensity (RM/m^2GFA)

Figure 8.25, Figure 8.26, Figure 8.27 and Figure 8.28 show scatter plot and error bar for PI. The cost per area means the cost per m^2 Gross Floor Area. When different targets are used, different groups have different values. This is to ensure the group sizes are balance (Refer Table 8.44). Bias decreases when the cost per m^2GFA increases. Bias is reduced in expensive projects. There is no consistency trend in lowest bid and it gets worse with the increase of cost/m^2GFA in mean of the bids and accepted bid.

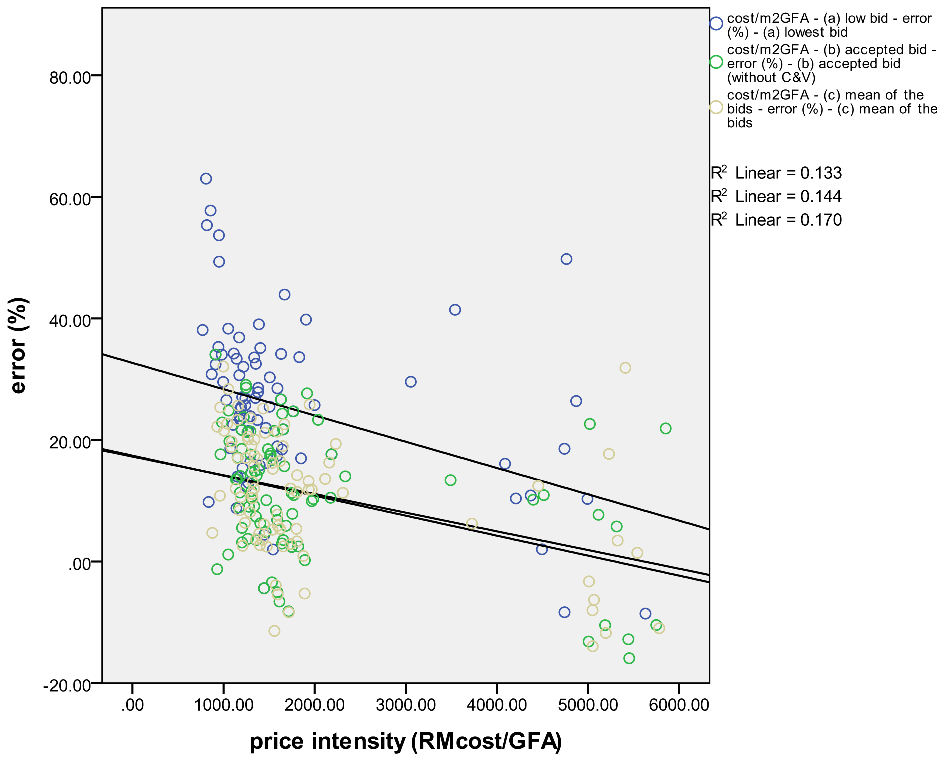


Figure 8.25: Scatter plot shows error (%) against cost/m^{2}GFA

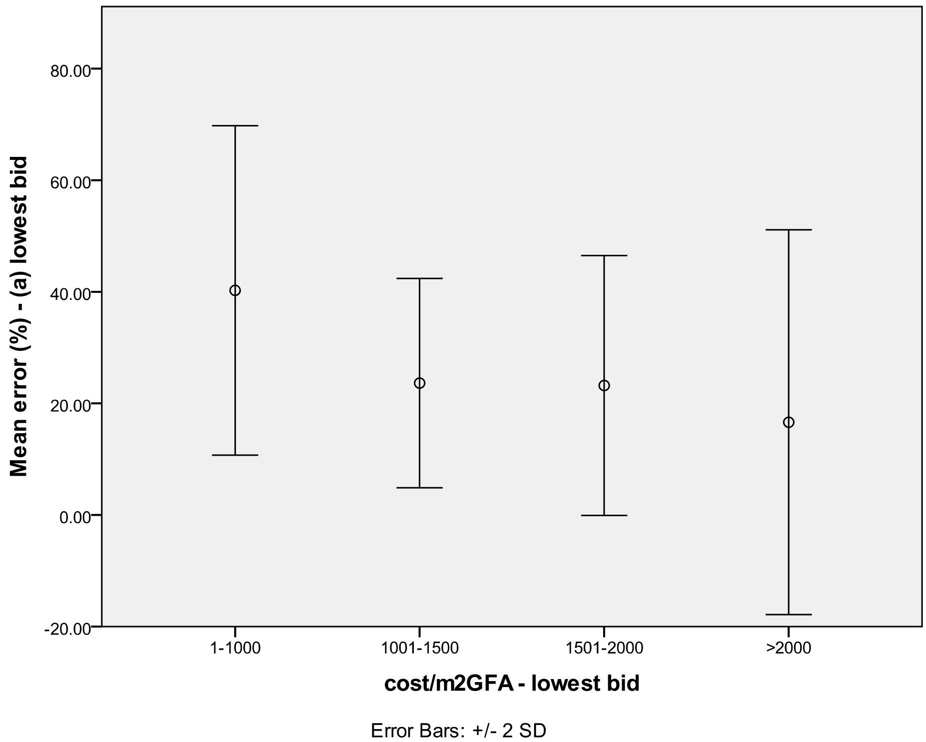


Figure 8.26: Error bar shows mean error (%) against cost/m^{2}GFA (lowest bid)

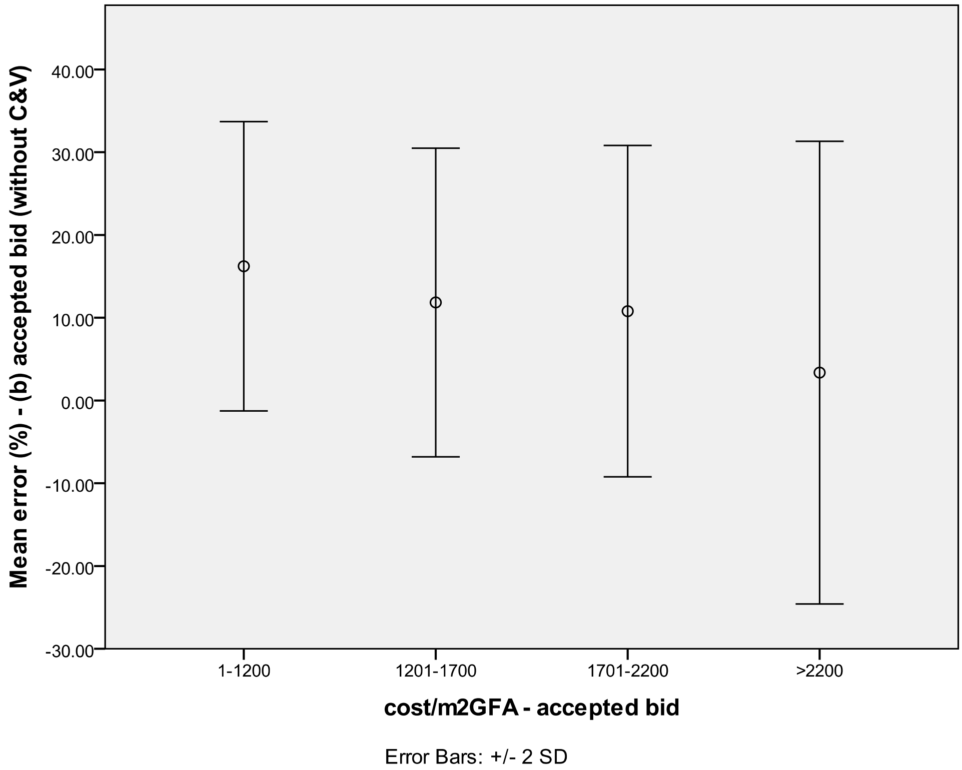


Figure 8.27: Error bar shows mean error (%) against cost/m^{2}GFA (accepted bid)

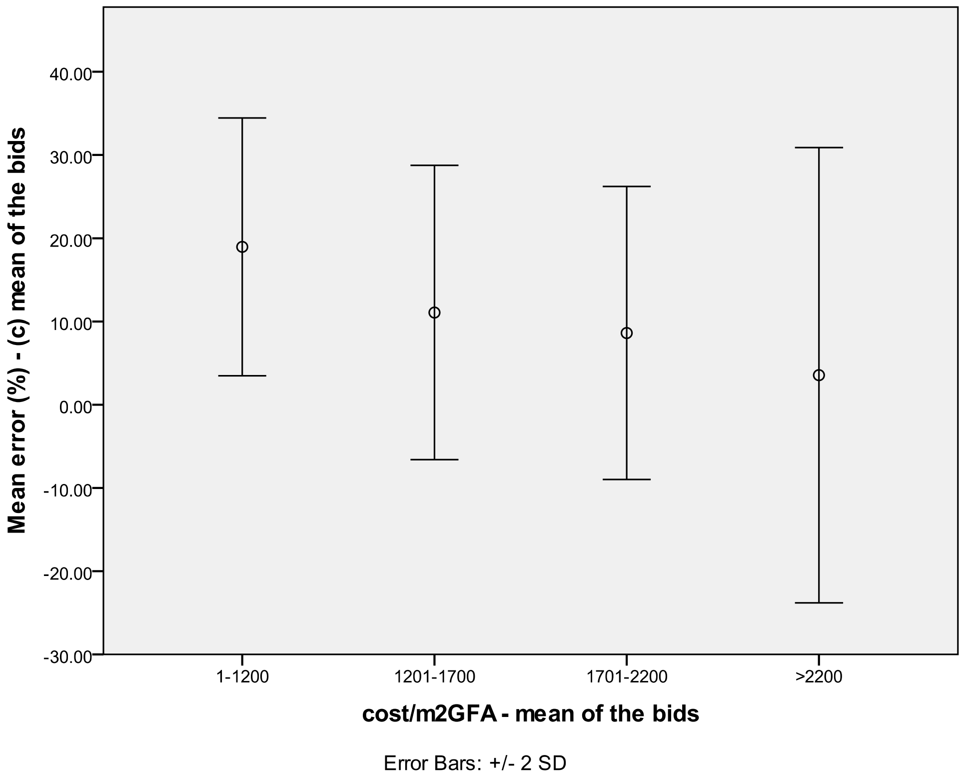


Figure 8.28: Error bar shows mean error (%) against cost/m^{2}GFA (mean of the bids)

D) Number of storeys

Figure 8.29 and Figure 8.30 show scatter plot and error bar for number of storeys. It depends on the building height. Bias increases when increases number of storeys. The consistency of estimates varies with the increase in the number of storeys. There is no consistency trend in lowest bid, but it improves when the number of storeys increases in accepted bid and mean of the bids.

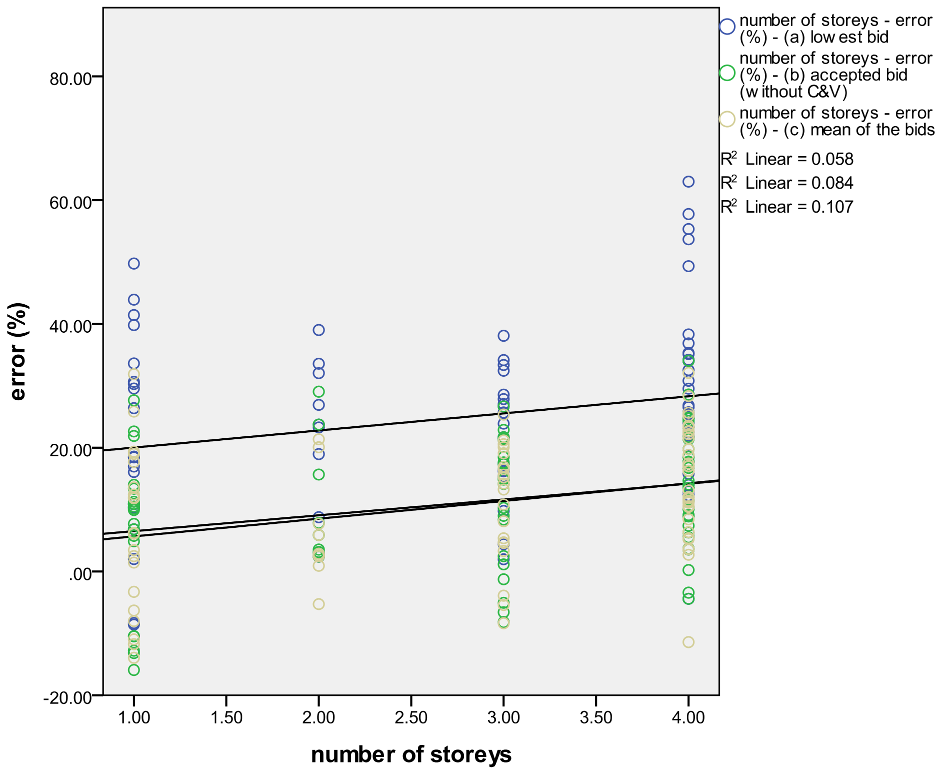


Figure 8.29: Scatter plot shows error (%) against number of storeys

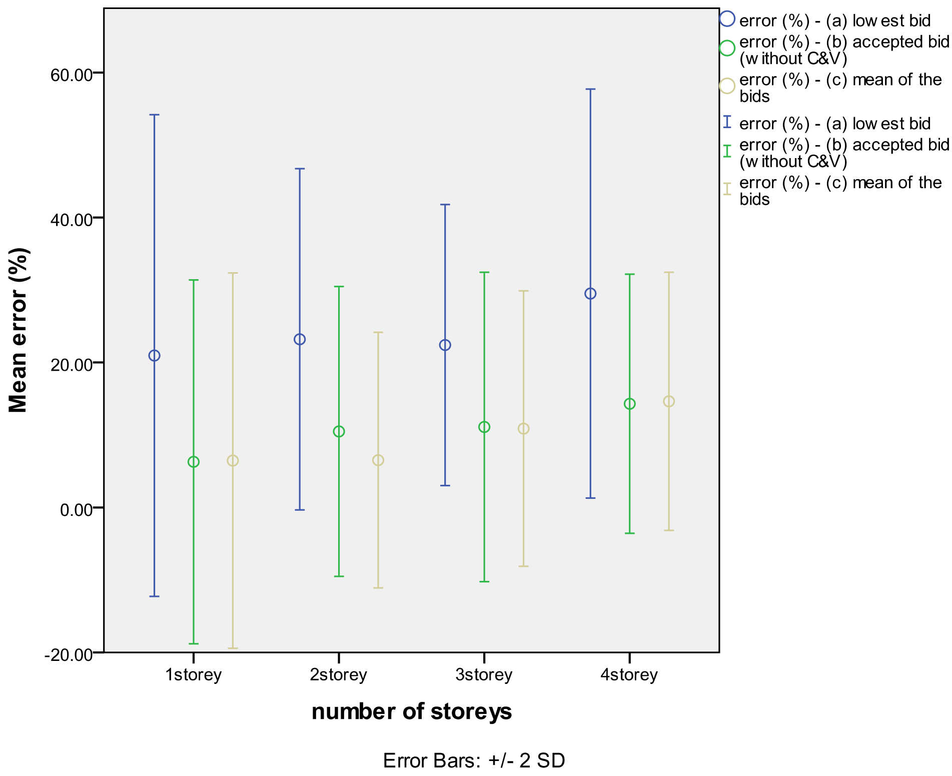


Figure 8.30: Error bar shows mean error (%) against number of storeys

E) Contract period (week)

Figure 8.31 and Figure 8.32 show scatter plot and error bar for contract period which is the period to complete the project. Bias increases when the contract period increases. Estimates are more consistent with the increase of contract period.

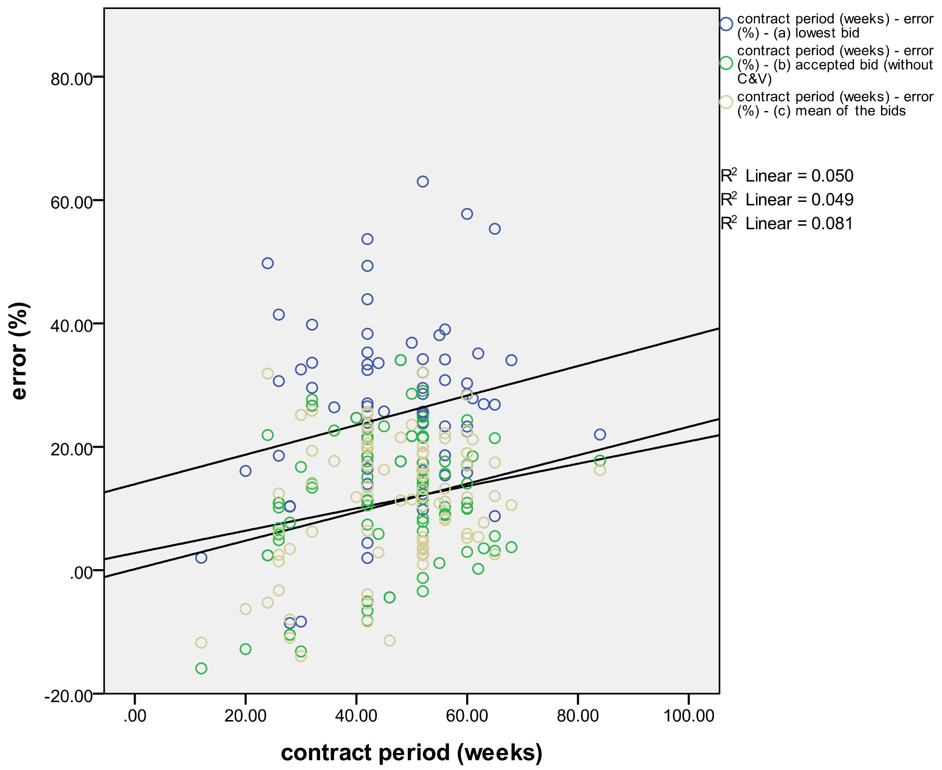


Figure 8.31: Scatter plot shows error (%) against contract period (weeks)

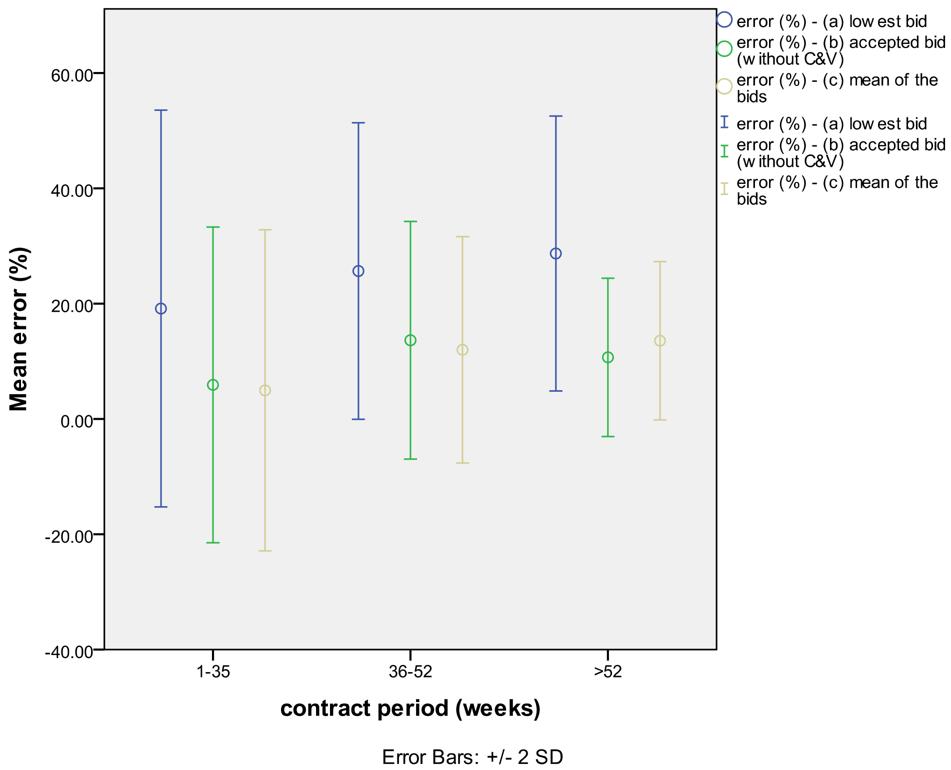


Figure 8.32: Error bar shows mean error (%) and contract period (weeks)

F) Number of bidders

Figure 8.33 and Figure 8.35 show scatter plot and error bar for number of bidders. It is the number of tenders, which take part in the bid auction. Bias trend varies according to test subjects. Bias increases with the increase in the number of tenders in the lowest bid and mean of the bids but no bias trend in accepted bid. There is no consistency trend in lowest bid and accepted bid but consistency improves when an additional bidder enter the bidding in mean of the bids. Figure 8.34 shows when only one bidder enters the bid, the price is almost 5% higher than the estimate but when more bidders enter the bid, the competition reduces the price.

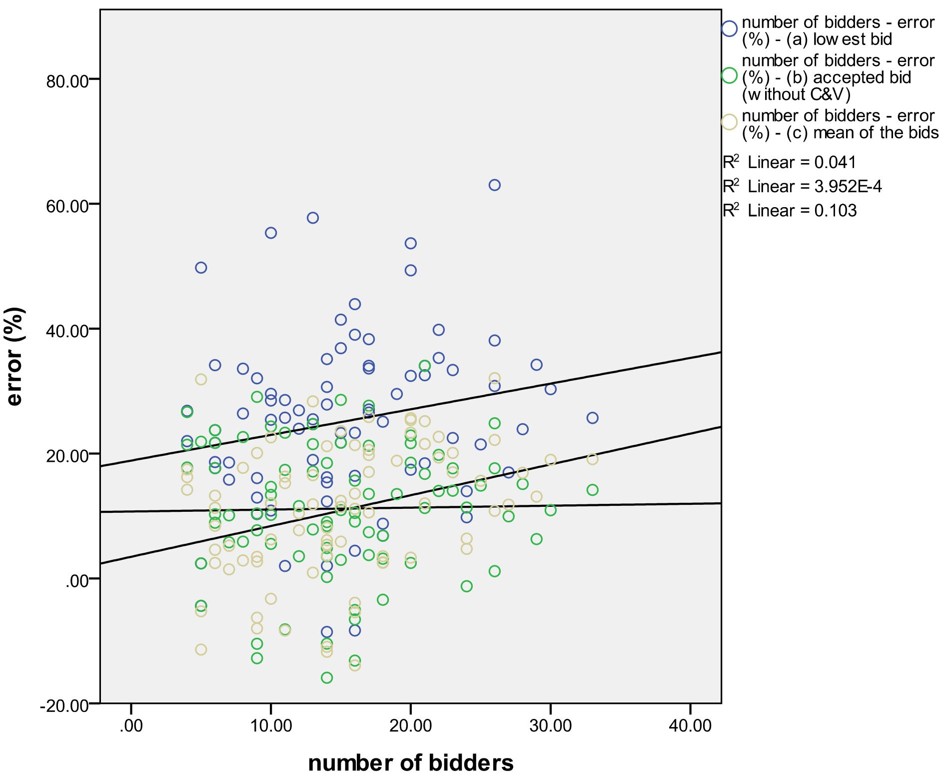


Figure 8.33: Scatter plot shows error (%) against number of bidders

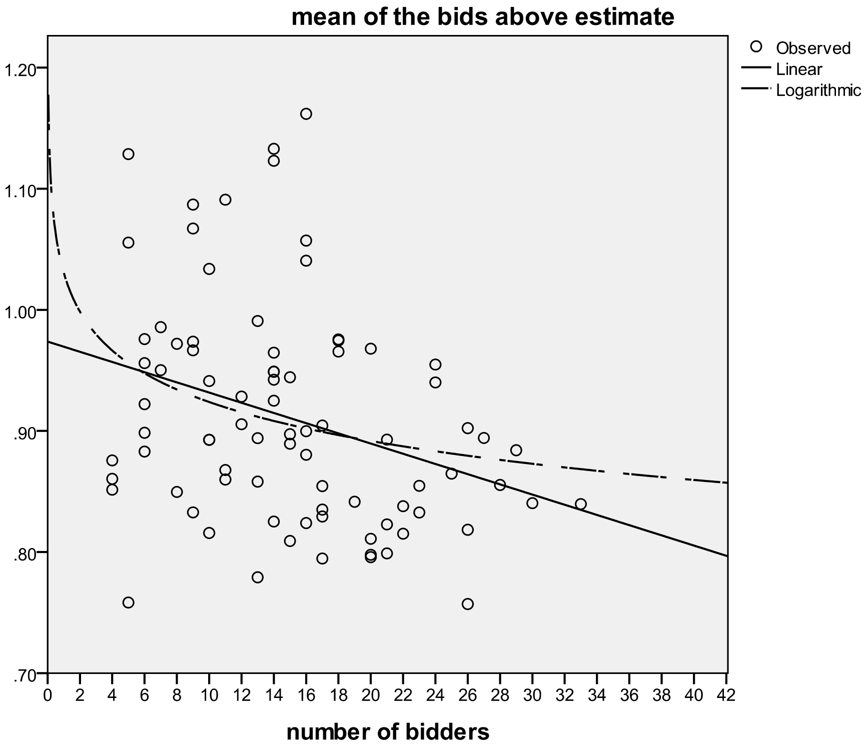


Figure 8.34: Mean of the bids above the estimate

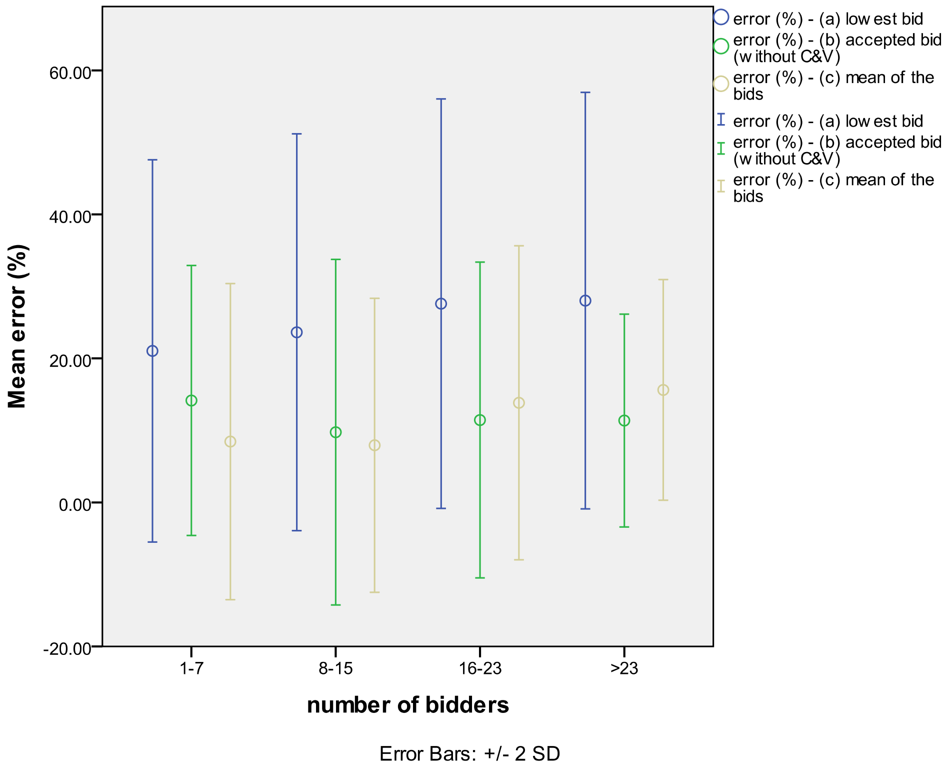


Figure 8.35: Error bar shows mean error (%) against number of bidders

G) State (location of project)

Figure 8.36 and Figure 8.37 show bar chart and error bar of the various states where the projects are located. Bias trend varies from state to state. Melaka has the most accurate estimates. Negeri Sembilan (N9) overestimates the estimates more than the other states in the lowest bid and mean of the bids. Johor overestimates the estimates more than the others in the accepted bid. In lowest bid, N9 has the most consistent estimates. Perak is the most consistent in accepted bid and mean of the bids if compared to other states.

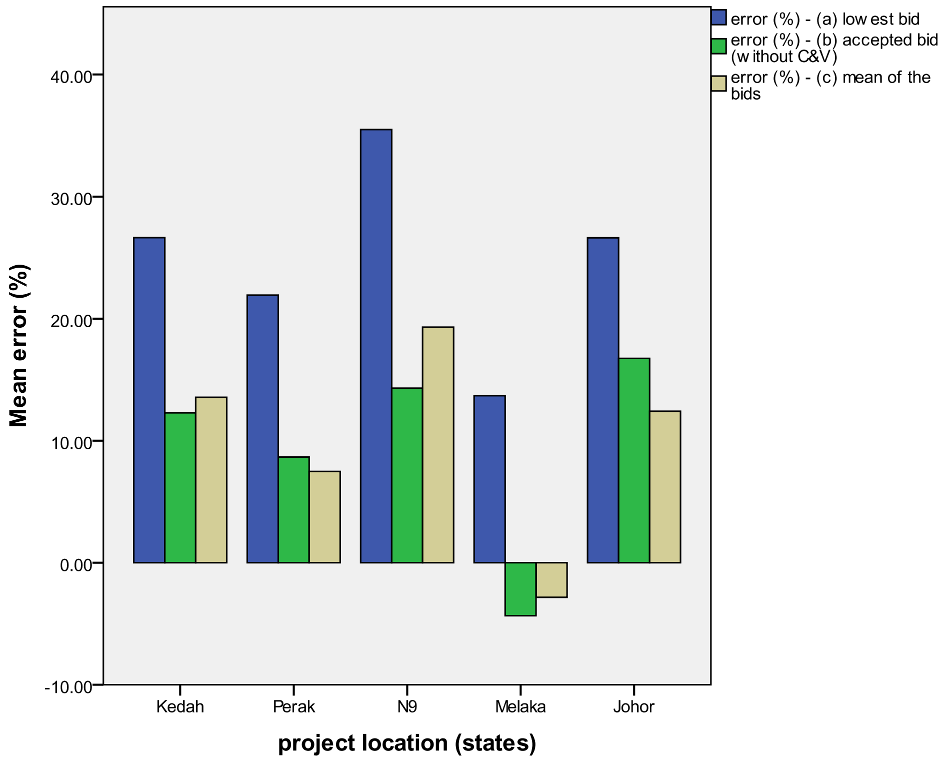


Figure 8.36: Bar chart shows error (%) against location (states)

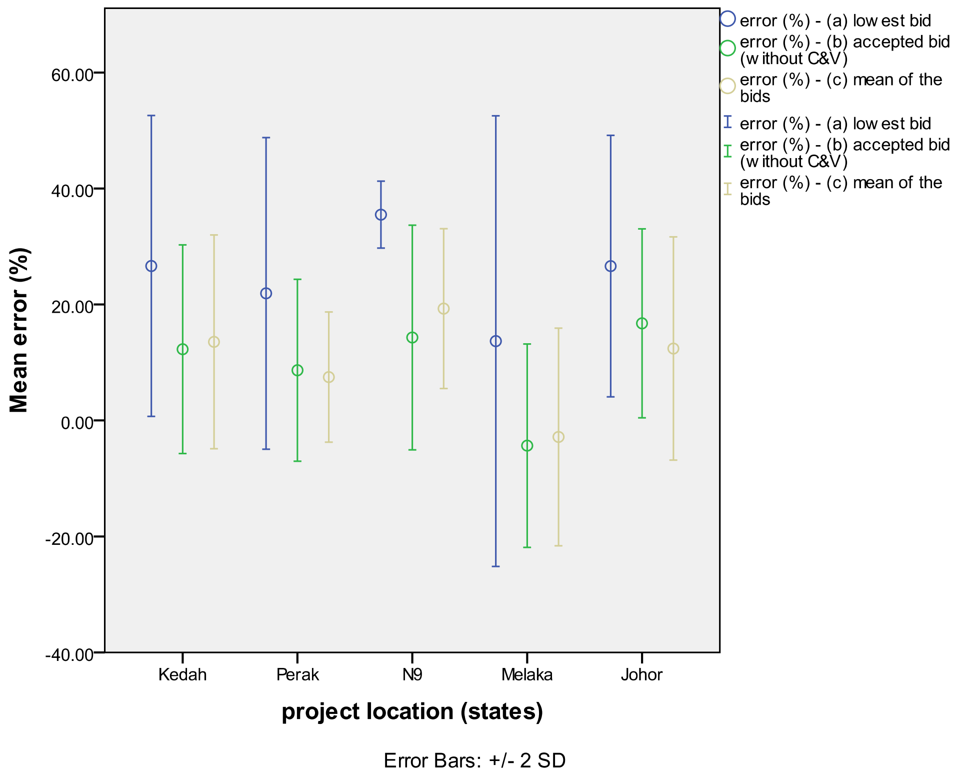


Figure 8.37: Error bar shows mean error (%) against location (states)

H) Types of schools

Figure 8.38 and Figure 8.39 show the bar chart and error bar for two (2) types of schools (primary and secondary). Secondary school is more biased and more consistent than primary school in all targets.

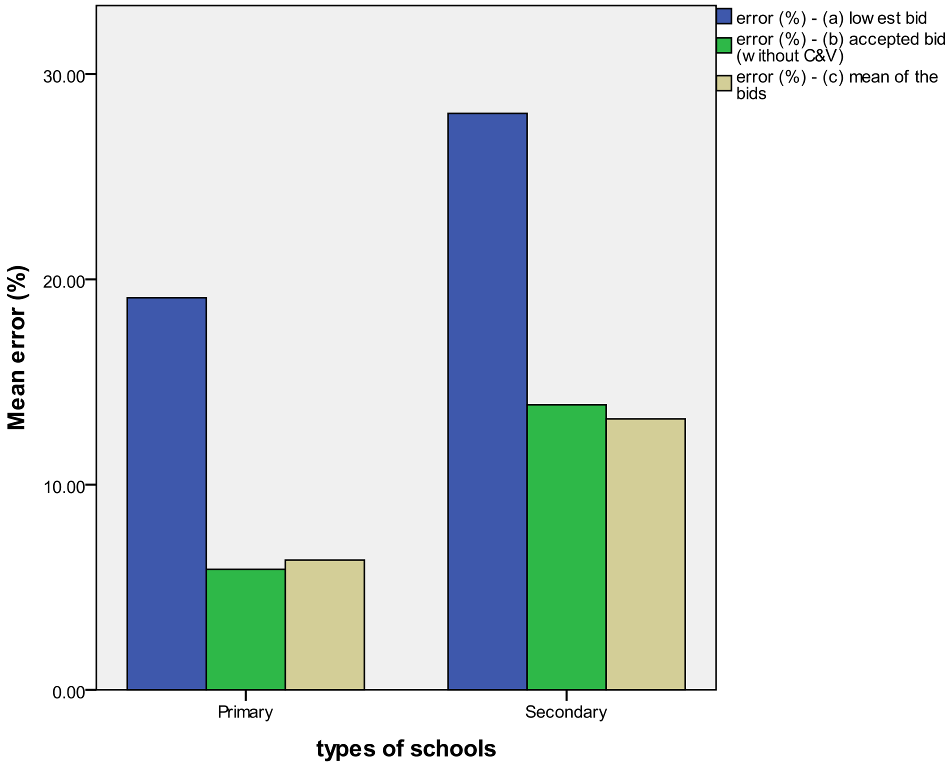


Figure 8.38: Bar chart shows error (%) against types of schools

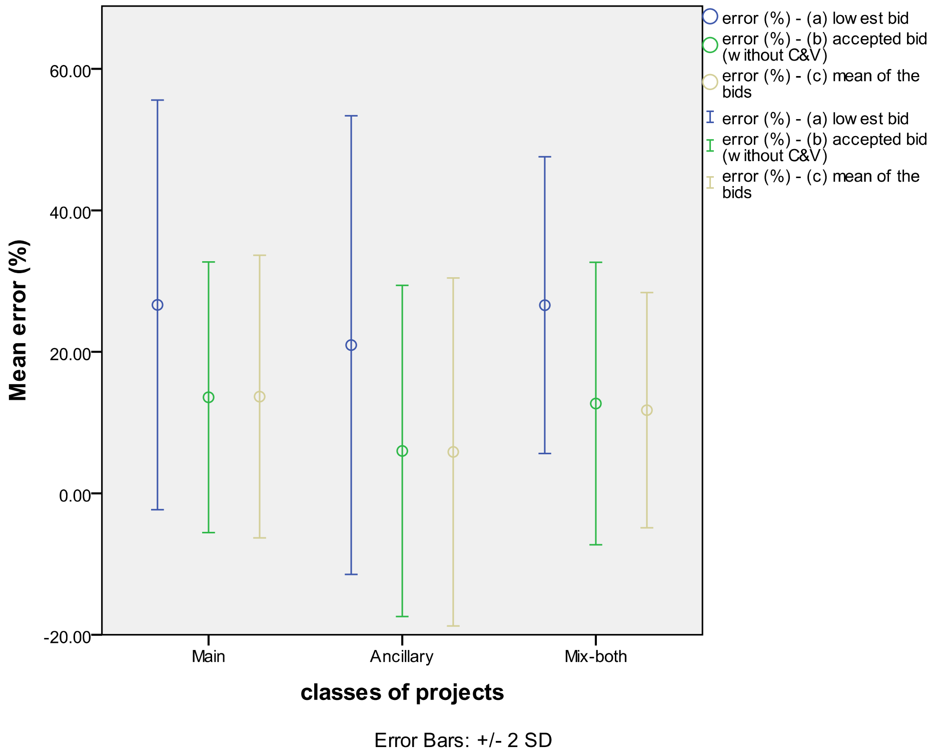


Figure 8.39: Error bar shows mean error (%) against types of schools

I) Classes of projects

Figure 8.40 and Figure 8.41 show bar chart and error bar for classes of projects. There are three (3) classes of projects. There are main buildings, ancillary and a mix of both. Main buildings are for school buildings only. Ancillary buildings are for support facilities such as staff resident, security room, hall and mechanical and electrical building. The mix buildings comprised both the mainbuildings and ancillary buildings. Ancillary buildings are less biased than the other buildings. Mix buildings are more consistent in lowest bid and in mean of the bids. Mainbuildings are the most consistent in accepted bid.

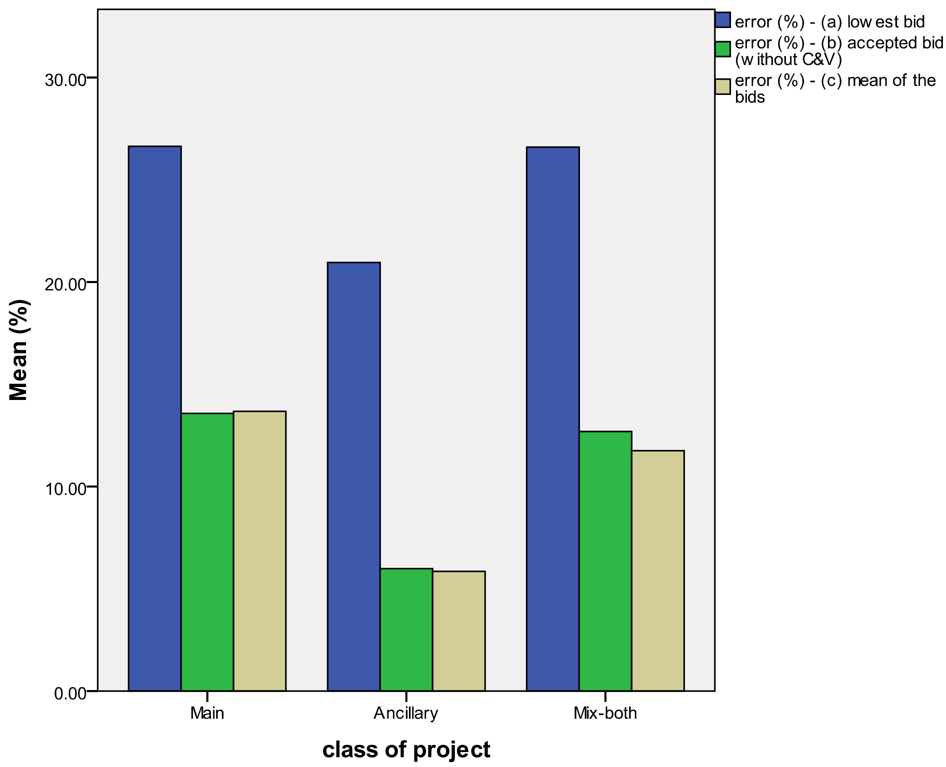


Figure 8.40: Bar chart shows error (%) against classes of projects

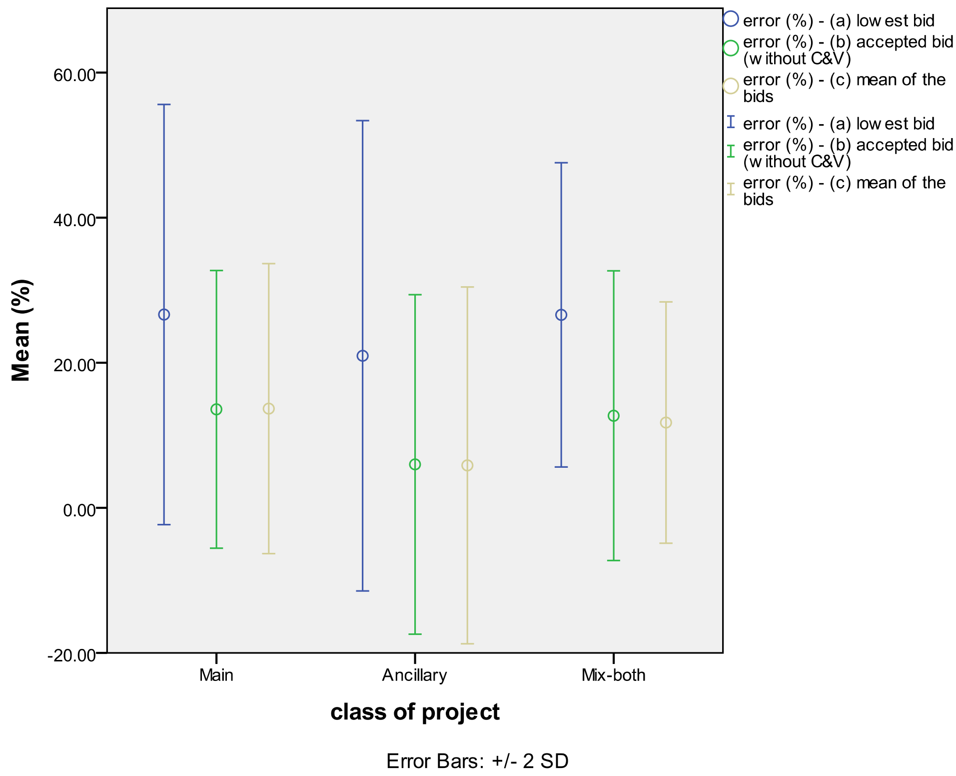


Figure 8.41: Error bar shows mean error (%) against classes of projects

8.2.2.2 ANOVA test

ANOVA test examines whether the mean bias (error) of estimates varies in different project characteristics. The significant relationship is taken at 5% level. Table 8.45 shows only some of the groups which are not equally distributed in lowest bid and accepted bid ($P<0.05$). It was found that all the groups in estimate / mean of the bids are equally distributed. The Levene's test (Table 8.46) shows the error variances of dependent variables are equal across the groups ($P>0.05$).

Table 8.45: Test results from Shapiro-Wilk test on groups of factors

Lowest bid			
Group	**Test statistic**	**df**	**P-value**
>RM 5,000,000	0.804	12	0.010
2501 – 3500m^2	0.865	21	0.008
Secondary school	0.956	55	0.044
Accepted bid			
Group	**Test statistic**	**df**	**P-value**
2 storey height	0.804	12	0.010

** Statistical significance is set at the 5% level*

Table 8.46: Levene's test on equality of error variances

Test subject	F	df1	df2	P
Estimate / lowest bid	0.909	72	10	0.626
Estimate / accepted bid	0.937	74	8	0.605
Estimate / mean of the bids	1.996	72	10	0.116

** Statistical significance is set at the 5% level*

Table 8.47 shows ANOVA test results. There are significant differences between the mean biases in the groups of factors. The mean bias of the groups in PI, state of project and types of schools are statistically different for estimate / lowest bid. For estimate / accepted bid, contract value and state are statistically different. For estimate / mean of the bids, project size, PI, state and types of schools are statistically different. The following are the results from Tukey's test, which examine the significant mean differences between the groups:

Estimate / lowest bid:

- PI of RM 1 – 1000/m^2GFA has a significant mean difference to other PI values.
- Melaka has a significant mean difference to other states except Perak.

Estimate / accepted bid:

- Project value of RM 1 – 1,000,000 has a significant mean difference to other project values.
- State of Melaka has a significant mean difference if compared to other states.

Estimate / mean of the bids:

- Project size of 1 – 1500m^2GFA has a significant mean difference to other project sizes.
- PI value of RM 1 -1000/m^2GFA has a significant mean difference to other PI values. PI value of >RM 2201/m^2GFA has a significant mean difference to other PI values but it has insignificant mean difference if compared to RM 1701-2200/m^2GFA.
- State of Melaka has a significant mean difference to other states. N9 has significant mean difference to the state of Perak.

8.2.2.3 Levene's test

Levene's test of homogeneity of variance examines the equality of variances of each project characteristics. In estimate / accepted bid and estimate / mean of the bids, <u>Contract period</u> has unequal variances (heterogeneous) if compared to other project characteristics (Refer to Table 8.48).

Table 8.47: ANOVA tests on project characteristics

ANOVA (bias)										
df error = 58	**df**	**Estimate / Lowest**			**Estimates/ Accepted**			**Estimate / Mean of the bids**		
Factor	**effect**	**F**	**P**	**$\eta^2 = r^2$**	**F**	**P**	**$\eta^2 = r^2$**	**F**	**P**	**$\eta^2 = r^2$**
Value (RM)	1	0.480	0.698	0.024	2.985	0.038*	0.134	2.176	0.101	0.101
Size (m^2GFA)	3	1.099	0.357	0.054	2.418	0.075	0.111	3.713	0.016*	0.161
Price intensity (cost/m^2GFA)	3	8.122	0.000*	0.296	0.306	0.821	0.016	4.271	0.009*	0.181
No. of storeys	3	0.495	0.687	0.025	1.576	0.205	0.075	1.011	0.394	0.050
Contract Period	2	0.183	0.833	0.006	2.790	0.070	0.088	0.081	0.922	0.003
No. of bidders	3	0.153	0.928	0.008	1.243	0.303	0.060	0.279	0.840	0.014
State	4	3.674	0.010*	0.202	7.223	0.000*	0.332	9.344	0.000*	0.392
Types of schools	1	5.917	0.018*	0.093	3.087	0.084	0.051	5.414	0.023*	0.085
Classes of projects	2	0.317	0.730	0.011	0.008	0.992	0.000	0.797	0.456	0.027

** Statistical significance is set at the 5% level*

Table 8.48: Levene's tests on project characteristics

Factor			Levene's test					
			Estimate / Lowest bid		Estimate / Accepted bid		Estimates/ Mean of the bids	
	df1	**df2**	**Statistic**	**P**	**Statistic**	**P**	**Statistic**	**P**
Value (RM)	3	79	2.392	0.075	1.379	0.255	2.651	0.054
Size (m^2GFA)	3	79	1.377	0.256	0.737	0.533	1.673	0.180
Price intensity (cost/m^2GFA)	3	79	2.123	0.104	1.910	0.135	2.396	0.074
No. of storeys	3	79	1.584	0.200	0.410	0.746	1.686	0.177
Contract Period	2	80	2.850	0.064	3.476	0.036*	4.193	0.019*
No. of bidders	3	79	0.128	0.943	0.935	0.428	0.479	0.698
State	4	78	2.030	0.098	0.116	0.977	1.003	0.411
Types of schools	1	81	2.335	0.130	0.655	0.421	1.249	0.267
Classes of projects	2	80	2.832	0.065	0.377	0.687	1.672	0.194

** Statistical significance is set at the 5% level. The test statistic is based on median value*

8.2.2.4 Multiple regression analysis on bias (MRA)

MRA demonstrates the linear relationship between project characteristics (x) and error of estimates (y). The models from lowest bid, accepted bid and mean of the bids are tested. The following are the nine (9) project characteristics regressed to signify the relationship between predictors and outcomes:

$$Y = \beta_0 + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4) + \beta_5(x_5) + \beta_6(x_6) + \beta_7(x_7) + \beta_8(x_8) + \beta_9(x_9) + \varepsilon$$

Y for estimating error (dependent)

β_0 for beta (intercept)

β_1 for beta (independent)

x_1 to x_9 for each of project characteristics' value

ε is random error of Y

Variables for state, types of schools and classes of projects are converted to different levels because these are the categorical variables (nominal scale). The adjusted formula is as follows:

$$Y = \beta_0 + \beta_1\,(\text{Contract Value}) + \beta_2(m^2 GFA) + \beta_3(cost/m^2 GFA) + \beta_4(\text{Storey}) + \beta_5\,(\text{Contract Period}) + \beta_6\,(\text{No. of Bidders}) + \beta_7(\text{Kedah}) + \beta_8(\text{Perak}) + \beta_9(\text{N9}) + \beta_{10}\,(\text{Melaka}) + \beta_{11}\,(\text{Johor}) + \beta_{12}(\text{Primary school}) + \beta_{13}(\text{Secondary school}) + \beta_{14}(\text{Main building}) + \beta_{15}(\text{Ancillary building}) + \beta_{16}(\text{Mix building}) + \varepsilon$$

Table 8.49, Table 8.50 and Table 8.51 show the results from MRA. "Enter" technique is used. It enters all variables at the same time. The models are created from lowest bid, accepted bid and mean of the bids which are useful ($P<0.05$). The predictors of the models that were taken into account are 22%, 40% and 42% (R^2 Adjusted) of variance in Y. The model from estimate / mean of the bids has the lowest standard error of the estimate than others. A model with a smaller standard error of the estimate is better. The MRA equations are as follows:

$$Y_1 = 5.307 - 4.740 \times 10^{-6} \text{ (Contract Value)} + 0.06 \text{ (m}^2\text{GFA)} - 0.003 \text{ (cost/m}^2\text{GFA)} + 0.055 \text{ (Contract Period)} + 0.253 \text{ (No. of Bidders)} + 3.119 \text{ (Storey)} - 0.898 \text{ (Perak)} + 15.423 \text{ (N9)} - 3.455 \text{ (Melaka)} + 4.077 \text{ (Johor)} + 10.474 \text{ (Secondary school)} + 11.050 \text{ (Ancillary building)} - 3.386 \text{ (Mix building)}$$

$$Y_2 = 11.461 - 3.817 \times 10^{-6} \text{ (Contract Value)} + 0.05 \text{ (m}^2\text{GFA)} + 0.000 \text{ (cost/m}^2\text{GFA)} - 0.059 \text{ (Contract Period)} - 0.019 \text{ (No. of Bidders)} + 0.256 \text{ (Storey)} - 2.074 \text{ (Perak)} + 6.071 \text{ (N9)} - 13.080 \text{ (Melaka)} + 6.163 \text{ (Johor)} + 7.024 \text{ (Secondary school)} - 2.513 \text{ (Ancillary building)} - 3.286 \text{ (Mix building)}$$

$$Y_3 = -14.070 - 2.971 \times 10^{-6} \text{ (Contract Value)} + 0.05 \text{ (m}^2\text{GFA)} + 0.001 \text{ (cost/m}^2\text{GFA)} + 0.069 \text{ (Contract Period)} + 0.417 \text{ (No. of Bidders)} + 2.671 \text{ (Storey)} - 1.777 \text{ (Perak)} + 11.124 \text{ (N9)} - 11.620 \text{ (Melaka)} + 2.877 \text{ (Johor)} + 6.684 \text{ (Secondary school)} + 4.455 \text{ (Ancillary building)} - 3.960 \text{ (Mix building)}$$

Y_1 for model using estimate / lowest bid

Y_2 for model using estimate / accepted bid

Y_3 for model using estimate / mean of the bids

Table 8.49: MRA test results for estimate / lowest bid model -

Predictor	Standard error	t-value	P-value	Adjusted R^2	F	Standard error of the estimate	P-value
constant	14.298	0.371	0.712	0.224	2.821	12.261	0.003
contract value (RM)	0.000	-1.563	0.123				
size m^2	0.004	1.732	0.088				
cost / m^2GFA	0.002	-1.264	0.210				
contract period	0.156	0.353	0.725				
number of bidders	0.258	0.982	0.330				
number of storeys	2.576	1.211	0.230				
Perak	5.831	-0.154	0.878				
N9	6.699	2.302	0.024*				
Melaka	6.113	-0.565	0.574				
Johor	4.613	0.884	0.380				
Secondary	3.314	3.161	0.002*				
Ancillary	7.572	1.459	0.149				
Mix	4.230	-0.800	0.426				

** Statistical significance is set at the 5% level.*

Table 8.50: MRA test results for estimate / accepted bid model

Predictor	Standard error	t-value	P-value	Adjusted R^2	F	Standard error of the estimate	P-value
constant	9.680	1.184	0.240	0.396	5.130	8.325	0.000
contract value (RM)	0.000	-1.854	0.068				
size m^2	0.002	2.069	0.042*				
cost / m^2GFA	0.001	-0.168	0.867				
contract period	0.106	-0.558	0.578				
number of bidders	0.175	-0.111	0.912				
number of storeys	1.744	0.147	0.884				
Perak	3.959	-0.524	0.602				
N9	4.551	1.334	0.187				
Melaka	4.227	-3.094	0.003*				
Johor	3.117	1.977	0.052				
Secondary	2.257	3.112	0.003*				
Ancillary	5.152	-0.488	0.627				
Mix	2.871	-1.145	0.256				

** Statistical significance is set at the 5% level.*

Table 8.51: MRA tests results for estimate / mean of the bids model

Predictor	Standard error	t-value	P-value	Adjusted R^2	F	Standard error of the estimate	P-value
constant	9.559	-1.472	0.146	0.423	5.617	8.040	0.000
contract value (RM)	0.000	-1.495	0.139				
size m^2	0.002	2.081	0.041*				
cost / m^2GFA	0.001	0.831	0.409				
contract period	0.103	0.671	0.504				
number of bidders	0.170	2.457	0.017*				
number of storeys	1.691	1.580	0.119				
Perak	3.825	-0.465	0.644				
N9	4.393	2.532	0.014*				
Melaka	4.059	-2.863	0.006*				
Johor	3.024	0.952	0.345				
Secondary	2.182	3.064	0.003*				
Ancillary	4.969	0.897	0.373				
Mix	2.772	-1.429	0.158				

** Statistical significance is set at the 5% level.*

8.2.3 Part Three (3) – Multiple regression method (MRM) to estimate the cost of building works

This part explains the use of MRM as an alternative method for estimating the cost of building works[38]. The model is developed from the previous project database.

8.2.3.1 Development of model

The linear relationship between the building cost (observed values) and independent variables are assumed as follows:

[38] architectural and structural works

$Y_{\text{building cost}} = \beta_0 + \beta_1$ (area of building) + β_2 (contract period) + β_3 (no. of bidders) + β_4 (no. of storeys) + β_5 (Kedah) + β_6 (Perak) + β_7 (N9) + β_8 (Melaka) + β_9 (Johor) + β_{10} (Primary) + β_{11} (Secondary) + β_{12} (Main) + β_{13} (Ancillary) + β_{14} (Mix)

β_0 and β_1 *to* β_{12} are for unknown parameters computed by statistical software. "Stepwise" technique was used to select significant variables in MRM cost model. It can be expressed as:

$$\textit{Building Cost}_1 = 147185.203 + 603.701 \times (\textit{size } m^2 \textit{GFA})$$

$$\textit{Building Cost}_2 = 97981.514 + 586.156 \times (\textit{size } m^2 \textit{GFA}) + 291443.135 \, x \, (\textit{Johor})$$

8.2.3.2 Analysis of developed model

Table 8.52 describes the analysis of regression model. The goodness of fit for the above equation is explained by adjusted R^2 value. Model no.1 has 87.70% adjusted R^2 value and Model no.2 has 89.90% adjusted R^2 value. The p-value for both models is extremely significant with $p < 0.0001$. The R^2 quantify the proportion of the variation in the dependent variable (Y - variables) accounted for by the predictors (x - variables). One more predictor is added to model no.2 because the state of Johor is included. According to PWD cost data, Johor state's locality cost index is among the highest (Refer to Table 8.53). The use of stepwise technique has deleted other variables with low impact to the final model. Simpler model are created because of the removal of insignificant variables. It makes sense because the use of same standard design reduced the number of predictors to be selected.

Table 8.52: Analysis of the regression model (Y = building cost)

Model	Predictor	Beta coefficient	Standard error	t value	P value	R^2 Adjusted
1	Constant Area (m^2)	147,185.203 603.701	59958.323 24.919	2.455 24.226	0.016 0.000	0.877 F = 586.907 P = 0.000
2	Constant Area (m^2) Johor	97,981.514 586.156 291,443.135	55581.168 22.970 67863.296	1.763 25.518 4.295	0.082 0.000 0.000	0.899 F = 365.870 P = 0.000

Table 8.53: States grouping for locality index adjustments (abstracted from: Public Works Department, 2009b)

Group	A	B	C	D	E	F
States	Perlis, Kedah and Pulau Pinang	Perak	Selangor, Wilayah Persekutuan KL, Negeri Sembilan and Melaka	Johor	Pahang	Terengganu and Kelantan
	1.0816	1.0466	1.0000	1.0567	1.0438	1.0417

However, the adjusted R^2 at 59.8% is found lesser if compared to the dependent variable being in cost (RM). Refer to Table 8.54. This is made when the observed variable is replaced by cost/m2 and the removal of area (m^2) and building cost (RM) from the model. This is similar with the finding by Lowe, et al. (2006). This is because some other variables which affect the cost/m^2 are unavailable to improve the value of adjusted R^2. The linear relationship between the cost/m^2 (observed values) and independent variables are assumed as follows:

$Y_{cost/m2} = \beta_0 + \beta_1$ (contract period) $+ \beta_2$ (no. of bidders) $+ \beta_3$ (no. of storeys) $+ \beta_4$ (Kedah) $+ \beta_5$ (Perak) $+ \beta_6$ (N9) $+ \beta_7$ (Melaka) $+ \beta_8$ (Johor) $+ \beta_9$ (Primary) $+ \beta_{10}$ (Secondary) $+ \beta_{11}$ (Main) $+ \beta_{12}$ (Ancillary) $+ \beta_{13}$ (Mix)

Table 8.54: Analysis of the regression model (Y = cost/m2)

Model	Predictor	Beta coefficient	Standard error	t value	P value	R^2 Adjusted
Cost/m^2	Constant	1196.28	264.212	7.157	0.000	0.598
	Ancillary	378.980	84.164	4.503	0.000	F = 31.522
	Melaka	363.301	92.152	3.942	0.000	P = 0.000
	Number of bidders	-12.306	4.335	-2.839	0.006	
	Contract period (weeks)	-6.854	2.879	-2.381	0.020	

8.2.3.3 Testing Assumptions

All assumptions need to be tested. If not the results are not reliable in generalizing the model of population. If the assumptions are met this model could form a stronger basis for this study.

A) Multicolinearity

No perfect multicolinearity was found in this model. Average Variance Inflation Factor (VIF) values are from 1 to 1.033, which is close to 1. In colinearity diagnostics, each predictor variance proportion is distributed across different dimensions of eigenvalue. The condition index is less than 4. Thus, the model has no serious problem on multicollinearity. These results show no predictors in the model are highly correlated.

B) Homoscedasticity

The graph (ZRESID against ZPRED) shows points are randomly and evenly dispersed (homoscedasticity) (Refer to Figure 8.42). In addition, histogram and normal probability plot are normally distributed and standardized residual points more or less lie on the line (Refer to Figure 8.43 and Figure 8.44).

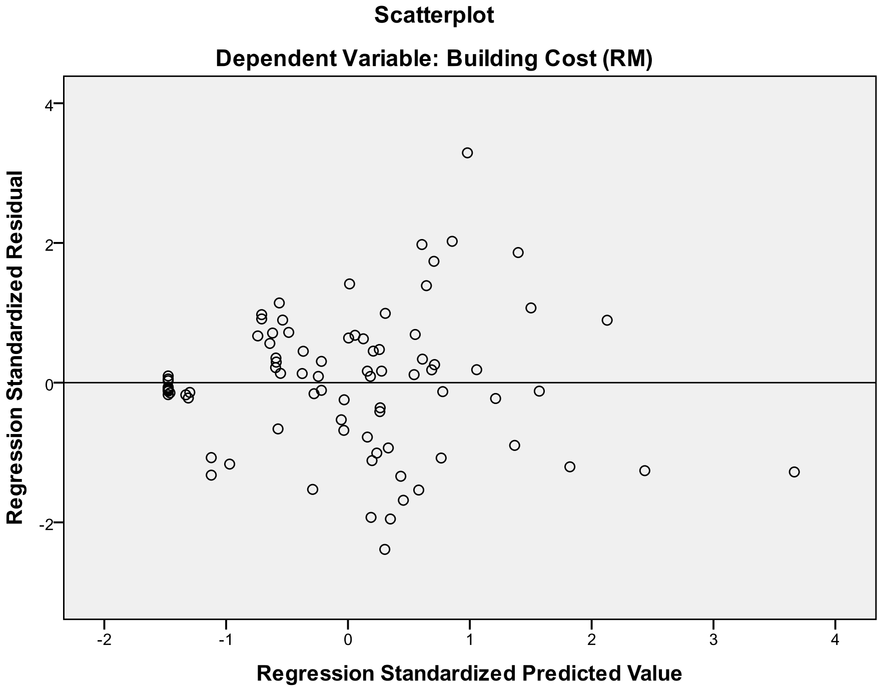


Figure 8.42: Standardized residuals against standardized predicted value

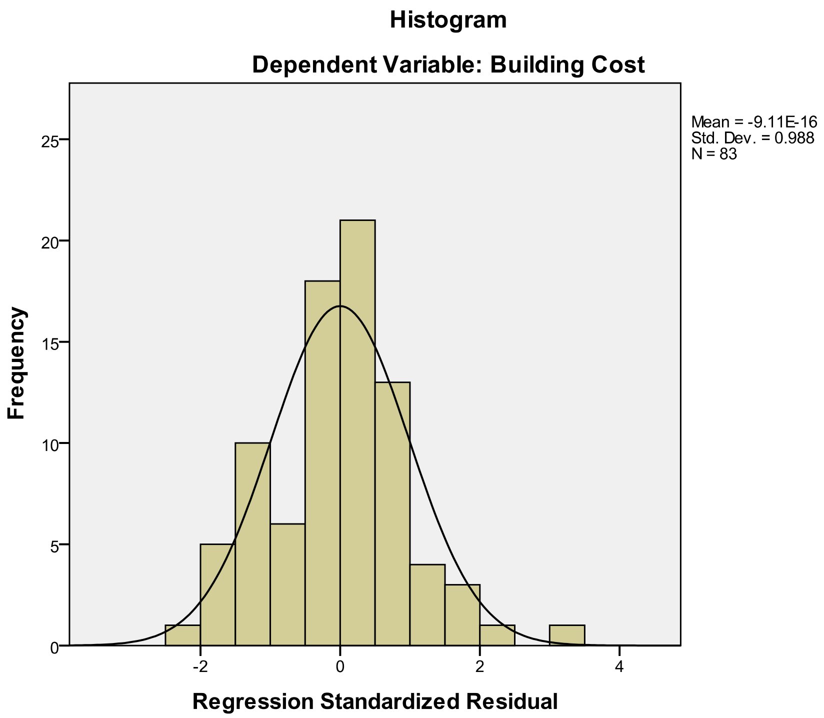


Figure 8.43: Histogram of regression standardized residual

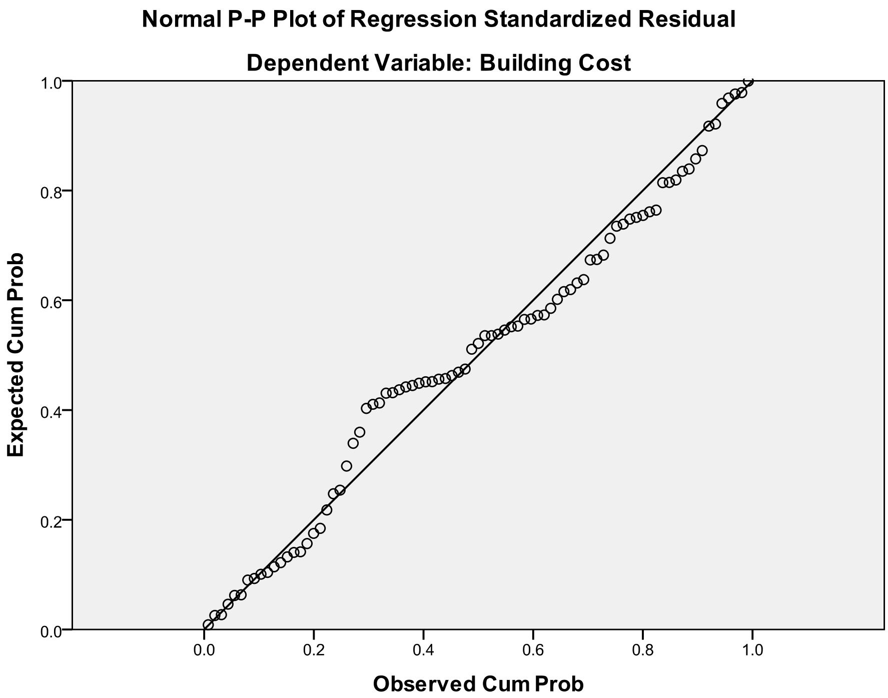


Figure 8.44: P-P plot of distributed residuals

C) Independent errors (autocorrelation) and normally distributed errors

Durbin Watson test detects autocorrelation between consecutive residuals. The Durbin Watson value is 1.787 which is closer to 2.00. The errors are independent, and the adjacent residuals are uncorrelated. The model standardized residual is normally distributed. The differences of values between the predicted model and the observed data are most frequently zero (mean standard residual value is zero) (Refer to Figure 8.43).

D) Linearity

The partial plot shows a strong positive linear relationship between size and building cost (Refer to Figure 8.45). It also shows a weak positive linear relationship for the state of Johor (Refer to Figure 8.46).

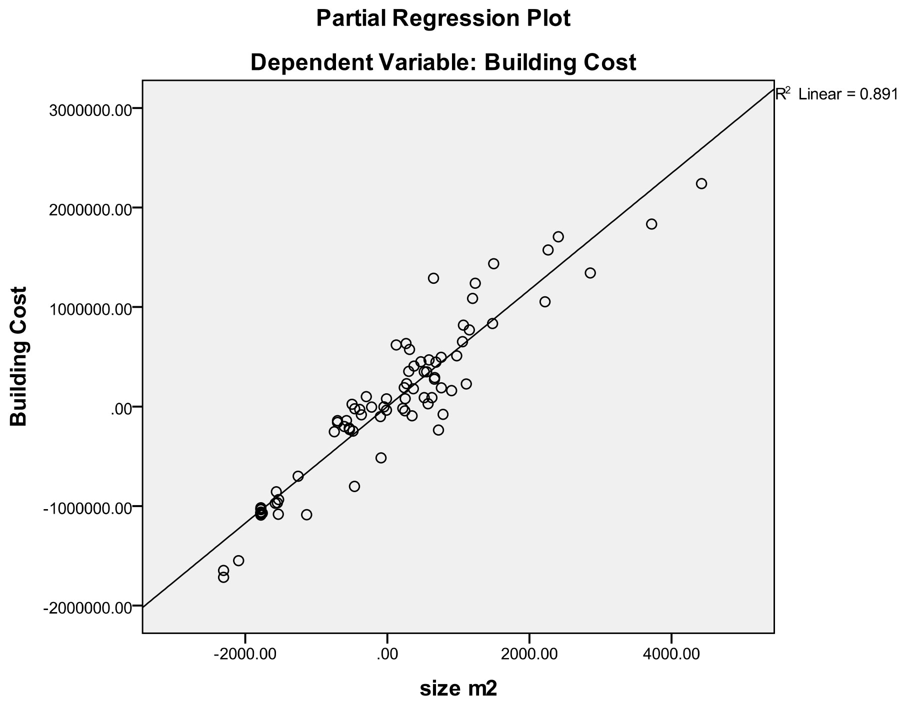


Figure 8.45: Partial regression plot of building cost (RM) against size (m^2GFA)

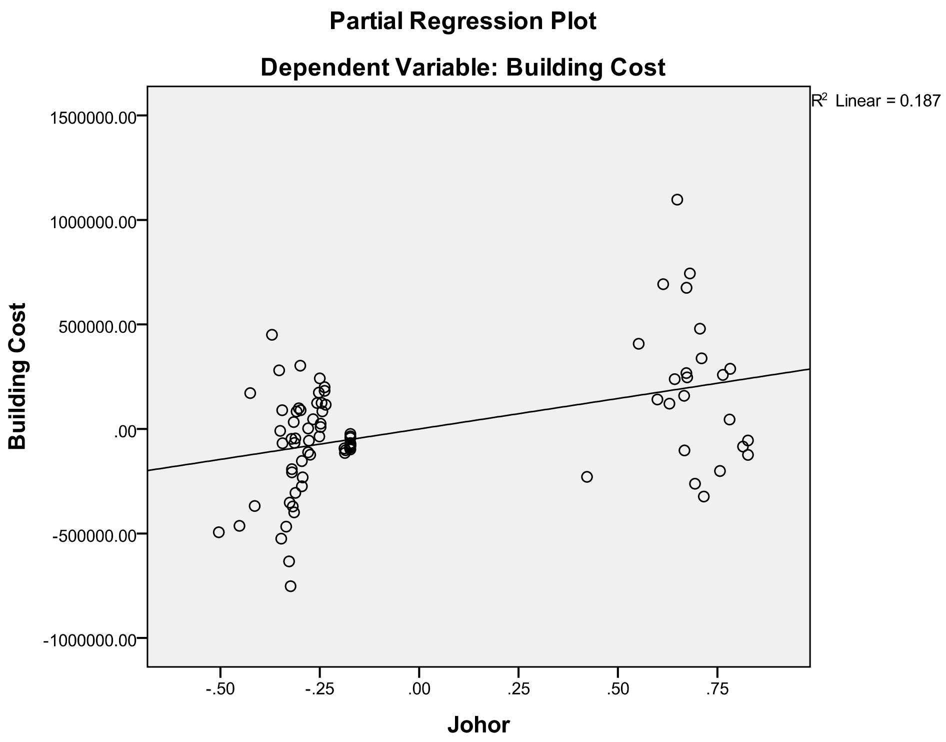


Figure 8.46: Partial regression plot of building cost (RM) against Johor (state)

E) Minimum Number of extreme cases which affect the model

Casewise diagnostic examines any extreme cases which affect the model (outliers). Only three (3) cases or 4% of are outside the range of +/- 2.00 standard deviation. The maximum Cook's distance value is 0.176, which is less than 1.00 and Mahal's distance maximum value is 13.551, which is less than 15. So, the assumptions are met. This shows the model is not significantly influenced by subsets.

8.2.3.4 Cross – validation of the model

A) Preliminary Validation

Cross-validation ensures the reliability of the sample to accurately represent the population. Stein's formula is used in preliminary validation to cross-validate the adjusted R^2 calculated by the statistical software. Cross-validation using real data gives the real comparison of the model performance in actual situation. Thus, the assumption of the model reliability could be proved valid. The adjusted R^2 values of model 1 and 2 lost its value by a small amount (0.879 - 0.877 = 0.002) = 0.2% and (0.901 – 0.899 = 0.002) = 0.2% respectively. It means some of the explanatory variables were unavailable if the model is drawn from population rather than from sample. It has lost some of its predictive power. Even though there is a drop in adjusted R^2 values, the drop is small and insignificant. Both values are very close to the observed value of R^2 (0.879 and 0.901). It shows the cross validity of this model is very good. The following is the formula and cross-validation of the two (2) models for the likely value of adjusted R^2 in different samples, Stein's formula was used:

$$adjusted\ R^2 = 1 - \left\{\left[\frac{n-1}{n-k-1}\right]\left[\frac{n-2}{n-k-2}\right]\left[\frac{n+1}{n}\right]\right\}(1-R^2)$$

n is number of sample
k is number of predictors in the model
R^2 is unadjusted value

$$adjusted\ R^2\ (model\ 1) = 1 - \left\{\left[\frac{83-1}{83-1-1}\right]\left[\frac{83-2}{83-1-2}\right]\left[\frac{83+1}{83}\right]\right\}(1-0.879)$$

$$= \underline{0.875}$$

$$adjusted\ R^2\ (model\ 2) = 1 - \left\{\left[\frac{83-1}{83-2-1}\right]\left[\frac{83-2}{83-2-2}\right]\left[\frac{83+1}{83}\right]\right\}(1-0.901)$$

$$= \underline{0.895}$$

B) Validation Using Real Data

Model no.2 is selected to predict the cost of building works because it has a better adjusted R^2 than model no.1, even there was a drop of F- ratio value when one (1) extra predictor entered the model. The selected model is capable to predict more explained variance. Eight (8) cases (project data) were used for holdout[39] set to determine the reliability of this model which was used in real situation. The selected final regression model is expressed as follows:

$$Building\ Cost_2 = 97981.514 + 586.156 \times (size\ m^2GFA) + 291443.135 \times (Johor)$$

The mean error for estimates using the regression model is – 4.00% and consistency of estimates is 6.31. The mean error which uses the traditional estimating model for building work is 24.26% and the consistency of estimates is 49.26%. Table 8.55 shows the cases for cross-validation and their accuracy:

[39] Leave-one-out data set with replacement.

Table 8.55: Cross-validation of the model using holdout samples and its accuracy

Project No.	**Area m^2GFA**	**State of Johor**	**Estimated Cost (RM) using MRM***	**Actual Bid price (RM)**	**Error (%)**
1	3,467.25	No	2,130,330.91	2,027,300.00	5.08
2	5,832.00	No	3,516,443.31	3,824,145.60	-8.05
3	1,744.78	No	1,120,694.78	1,192,257.65	-6.00
4	2,857.50	Yes	2,064,365.42	2,346,900.00	-12.04
5	2,685.00	Yes	1,963,253.51	2,082,000.00	-5.70
6	1,350.00	No	889,292.11	945,810.00	-5.98
7	1,440.00	Yes	1,233,489.29	1,290,000.00	-4.38
8	3,960.00	Yes	2,710,602.41	2,580,000.00	5.06
				Mean error (%) =	**-4.00**
				Standard deviation =	**6.05**
				Coefficient of variation =	**6.31**

* using the proposed regression model

8.3 Chapter summary

Most respondents are experience in estimating. They believe overestimated the estimates are the most acceptable value for most clients than underestimated estimates. A margin of +/- 10% is the acceptable measure of accuracy but the respondents' assumptions are different if compared to analyzed sample. They believe the accuracy could be measured using the mean of returned tenders (mean of the bids). PWD has a department to collect and distribute the cost data unlike the private sector, which rely on individual QS executive to work out their own cost data. Almost half of respondents say they did intentionally mark-up the estimates because they are concerned with underestimate estimates. However, more respondents from private QS consultants are against this practice. The respondents are satisfied with the accuracy of estimates they prepared. Most QS perceive local graduates as not having the necessary estimating knowledge. They agree alternative estimating methods should be introduced in PWD procurement policy in the future. Respondents agreed that design scope, cost data, location, QS experience, design team experience, project technology and market conditions are the seven most important factors which affect the accuracy of estimates. They considered QS stress level is not that important. They have significant differences in opinion regarding the location of project (scope quality), project technology (uncertainty level) and basis of selection (scope quality). There are five groups of factors, out of this, only uncertainty level group of factor has a moderate level of agreement. Other groups have a weak level of agreement.

There are 14 methods of improving the current estimating process. All are important to improve the accuracy of estimates such as sufficient design information from designers has the highest score. It is followed by a proper design documentation and information management, update of cost data with new cost and creating a feedback system on the data collected, effective communication between designers, ascertaining assumptions, giving more time for QS to prepare estimates, QS need to take into account the market conditions and market sentiments when preparing estimates. However, the respondents have different opinions on cost planning and cost control during design stage. QS in PWD ranked it not that important. There are six new approaches examined in order to improve the accuracy of estimates. All approaches are considered important in improving the accuracy of estimates. Investing in estimating training is the most important which is followed by sharing cost data among private consultants and PWD and the introduction of standardized rules of measurement.

Data from 83 projects are collected from PDA and ATDA. There are some outliers (estimating error) in the analysis. The author has decided not to exclude these outliers in the analysis in order to show overestimated and underestimated estimates. The estimates prepared by PWD are generally overestimated. Bias in the estimates, which use the lowest bid as the target has the highest value and it is the most inconsistent estimates. Estimating accuracy using the mean of the bids and accepted bid are less biased and more consistent. This happens because of the different tender bids used as the targets. Estimates are more accurate when accepted bid and mean of the bids are used as targets. All estimates are overestimated at 95% confidence interval. The occurrences of underestimates are highly improbable. Accuracy of estimate within +/- 20% is significantly different if compared to the accuracy outside this limit. Only 34% of estimates are accurate if lowest bid is used as the target. A large number of estimates (77%) are accurate if mean of the bids and accepted bid are used as targets. If +/-20% is the acceptable error of estimate, the cost estimates prepared by PWD are acceptably accurate. Accuracy of estimates of construction elements is inconsistent because of the high value of coefficient of variation (cv). The cost of building per se is about half the total cost of project but it is the least bias. The most bias estimates are piling and foundation. In addition, it is also the most inconsistent. A number of projects were overestimated in terms of the need of piling works. External works is less bias than piling and foundation. In ATDA, the percentage of VOP increased but percentage of contingencies decresed. Most contingencies are priced less than 5% during estimate and more than 2% at tender stage. Building price index is unpredictable because of the fluctuation in price.

Table 8.56, Table 8.57 and Table 8.58 show the summary of test results. ANOVA test examines the mean bias of each project characteristic for significant differences. PI, state and types of schools are significant for estimate / lowest bid. Project value and state are significant for estimate / accepted bid. Project size, PI, state and types of schools are significant for estimate / mean of the bids. Levene's test shows consistency varies (heterogeneous) for contract period in accepted bid and mean of the bids. MRA shows state (location) and types of schools are significant predictors for estimate / lowest bid. Project size, state, and types of schools are significant for estimate / accepted bid. Project size, number of bidders, state and types of schools are significant for estimate / mean of the bids. MRA found all models from lowest bid, accepted bid and mean of the bids are significant. Nevertheless, the model created from the mean of the bids is the best model to explain the systematic bias in estimates because its predictors contribute 42% (adjusted R^2) of variation.

The model created from MRM (based on cost as dependent variable) is more accurate than the current traditional model of single area for building works estimating but the model created contains only few significant variables. The model which is based on cost/m2 appears to have less adjusted R^2 but with more significant variables. It means the model efficiency must be improved to include more variables. The analysis of the model has a mean error of -4.00% and coefficient of variation (cv) is 6.31%. In comparison, the traditional model has the mean error of 24.26 % and coefficient of variation of 49.26%. Estimates using the traditional model cause overestimation (more bias) and inconsistency. It was found the MRM created would produce underestimated results but close to the contract prices (less bias), and it is consistent than the traditional model which use the area model. All assumptions needed to support the model have been met.

Table 8.56: Test results for estimate / lowest bid

			Test results			
	Variables	Bias	ANOVA test	β coefficient	Consistency	Consistency homogeneity
1	Project Value (RM)	more with increase value	not significant	not significant	improves with increase value	Homogeneous
2	Project Size (m^2)	more with increase size	not significant	not significant	improves with increase size	Homogeneous
3	Price Intensity (RM/m^2GFA)	reduces with increase cost/m^2	significant*	not significant	no trend with increase cost/m^2	Homogeneous
4	Storey Height	more with increase storey	not significant	not significant	no trend with increase storey height	Homogeneous
5	Contract Period (weeks)	more with increase period	not significant	not significant	no trend with increase contract period	Homogeneous
6	Number of Tenders	more with increase tender	not significant	not significant	no trend with increase number of tenders	Homogeneous
7	State	differences between state	significant*	significant*	differences between state	Homogeneous
8	Types of schools	differences between school	significant*	significant*	differences between school	Homogeneous
9	Classes of projects	differences between project	not significant	not significant	differences between project	Homogeneous

*statistical significance (P<0.05)

Table 8.57: Test results for estimate / accepted bid

	Test results					
	Variables	Error (bias)	ANOVA test	β coefficient	Consistency	Consistency homogeneity
1	Project Value (RM)	more with increase value	significant*	not significant	improves with increase value	Homogeneous
2	Project Size (m^2)	more with increase size	not significant	significant*	improves with increase size	Homogeneous
3	Price Intensity (RM/m^2GFA)	reduces with increase cost/m2	not significant	not significant	reduces with increase cost/m^2	Homogeneous
4	Storey Height	more with increase storey	not significant	not significant	improves with increase storey	Homogeneous
5	Contract Period (weeks)	more with increase period	not significant	not significant	improves with increase storey	Heterogeneous*
6	Number of Tenders	no trend with increase number of tenders	not significant	not significant	no trend with increase number of tenders	Homogeneous
7	State	differences between state	significant*	significant*	differences between state	Homogeneous
8	Types of schools	differences between school	not significant	significant*	differences between school	Homogeneous
9	Classes of projects	differences between project	not significant	not significant	differences between project	Homogeneous

*statistical significance (P<0.05)

Table 8.58: Test results for estimate / mean of the bids

	Test results					
	Variables	Error (bias)	ANOVA test	β coefficient	Consistency	Consistency homogeneity
1	Project Value (RM)	more with increase value	not significant	not significant	improves with increase value	Homogeneous
2	Project Size (m^2)	more with increase size	significant*	significant*	improves with increase size	Homogeneous
3	Price Intensity (RM/m^2GFA)	reduces with increase cost/m^2	significant*	not significant	reduces with increase cost/m^2	Homogeneous
4	Storey Height	more with increase storey	not significant	not significant	improves with increase storey	Homogeneous
5	Contract Period (weeks)	more with increase period	not significant	not significant	improves with increase storey	Heterogeneous*
6	Number of Tenders	more with increase number of tenders	not significant	significant*	improves with increase number of tenders	Homogeneous
7	State	differences between state	significant*	significant*	differences between state	Homogeneous
8	Types of schools	differences between school	significant*	significant*	differences between school	Homogeneous
9	Classes of projects	differences between project	not significant	not significant	differences between project	Homogeneous

*statistical significance (P<0.05)

CHAPTER 9: DISCUSSION

This chapter discusses the findings from both literature review and data analysis. This chapter makes comparison on the results studied based on empirical evidences and theories, which is the subject matter of this study. This chapter looks for relationships, generalizations and trends as well as the exceptions. It is divided into six (6) sections:

Section one (1) - factors, which affect the accuracy of cost estimates

Section two (2) - approaches, which can improve accuracy of estimates

Section three (3) - systematic bias and consistency affected by project characteristics

Section four (4) - allocation on contingencies and VOP

Section five (5) - reliability of MRM for estimating

Section six (6) - accuracy of project estimates and elemental costs.

9.1 Section one (1) – Factors which affect the accuracy of estimates

The respondents consider all factors, which affect the accuracy of estimates, are important except for QS stress level (estimator performance). This is because QS consultants are more focus on the preparation of bills of quantities rather than cost estimates. Estimates and construction pricing are more rigorously prepared in the construction firms because they need to allocate more resource on the bidding as the success of the firms relates to their bidding performance. The respondents do not agree on three factors. These are basis of selection - number of bidders (scope quality), location (scope quality) and project technology and complexity - project size and design (uncertainty level). However, results from project data reveal these factors are significant and important in order to explain the bias in the estimates. QS were not aware of the bias trend in the estimates as this only could be observed after conducting statistical analysis rather than based on experience. QS could not see the persistent error trend that developed during estimation (Morrison, 1984). The level of agreement on groups of factors is moderate for uncertainty level while in others they are weak. This happens because QS has different perception and view on the factors. QS experience is specific on previous project of certain types only (Ashworth & Skitmore, 1982).

9.2 Section two (2) – Approaches to improve the accuracy of estimates

All methods studied to improve estimation process are important. The results obtained are slightly different from the findings of Aibinu and Pasco (2008) and Ling and Boo (2001). Checking on assumptions, cost planning and realistic time taken to prepare estimates are considered important in Australia and Singapore. Cost planning and cost control are ranked very low by PWD officers. Therefore, these methods are seldom employed by PWD. The government does not prepare more rigorous cost estimate unlike the private sector, which prioritise profit and cost saving. It could be happened because of government projects have to follow standard and cost guidelines. However, cost planning and cost control method are very important without which the estimate would be inaccurate because of lack of cost checking (Ferry, et al., 2007; Smith & Jaggar, 2007). This could be explained because in practice, government project design evolves from preliminary design to tender design but the process misses out the detail design, which involves a lot of cost checking. This study also shows the importance of sufficient design information, proper design documentation and updating of cost data. The early cost estimates of PWD procurements are held back by the lack of design information and insufficient cost data. This explains why QS overestimated the estimates in elemental costs by a large margin.

All new approaches are important to improve the accuracy of estimates. PWD and private consultant should invest in estimating training and data collection system in order to improve performance of QS. Cost data is the second most important factor, which affects the accuracy of estimates. PWD has its own systematic data collection but a considerable number of QS consultants rely on individual effort to collect his own data. Cost data should be shared among private consultants and the government (BRB & NRC, 1990). According to Yeung (2009), projects with less variance in the specification and having large cost references could provide more accurate estimates than projects with large variance. It is known that most government projects are more or less are regulated through standard regulation (Economic Planning Unit, 2005). Government departments and private consultants do have the same type of projects and both should have a standard estimating procedure. Respondents suggest the traditional ways of working need to be improved first, before embarking on alternative estimating methods and value engineering. Standardized procedure could improve the accuracy of estimates, as QS who involve with PWD procurement will use standard procedures and terminologies. The use of unstandardized terminologies is one of concern to private consultants (Abdul-Rashid Abdul-Aziz & Normah Ali, 2004). The data analysis on project data shows some of the elements (foundation and external works) are highly overestimated because QS make unnecessary assumption which could lead to the increase of the pricing level (Soo & Oo, 2007). In order to avoid overestimation bias, standardized procedures must include acceptable level of project definition. Most QS are not satisfied with the estimating knowledge of junior local graduates. According to

Alroomi et al. (2010), the knowledge on estimating could be learn over time. Universities should focus more on specific estimating knowledge and employers should provide practical estimation training for their employees (Hackett & Hicks, 2007).

9.3 Section three (3) - Systematic bias and consistency of project characteristics

This section discusses about systematic bias and consistency of project characteristics. This study includes the PI theory

9.3.1 Bias and consistency of estimates

The increase in project value (RM) and project size (m^2GFA) increased bias. This is consistent with the findings of Kiew (2009) in Sarawak, Skitmore and Drew (2003), Flanagan and Norman (1985) and Morrison and Stevens (1980). This finding is different if compared to Harvey (1979), Skitmore and Tan (1988) and Gunner and Skitmore (1999a). There is some reason pertaining to this phenomenon. QS in PWD are more biased towards more expensive projects and large project size as those projects are more complicated. This will result in overestimate if compared to inexpensive and smaller project. The increase in project value (RM) and project size (m^2GFA) improved consistency. This is consistent with the findings of Morrison and Stevens (1980), Skitmore and Tan (1988) and Gunner and Skitmore (1999a). However, it disapproves the finding of Ogunlana and Thorpe (1991). Estimates are more consistent due to the importance of the expensive projects to QS than small and inexpensive ones. The preliminary finding of PI theory in term of cost/m^2GFA which was suggested by Gunner and Skitmore (1999b) and Skitmore and Drew (2003) is similar to this finding.

Buildings with low unit rate are overestimated, while high unit rate are underestimated. This PI variable is tested significant in ANOVA test if lowest bid and mean of the bids are used as targets. Nevertheless, the outcome from MRA shows PI is not the significant predictors. This happens because of some confounding variables (confounding effect) in the model (Gunner & Skitmore, 1999b). In common practice, QS take price per metre square floor of comparable building as the starting point for forecasting and then adjust anticipated value. Therefore, in theory, bias in estimates by QS will be the deciding factor when cost data / m^2 pooling is made.

The additional number of bidders has led estimates to be more biased. MRA shows the predictor is significant in estimate / mean of the bids. This finding is similar to Harvey (1979), McCaffer (1975) and Flanagan and Norman (1983). It happens because bidders will likely decrease their bid amount when additional number of bidders enters the bid. This reduces the amount of bids. However, QS did not see the intensity of competition on bidding. No consistency trend in estimate / lowest bid and accepted bid but consistency improves with additional bidder enter the bid in mean of the bids. The use of accepted bid as target has no effect on the correlation between estimate and bid. This suggests the use of accepted bid could have some disadvantage because it is unable to detect the intensity of competition. All comparisons in ANOVA test show there are bias differences from state to state (location) which is similar to the findings of Harvey (1979), Aibinu and Pasco (2008) and Ogunlana and Thorpe (1991). According to Pegg (1984) the differences of prices for labour, materials and machineries in various locations is one of the reasons that cause the bias. The result from ANOVA shows the high impact of bias (effect size) for state variable except in estimate / lowest bid. Melaka is the one, which has significant differences from other states. Melaka and

Negeri Sembilan are grouped in the same location in PWD cost data. However, this finding shows the differences in prices between these two states are significant. Biases and consistencies are different in types of schools (primary and secondary). ANOVA test shows types of schools have significant mean differences for lowest bid and mean of the bids. This is proved by MRA which shows all comparisons are statistical significant. These are similar to findings of Harvey (1979), Morrison and Stevens (1980) and Skitmore (1985), but their results are based on different type of schemes. It was found only a contract period is statistically significant for consistency homogeneity. The consistency improves when contract the contract period increases. It suggests estimates for small projects, which have shorter construction period, are most likely unpredictable than bigger projects. Bias worsens but consistency improves when increased of additional storey of building. However, it was not statistically significant during ANOVA and regression analysis. This rejects the finding by Aibinu and Pasco (2008).

9.3.2 Regression analysis on estimating bias

The regression model shows project size, number of tenders, types of schools and state are the best-fit predictors to explain the estimating bias. Unlike the ANOVA, the test result did not support the PI Theory forwarded by Gunner and Skitmore (1999b). As previously stated, this is caused by confounding effect of some variables. The cost/m^2GFA is not a significant predictor to explain bias in the estimates. Estimate / mean of the bids model is the best model because it has a large value of adjusted R^2, which is able to explain the variance of dependent variables.

9.4 Section four (4) – Allocation on contingencies and VOP

Contingencies in PDA are slightly more than ATDA. Some authors said the contingencies allowance should be reduced from cost estimates to project realization as most design risks and pricing risks has been reduced due to more information gathered and extensive cost planning and cost control are used during pre-tender stage (Dell'Isola, 2002; Loosemore & Uher, 2003; Smith & Jaggar, 2007). Standard designs are employed in this research. The repetition of design should minimally decrease the risks from PDA to ATDA. However, it was found only four percent of contingencies allocation at contract stage were less than 2% (theoretical value) as suggested by Smith and Jaggar (2007). However, PWD allows its QS to allocate not more than 10% of total development cost. QS allocate contingencies sum based on his experience because no extensive guideline is provided for by PWD.

VOP is based on upward and downward of building cost index (usually at 5% of builder's works). It was found the VOP increased from PDA to ATDA. The graph of building cost index in the year 2007 to 2008 shows the unpredictable price movement. This explains the uncertainties present in the market could affect the VOP allocation especially when there is a sharp increase in price. The government still has to absorb more risks if price of building materials increases. No guideline or standard procedure is available on how contingencies and VOP allocation should be priced in detail as practiced by AACE and EPRI. They suggest percentage allocation is based on accuracy of estimates (estimates and final accounted costs). This is supported by Skitmore and Cheung (2008), Karlsen and Lereim (2005) and Picken and Mak (2001) which suggest the use of probabilistic approach to estimate the contingencies. The addition and reduction of contingencies and VOP may have influence the bias but, since conventional projects were being used in this research, QS PWD price contingencies and VOP rather than the bidders price the contingencies and VOP. In design and build projects, bidders and PWD independently allocate the Contingencies and VOP into their pricing. This study may not go deeper into analytical venture. It is suggested that some sort of guideline and procedure are necessary to facilitate QS in determining price contingencies and VOP in a more profound meaning. The contingencies and VOP could affect the accuracy of estimates if design and build procurement is used.

9.5 Section five (5) – Multiple regression method (MRM) for estimating

MRM is more accurate than the area method which is traditional. Similar research has been conducted in Hong Kong and the United States, which found MRM, is accurate within 5% (Butts, 2006; Hammad, et al., 2010; Li, et al., 2005). Even though the model underestimates the estimates more frequently but it has less bias and more consistent. This is similar to the finding in the UK by Lowe et al. (2006). Regression model is better than traditional estimating but it is inferior to neural network. This model is prepared only for standard pre-design school projects. This result could be different if it is used in other types of designs especially to those projects with large variance in project specification (Yeung, 2009). The use of custom-made design could affect the model because of the different variables, which affect the uniformity of the model. However, this model is based on dependent variable being in dollars and not cost/m^2. The result when using cost/m^2 shows the value of adjusted R^2 is lower if compared to dependent variable being in dollars. There are some other independent variables could be available to improve the value. The result shows the model that is based on cost/m^2 has more variables that are significant i.e. contract period, type of building, number of bidders and state. Majority of respondents agree with the introduction of alternative estimating method to PWD pre-contract procedure.

9.6 Section six (6) – Project accuracy and elemental accuracy

There is evidence estimates prepared in PWD are positively bias (overestimated). Research by Gunner and Skitmore (1999b) and Aibinu and Pasco (2008) also shows the same result. Overestimate is more acceptable to QS and Client (Cheung, et al., 2008; Magnussen & Olsson, 2006). Almost half of QS said they intentionally mark-up the estimates because they were concerned with underestimation. This is supported by Flyvberg et al (2002), which believe QS are deliberately bias rather than it happened unintentionally. Nevertheless, Soo and Oo (2007) point out QS overestimate the estimates because of the lack of information available. If estimate / low bids are used as the target, estimates in PWD are the most bias when compared to previous finding. However, it could be disputed because the problem of low bid price submission has always been the issue in PWD contract tendering and now the PWD uses average bid method for selecting tender prices. According to official statement from PWD itself, the reliability of QS department in performing estimating was disputed (Public Works Department, 2004, 2005). This lack of accuracy brought about changes in selecting tenders. The "cut-off" system based on average bid method was introduced to reduce low bids tenders from being accepted. The use of lowest bid could have included suicidal low bidders (Skitmore & Lo, 2002). This could explain why the average bid method is adopted in selecting a favourable bidder (Public Works Department, 2005). Both sides of respondents (PWD and private QS) were satisfied with their performance in preparing estimates. This corresponds with the finding in Hong Kong Cheung, et al.

(2008), but findings in Australia shows most QS were not satisfied with their performance in preparing estimates (Aibinu & Pasco, 2008). Level of satisfaction is a subjective matter as it depends on many factors including perception.

Most respondents agreed the acceptable accuracy is +/-10% from the target. It shows the respondents are not so well informed about the factual estimating accuracy as it is so different if compared to respondents' estimation if +/- 26% (13% cv)[40] by Morrison (1984) is used as the benchmark. There are other range of accuracies which were suggested by different researchers such as -10% to 15% margins by Potts (2008) and +/-15% by Chappell (2001) and Skitmore and Ng (2000). When analysis on single estimate was made, 33% of estimates were outside the +/-20% limit. It shows that most estimates prepared are accurate in terms of error. It could be due to standard design is used for this research. Using lowest accepted tender bids, accepted bid and mean of the bids appeared to have less overestimated estimates with the mean error of 11% to 18% if compared to lowest bid. On average, most estimates are overestimated by more than 10%. The use of accepted bid method is bias because QS and clients involve in determining the level of accuracy (Skitmore, 2010). Thus, unbiased ways to measure the level of accuracy should be determined. Most projects in this research are using average bid method, which is more appropriate. According to McCaffer (1976), the use of mean of the bids have a less intervening variables and thus more likely to be accurate to measure the accuracy of estimates. However, Raftery (1991) points out, the use of mean of the bids as the target could be intervening by the uncompetitive bids (high-priced bids). Thus, the author has decided not to incorporate more than eight bidders in mean of the bids calculation. It is because some research shows that bidders whose tender

[40] +/- 22.5% for uniform distribution and +/- 26% at 95% confidence level for a normal distribution

price is at number nine and onwards are not competitive (Carr, 2005; Dell'Isola, 2002). The result shows most respondents inclined towards mean of the bids as the target to measure the accuracy of estimates. It means they do not want to take risk or they accept the use of average bid method by PWD as the price selection. Estimates in PWD are consistent due to cv is around 9% which is at 9% to 10%. These are estimates for school projects and constructed using standard pre-design. Consistency should be around 9% cv according to McCaffrey (1980) and Marr (1977). This is because substantial design is already completed.

Accuracy of elemental items shows a high margin of error and highly inconsistent. Building works is the highest amount, which contribute about half of the total cost of projects. The mean error of estimates using area method is 25% of building works. The mean error for piling/foundation works and external works is 45%. According to Skitmore and Patchell (1990) and Boussabaine (2007), the use of area method and approximate quantities give a mean error of around 20 - 30% and 15 – 25% respectively. Perhaps, this gives us the indication that a less rigorous estimating methods was used and lack of information supplied when preparing prepare the estimates for piling / foundation and external works. There is evidence that a number of projects were found not required piling works at all.

One conclusion by Armitt the Costain Group[41] Chief Executive Officer (1997 – 2001) regards the company losses most of the time happened due to ground condition (White, 2000):

> *"Ground risk is one the biggest risks in construction, we may decide that we need to do more site investigation at the beginning of the process. It could well be that spending £500,000 on a soil investigation is worth it in order to avoid a major delay at a later date."*

The use of PWD's Average Cost per metre square of Building Construction Cost Handbook, suggests the use of single rate estimate and percentage allocation (for external works) are suspected to give inaccurate estimates. Most authors like Ferry et al. (2007), Seeley (1996) and Skitmore and Patchell (1990) agreed these methods were not accurate if compared to approximate quantities and elemental estimate. Smith and Jaggar (2007) said that the area method which use average rate from previous average multi-project gave a mean error of 15.50% and consistency of 19% cv. Single project with almost the same attributes gave a mean error of 9% and consistency of 11% cv. According to Gunner and Skitmore (1999b), the percentage allocation method, would lead to insufficient adjustment as the average cost from all projects were not the same as the new projects. Meanwhile, James (1954) suggests external works and services should be measured according to approximate quantities in order to allow for better accuracy.

Data analysis shows element of substructure (Piling and Foundation) and external works elements are the most bias and inconsistent estimates. This is because piling works and external works are not identical from one project to another due to different soil and site

[41] Constain Group is one of the oldest construction firms. It was formerly owned by Renong Berhad. Renong had to sell the company because of it was burdened by a huge debt during Asian Financial Crisis (1997 – 1998).

condition. Perhaps, in order to improve the accuracy of these two (2) elements, the engineers concerned should provide more detail information about the site soil condition. In addition, building work still constitute the highest amount of the construction works. A larger error in this element affects greatly the total accuracy of construction works. Reliable estimating methods are needed to improve the accuracy of this element. The estimate for internal services is more accurate because most of these items are allocated in provisional sums and prime cost sums.

CHAPTER 10: CONCLUSION AND RECOMMENDATION

This chapter concludes the five (5) research questions. This research addressed itself to the problems of inaccurate preliminary cost estimates in PWD. The survey on factors, which affected the accuracy of preliminary cost estimates were conducted with QS from PWD and private consultants as respondents. New approaches were also examined so that they could be used in the future for improvement of accuracy of preliminary cost estimates in PWD. Results of the analyses were obtained by using different targets such as estimate / lowest bid, estimate / accepted bid and estimate / mean of the bids. Project characteristics, which affect systematic bias, were also discussed and analyzed. Comparisons were also made between estimating components of elemental costs and project characteristics. Contingencies and variation of price were analysed so their importance when preparing estimates are recognised. To date, percentage allocated to contingencies are based on personal judgement rather than using scientific method. Traditional estimating methods remain the most favourable method approved by QS and are the only method approved by PWD. The need for better estimating method is urgent and MRM is chosen in order to determine the reliability of the alternative estimating method.

10.1 The answers to research questions

The following are the answers to research questions:

10.1.1 What are the factors, which affect the accuracy of preliminary cost estimates?

All factors affecting the accuracy of estimates are considered important except QS stress level (estimator performance). Design scope (scope quality), experience (estimator performance) and market conditions (uncertainty level) are the highest perceived by QS. Basis of selection (scope quality), location (scope quality) and project complexity (uncertainty level) - could be related to project size are perceived as less important by QS consultant but it should not be the case. There is evidence from project data analysis that rejects this belief. It was found that number of tenders, state and project size significantly affect the bias in the estimate. The best way to conduct the relevant research is by using project data because it gives more evidence that is concrete while research by survey depends on responses by respondents who tend to generalise their experience. It is very important to carry out further study on the estimates prepared by QS consultants because they have a significant difference opinion on the factors above but it was proven the other way around when analysis on project data is made. It is because these factors significantly affect the performance of QS in PWD. If not, QS consultants might not realise the persistent error trend occurs during the estimation.

10.1.2 What approaches can improve the problems related to inaccurate estimates?

All methods to improve accuracy during estimation process are important. However, the availability of sufficient design information and cost data are the most important to QS in their approach to prepare accurate estimates. Estimates are always without sufficient drawings and information. Nevertheless, it is important for QS to decide on the level of information needed from the designers. This is to ensure a significant amount of information should be included rather than letting the QS make a more risky assumptions. The designers could provide the quality and dimension of the construction items. Piling/foundation and external works are the ones with the most bias and inconsistent estimates. It is vital for structural engineer to supply the acceptable information regarding penetration depth, foundation designs and the quality of materials used for construction before estimating work starts. Perhaps, soil analysis should be carried out first before embarking on estimation. Civil engineer needs to supply more information regarding external works. The use of percentage allocation by PWD could lead to more bias estimates.

The analysis on projects characteristics of size and project value reveals the tendency of estimates to be more biased (overestimate) with a larger and more expensive project. Large building needs deeper piling works and extensive design on foundation. A large building needs a larger site area. This leads to more extensive external works for e.g. works on drainage for a larger building is more than a smaller one. QS intentionally mark-up the estimates in order to fill the void of insufficient information. There is a need for new procedures formulated by PWD in order to overcome a high level of error and inconsistent estimate in every element. The use of standard repetition design usually results in more accurate estimates due to it familiarity with QS. The use of more rigorous or alternative estimating method is believed to reduce inaccurate estimates in building works which is about half of the construction cost. The use of percentage distribution in estimates is not recommended if a high level of accuracy is to be achieved. This confirms previous studies in that the trend is more than proportional and less than additive function. What is needed is a linear function. Mixed use of approximate quantities and elemental analysis are also recommended. The finding shows that QS in PWD consider cost planning and cost control is not that important. However, this opinion is not appropriate if QS need to prepare estimate for large and complicated project because the result shows the estimate is biased when project size increased. Preparation of cost estimate for large project should involve a number of cost planning phases i.e. preliminary design, detail design and tender drawing. Skipping from preliminary drawing directly to tender drawing and without having detail design is not recommended if an accurate estimate is needed. PWD and private consultants should continuously invest in the training of QS, so they could make a better estimating. Local universities should also focus more in estimating course, as for now the course is more focused towards preparation of bills of quantities. The introduction of standard method of measurement for estimating work is recommended. It allows QS to prepare their estimates based on standard procedures and terminologies. In addition, this standard should emphasize on the acceptable level of project definition especially on magnitude of information needed. PWD and private QS consultants and designers should prepare this standard.

10.1.3 To what extent the project characteristics, measures of target, elemental costs, contingencies and variation of price and other theories could significantly affecting the preliminary cost estimates prepared by the PWD?

The location of project is found to be statistically significant in ANOVA test and MRA. It also possesses a larger effect size if compared to other predictors. State (location) is the ultimate predictor to explain the bias in the estimates. Estimates of larger project in terms of size (m^2GFA) and value (RM) tend to be more biased than estimates of smaller project but they are more consistent. There is a linear evidence of overestimation when an additional bidder enters the contract as it is related to intensity of competition when there are more bidders. Contract period affects the consistency in accepted bid and mean of the bids. Area of improvement should be focused on Piling Works, External Works and Buildings, as these components were found with a high margin of error and largely inconsistent. PI theory (cost/m^2GFA) was partly accepted in this research even though it had no effect in the final model of MRA. Nevertheless, PI was found significant in preliminary analysis and ANOVA test. It is because of confounding effect of some variables in the model. Contingencies and VOP may influence the accuracy but there is no certainty on how it should be measured because QS are the ones who price Contingencies and VOP rather than the bidders when using conventional procurement. Contingencies and VOP could affect the accuracy in design and build project. To date, no guideline is available on how to allocate these sums scientifically. Most of the time, QS personal judgements determine the allocation for contingencies.

QS needs to pay greater attention to locality (projects in states), types of schools (or types of projects), size of project, value of project and competiveness of tender and contract period. Pooling of cost data and adjustments need to be reviewed more rigorously in order to improve the current practice. It is advisable to structure cost database according to known project characteristics. Information regarding the area of building, project value, storey height, contract period, number of tenders, contractual arrangement and basis of selection should be specified by PWD in its yearly published Average Cost per Meter Square of Building Construction Cost Handbook. The cost derived from the analysis of single building gives QS more contextual information regarding the specifications and other details for a better data pooling. It is high time for PWD to construct some sort of computerized database for cost data sharing and this system should include BIM and data mining algorithm. It is suggested that PWD should divide the tender price index according to individual state if not this could increase its estimating variability. A clear guideline for contingencies and VOP using scientific method should be available to QS for e.g. by using a probabilistic approach.

10.1.4 How reliable is the estimating using linear multi regression method (MRM)?

MRM (alternative) used for calculating estimates of building works is more accurate (less bias and more consistent) than traditional estimating model. It is suggested that in order to use this regression model, some technical guidelines are needed for data pooling, software on MRM and other written guidelines. This is important because the model is characterized by technical complexities, but it could provide quick estimating for standard repeated building. However, the model must be enhanced first in order to make it more useful and more accurate. There is a need to include more significant variables in order to make it more impressive. However, the use of traditional cost model could achieve same result if proper adjustment and pooling of cost data are made.

10.1.5 How accurate are the preliminary cost estimates prepared by PWD?

Most of the time, estimates are biased (positive). However, the estimates are acceptably accurate as it is less than +/- 20%. It may be occurred because of standard repeated design is used. It could be a different result if customize and more complicated design is used. From the analysis, it is predicted that the estimates for large projects will become more bias positively. In general, most estimates are consistent. The use of standard pre-design school projects could improve the consistency due to QS' familiarity with the design. Estimates are more consistent when using mean of the bids as target. The accuracy can be improved further with the use of improved cost data pooling, more rigorous estimate and alternative cost model. It was discovered the use of different targets gave different mean error and consistency level. The use of accepted bid as target may have been influenced by the QS and therefore interdependent to some extent with the estimates. The use of lowest bid as the target may also have some drawback because a bidder may present a suicidal low bid. Mean of the bids is more appropriate because of the use of average bid method, which is used as the target by PWD. It was found that mean of the bids (as the target) is the best-fit linear model to explain bias estimates. It is more appropriate if the lowest bid is used as a target for lowest bid selection only while mean of the bids should be used in the average bid method selection.

10.2 Contribution to knowledge

The estimate / mean of the bids is the best model to explain the accuracy of preliminary cost estimates in PWD. Location of project (state) is the most significant predictors, which affect the bias in estimate, while the consistency of the estimate is affected by contract period. A construction firm, which is interested to bid a contract, could offer its price according to known bid method. If he knows the contract award is determined by the use of average bid method, he should price it accordingly. Lowest price is less likely to be accepted. There is evidence that the mean of the bids is the most likely accepted bids. When cost data pooling is prepared, it should be divided according to known bid method. The use of inappropriate cost data for example data from lowest bid affects the variability of cost estimate when the tender price selection is based on mean of the bids.

The analysis on project characteristics and elemental costs show there was a lack of accuracy in early design stage because of the lack of information. It shows that piling works and external works were the ones with less information. It could be happened because the present pre-contract procedure does not emphasize on the important of these elements. The problems when using accepted bid, as the target is that it could not show the intensity of bidding when more bidders enter the contract bidding. This could affect the observation of systematic bias in the analysis when different targets are used. There is a need to review location index prepared by the PWD because the estimating bias of one state is significantly different if compared to other state even though they are in the same group. Overestimation bias by QS could affect average bid method (cut-off method) used to select the acceptable prices because the inclusion of the bias estimate to calculate the mean will increase the mean price higher (most of the time) or lower as it depends on the accuracy. It is suggested that the estimate prepared by QS should not be included during the calculation to reduce bias estimate affects the mean value.

10.3 Recommendation for future research

Future research could be done on how outliers could be removed so an unbiased way to determine price reference point using mean of the bids can be achieved. To date, public procurement in Malaysia does not use scientific method to determine the price of contingencies and VOP. There is a need for more extensive study by PWD and other researchers on how biases affect the accuracy of estimate. The next research should be expanded to numerous types of buildings, different contractual arrangement, different QS consultants and the effects of economic conditions on estimating accuracy. Improvement on MRM is needed to allow inclusion of more significant variables.

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APPENDICES

Appendix 1: Preliminary Detailed Abstract (PDA)

LAMPIRAN II

(PWD 142A - Rev.'91)

JABATAN KERJA RAYA

PRELIMINARY DETAILED ABSTRACT FOR

HEAD	SUBHEAD	YEAR	TOTAL PROVISION RM
			PROVISION FOR CONSTRUCTION RM

	BRIEF DESCRIPTION OF BUILDINGS							
	BUILDING	Frame	Wall	Roof	Floor	Ceiling	Window	Standard
a								
b								
c								
d								
e								
f								
g								
h								
j								
k								

	BREAKDOWN OF PRELIMINARY COST ESTIMATE				**COST RM**
1	**PRELIMINARIES**				
2	**PILING/SPECIAL FOUNDATION** **Type and Size**				
a					
b					
c					
3	**BUILDING**	**Drawing No.**	**Floor Area m2**	**Cost/m2**	
a					
b					
c					
d					
e					
f					
g					
h					
j					
k					
4	**INTERNAL SERVICES**				
a	Plumbing Installation				
b	Sanitary Appliances				
c	Electrical Installation				
d	Fire Protection Installation				
e	Air Conditioning Installation				
f	Lift & Conveyor Installation				
g	Communication Installation				
h					
j					
k					
	SUBTOTAL carried forward				

	BREAKDOWN OF PRELIMINARY COST ESTIMATE (CONT'D)	COST RM
	SUBTOTAL brought forward	
5	**EXTERNAL WORKS**	
a	i) Site Preparation	
	ii) Earthwork	
b	Roads,Hardstanding,	
	Footpaths & Paving	
c	Fencing & Gates	
d	Turfing & Soft Landscaping	
e	Surface Drainage	
f	Sewerage	
g	External Electrical Installation	
h	External Water Supply Installation	
i	External Telephone Installation	
j		
k		
6	**VARIATION OF PRICES**	
7	**CONTRIBUTION FEE TO LOCAL & UTILITY AUTHORITY**	
a	Tenaga Elektrik Nasional	
b		
c		
8	**MISCELLANEOUS**	
a	Advertisement	
b	Documentation	
c		
9	**CONTINGENCIES**	
	ALL IN UNIT RATES (of Total items 1 to 9) — TOTAL (items 1 to 9)	
	Total Floor Area m2 : — **Cost/m2 :**	
10	**SUPERVISION**	
11	**PROFESSIONAL FEES**	
a	Architect	
b	Civil & Structural Engineer	
c	Mechanical Engineer	
d	Electrical Engineer	
e	Quantity Surveyor	
f		
	TOTAL COST OF PROJECT	

Quantity Surveyor/Estimating Officer	State Director of Works	Portfolio Branch Director of Works
Date:	Date:	Date:

* Only necessary if PDA is prepared at JKR State level

Appendix 2: As Tendered Detailed Abstract (ATDA)

(PWD 142B - Rev.`91)

JABATAN KERJA RAYA

AS TENDERED DETAILED ABSTRACT FOR		Total Amount of Main Tender: RM	
		Contractor for Main Works	Class
Head Sub/Head Year	Total Prov. RM Prov. for Const. RM	Closing Date of Tender	Tender Valid Until

	COMPETITIVE TENDER LIST			
Contract Period:	Tender No.	Tender Sum	Tender No.	Tender Sum
Type of Contract:				
Form of Contract:				
Basis of Tender:				
No. of Tenders Received:				

	BRIEF DESCRIPTION OF BUILDINGS							
	BUILDING	Frame	Wall	Roof	Floor	Ceiling	Window	Standard
a								
b								
c								
d								
e								
f								

	PRIME COST AND PROVISIONAL SUMS		
	ITEM	ALLOWED RM	ACTUAL RM
a			
b			
c			
d			
e			
f			
g			
h			

	BREAKDOWN OF COST	**COST RM**					
1	PRELIMINARIES		Being % of Remainder of Main Tender				
2	PILING/SPECIAL FOUNDATION Type and Size		Unit	Quantity		Unit Cost	
a			M				
b			M				
c							
3	BUILDING		Drawing No.	Floor Area m2	0 Cost/m2	Vol.m3*	Cost/m3*
a							
b							
c							
d							
e							
f							
g							
	SUBTOTAL **carried forward**	-					

*Refer to Note 8.2 (b)

	BREAKDOWN OF COST (CONT'D)		COST RM				
	SUBTOTAL brought forward						
4	**INTERNAL SERVICES**	*		**Building Served**		**Cost /m2 RM**	**% of Bldg. Cost**
				Ref. No.	Floor Area Served		
a	Plumbing Installation						
b	Sanitary Appliances						
c	Electrical Installation						
d	Fire Protection Installation						
e	Air Conditioning Installation						
f	Lift & Conveyor Installation						
5	**EXTERNAL WORKS**			Appropriate Unit		Quantity	Unit Cost
a	i) Site Preparation			i) Hectares			
	ii) Earthwork (I.f. = %)			ii) Cu. m moved (m3)			
b	Roads, Hardstanding,			Surface Area (m2)			
	Footpaths & Paving						
c	Fencing & Gates			Perimeter (m)			
d	Turfing & Soft Landscaping			Turfed Area (m2)			
	(S.t. = %)						
e	Surface Drainage			Tot. length of drn. & pipes (m)			
f	Sewerage			No. of occupants served			
g	External Electrical Installation			No. of KVA required			
h	External Water Supply Installation			No. of occupants served			
i	External Telephone Installation			No. of Tel. points served			

6	**VARIATION OF PRICES**	
7	**CONTRIBUTION FEE TO LOCAL AND UTILITY AUTHORITY**	
a	TNB & JBA	
b	Telekoms	
8	**MISCELLANEOUS**	
a	Advertisement & Documentation	
b	Soil Investigation	
9	**CONTINGENCIES**	
	TOTAL (Items 1 to 9)	
10	**SUPERVISION**	
11	**PROFESSIONAL FEES**	
a	Architect	
b	Civil & Structural Engineer	
c	Mechanical Engineer	
d	Electrical Engineer	
e	Quantity Surveyor	
	TOTAL COST OF PROJECT	

ALL IN UNIT RATE (of Total Items 1 to 9)	
Total Floor Area m2 : 4449	Cost/m2 : 0.00

Quantity Surveyor/
Superintending Officer's Representative

Date :

Superintending Officer/
State Director of Works

Date :

Portfolio Branch Director of Works

Date :

Appendix 3: Average cost per metre square (Source: Public Works Department, 2009b)

KOS PURATA SEMETER PERSEGI BAGI BANGUNAN-BANGUNAN DI SEMENANJUNG MALAYSIA (1980 - JUN 2009)

KATEGORI BANGUNAN : PENDIDIKAN (Sekolah 4 Tingkat)

	Kawasan	Kawasan A		Kawasan B		Kawasan C		Kawasan D		Kawasan E		Kawasan F		Purata Sem. M'sia	
Bil.	Jenis Bangunan dan No. Lukisan	Bil. Kajian	Purata	Bil. Kajian	Purata	Bil. Kajian	Purata	Bil. Kajian	Purata	Bil. Kajian	Purata	Bil. Kajian	Purata	Jumlah Bil. Kajian	Purata
	BLOK SEKOLAH - 4 TINGKAT														
	SEKOLAH & BILIK DARJAH														
1	Blok Akademik BKP(A)/167/90/1									1	422.53			1	422.53
2	Blok Akademik 4 tkt. BKP(DBKLMJ)400/96 siri							3	682.80					3	682.80
3	Blok Sekolah BKP(DBKLWM)400/96/M	1	836.14	1	379.56									2	607.85
4	Blok Bilik Darjah BKP 304/79 Siri	5	603.71	1	430.05	13	482.94			4	742.85	6	618.64	29	565.87
5	Blok Sekolah BKP(SP)404/90 & 91 Siri	32	923.56	10	595.62	127	520.06	53	546.28	11	605.66	29	587.83	262	588.63
6	Blok Sekolah JKR/PT/BS37 & 38/91					4	551.72							4	551.72
7	Blok Bilik Darjah BKP 304/79 Siri	8	746.16			12	636.33			4	681.35	3	628.19	27	674.64
8	Blok Bilik Darjah BKP(W)93/106/2					1	439.90							1	439.90
9	Blok Bilik Darjah BKP(W)93/108/1-5					1	425.10							1	425.10

Appendix 4: The percentage allocation for preparation of the estimate (Source: Public Works Department, 2009b)

KOS KERJA-KERJA LUAR BANGUNAN (EXTERNAL WORKS) DAN KERJA CERUCUK (JAN. 2009 - JUN 2009)

JENIS BANGUNAN	SISTEM PEMBETUNGAN		TAPAK BINA		SALIRAN AIR PERMUKAAN		JALAN DAN DATARAN KEJAT		PENANAMAN RUMPUT		PAGAR		LAIN-LAIN KERJA LUAR		CERUCUK	
	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama	Bil. contoh yang diambil	Peratus kerja luar dari kerja utama
1. BANGUNAN PENDIDIKAN																
1 Sekolah	6	3.93%	5	0.39%	6	1.20%	5	4.78%	6	1.10%	5	5.26%	6	2.39%	-	-
2. BANGUNAN KESIHATAN																
1 Klinik Kesihatan 3																
2 Blok Sokongan C																
3 Blok Stor																
4 Blok TNB																
5 Depo Sampah																
6 Garaj Ambulan																
7 Pondok Pengawal																
8 Rumah Pam																
3. BANGUNAN PEJABAT KERAJAAN																
1 Pejabat	1	1.53%	-	-	1	13.33%	1	13.09%	1	0.54%	1	2.42%	1	90.23%	1	23.35%
4. RUMAH KEDIAMAN KERAJAAN																
1 Kelas D																
2 Kelas F																
3 Kelas G																
5. RUMAH KEDIAMAN BIASA																

Appendix 5: Questionnaire

UNIVERSITY OF MALAYA
FACULTY OF BUILT ENVIRONMENT
MASTER OF SCIENCE (BUILDING)
Building and Construction Economics

This questionnaire is prepared to study the estimating knowledge of experienced QS in both PWD and private consultants especially on Preliminary Cost Estimate or Pre-Tender Estimate that involve PWD procurements. All the data and information collected are for academic use only and treated as confidential. This research is funded by Universiti Teknologi MARA (UiTM) and Ministry of Higher Education (MOHE). The questionnaire is intended to be answered by:

a) QS PWD officer (J44 and above) or
b) Senior / Experienced QS in private consultant practice

All respondents' information for this research is provided by Corporate Division of CKUB, PWD. Completed questionnaire if possible should be submitted by **Monday, 2rd May 2011**

Senarai soalan ini disediakan untuk mengetahui pengetahuan penganggaran kos Pegawai Ukur Bahan JKR dan juga Perunding Ukur Bahan swasta yang berpengalaman semasa menyediakan anggaran kos awalan yang melibatkan projek kerajaan (Jabatan Kerja Raya). Semua data yang dikumpul akan digunakan untuk tujuan akademik sahaja dan maklumat yang dikumpul adalah rahsia. Penyelidikan ini dibiayai oleh Universiti Teknologi MARA (UiTM) dan Kementerian Pengajian Tinggi (KPT).Senarai soalan disediakan untuk dijawab oleh:

a) Pegawai Ukur Bahan(J44 dan keatas)
b) Senior / Eksekutif yang berpengalaman di perunding QS swasta

Semua maklumat mengenai responden untuk kajian ini disediakan oleh Bahagian Korporat CKUB, JKR. Senarai soalan yang telah siap jika mungkin dapatlah dihantar sebelum hari ***Isnin, 23hb Mei 2011***

SECTION A – Personal Details and Experience

Tick (√) "ONLY ONE" of the answers provided

1. How many years of experience do you have?

☐ Less than 5 years ☐ 5 – 10 years

☐ 11 to 15 years ☐ More than 15 years

2. Which organization are you currently attached to?

☐ Public Sector (PWD) ☐ Quantity Surveyor Consultant

3. Which estimate's value is more tolerant to client in public sector?

☐ Underestimated value ☐ Overestimated value

☐ Don't know

4. How much is the accuracy do you think the estimates should be prepared when it's compared with accepted tender bid?

☐ +/-5% ☐ +/-10% ☐ +/-15% ☐ +/-20%

☐ +/-25% ☐ +/-30% ☐ +/-35% ☐ +/-40%

5. Did your organisation ever done any performance review on the estimates prepared to measure its quality (accuracy) from time to time?

☐ Yes ☐ No ☐ Don't know

6. Did your organisation implement the systematic data collection system for future estimating use?

☐ Yes ☐ No ☐ Don't know

SECTION A – Personal Details and Experience (cont'd)

Tick (√) "ONLY ONE" of the answers provided

7. Did the QS sometimes intentionally mark-up their estimates because they did not want the estimates to be the lowest?

☐ Yes ☐ No ☐ Don't know

8. Are you satisfied with the current level of Preliminary Cost Estimates accuracy prepared by your company/department?

☐ Yes ☐ No ☐ Don't know

9. Do you think the estimating knowledge from local universities is adequate for practice?

☐ Yes ☐ No ☐ Don't know

10. Did you think new scientific based estimating techniques i.e. Mathematical, Knowledge based, Value-related and Neural models should be introduced by the government as additional methods in the current traditional estimating policy?

☐ Yes ☐ No ☐ Don't know

11. What amount should be used as the target in order to measure the performance of preliminary cost estimate?

☐ Lowest tender bid ☐ Accepted tender bid

☐ Average of the returned tender ☐ Final contract sum

☐ Don't Know

FOR QUESTION 12 T0 14:				
ASSESSMENT SCALES				
not important	*little important*	*somewhat important*	*important*	*very important*
1	*2*	*3*	*4*	*5*

SECTION B - Factors which affect the accuracy of preliminary cost estimates

12. How do you consider the significance of the following factors which influence the QS in preparing accurate Preliminary Cost Estimate for PWD? ("5" is the highest score)

Building scope (Plan shape, size m^2GFA, height, specification and performance)	1	2	3	4	5
Design team experience (architect, engineers and etc)	1	2	3	4	5
Unclear documentation (project brief / drawings)	1	2	3	4	5
Location of the project (site locality, soil conditions and extent of services)	1	2	3	4	5
Type and condition of contract	1	2	3	4	5
Basis of selection (open, selective and direct negotiation)	1	2	3	4	5
Commitment of client to project	1	2	3	4	5
Cost data (historical and current information)	1	2	3	4	5
Project technology and complexity level	1	2	3	4	5
Market conditions and sentiments	1	2	3	4	5
QS' experience	1	2	3	4	5
Ability of QS to cope with stress	1	2	3	4	5
Communication barrier	1	2	3	4	5
Familiarity of QS with the type of project	1	2	3	4	5
Perception of estimating importance	1	2	3	4	5
Expected level of error in estimate	1	2	3	4	5
Limited time to prepare estimate due to dateline	1	2	3	4	5
Rigorous estimating method used in the preparation of estimate	1	2	3	4	5
Application of new estimating techniques by your organisation	1	2	3	4	5
Availability of estimating procedures in organisation	1	2	3	4	5

SECTION C - Ways to improve estimating procedures

Part I - Priority of estimating process

13. How do you consider the importance/priority of the following process will improve the accuracy of the Preliminary Cost Estimate for PWD? ("5" is the highest score)

Proper design documentation and information management	1	2	3	4	5
Effective communication and coordination between designers	1	2	3	4	5
Sufficient design information from the designers	1	2	3	4	5
Ascertained assumptions from designers and clients	1	2	3	4	5
Establish formal feedback for design and estimating activities	1	2	3	4	5
Realistic time for estimating activity	1	2	3	4	5
Use more rigorous estimating method	1	2	3	4	5
Incorporate market sentiments and economic conditions into estimate	1	2	3	4	5
Tender documents used as estimate	1	2	3	4	5
Quantification of design and construction risks	1	2	3	4	5
Cost planning and cost control during design stage	1	2	3	4	5
Subdivided the large item into small items to reduce pricing errors	1	2	3	4	5
Improve methods of selection, adjustments and application of cost data	1	2	3	4	5
Update cost data with new cost and create feedback system for improving estimating accuracy	1	2	3	4	5

Part II - Improvement by introduction of new technique, training and etc

14. How do you assess the priority of the following introduction will improve the accuracy of the Preliminary Cost Estimate for PWD projects? ("5" is the highest score)

Investing and collaborating in cost estimate research between PWD and consultants	1	2	3	4	5
Sharing of Cost Data among private consultants and PWD	1	2	3	4	5
Introduction of scientific based estimating methods i.e. Mathematical, Knowledge based, Value-related and Neural models as additional tools for decision making	1	2	3	4	5
Introduction of value engineering for estimate as course of action will be coordinated and comprehensively prepared	1	2	3	4	5
Investing in estimating training for QS officers / consultants' executives	1	2	3	4	5
Introduction of standardized rules of measurement for estimating and cost planning in detail by BQSM and ISM	1	2	3	4	5

Prepared by: Mohd Azrai Bin Azman

Contact: 017-6016945 / azrai@siswa.um.edu.my

Appendix 6: Schedule of original project data collection

Project No.	Estimate + (C+V)	Estimate - (C+V)	Accepted Tender + (C+V)	Accepted tender - (C+V)	Lowest Bid	Mean of the bids	Amount of C+V at estimate	Amount of C+V tender stage
1	6,177,485.34	5,835,700.32	5,626,000.00	5,300,320.00	5,038,880.00	5545172.71	341,785.02	325,680.00
2	9,258,741.00	8,763,741.00	8,219,000.00	7,720,120.00	6,765,000.00	7374624.00	495,000.00	498,880.00
3	5,457,951.40	5,002,951.40	4,943,000.00	4,638,582.00	4,205,000.00	4956937.63	455,000.00	304,418.00
4	7,540,000.00	7,060,590.00	7,146,000.00	6,690,190.00	4,545,384.40	6302913.04	479,410.00	455,810.00
5	5,721,500.00	5,467,639.00	4,978,600.00	4,683,387.39	4,125,208.00	4367876.91	253,861.00	295,212.61
6	6,476,045.00	6,276,045.00	5,568,000.00	5,089,000.00	4,991,599.00	5396657.00	200,000.00	479,000.00
7	7,195,350.00	6,845,350.00	5,927,600.00	5,505,555.00	5,327,040.00	5584025.65	350,000.00	422,045.00
8	7,286,852.60	6,786,852.60	6,098,000.00	5,728,260.00	5,308,000.00	5600067.18	500,000.00	369,740.00
9	7,697,883.74	7,283,698.80	6,383,400.00	5,999,239.00	5,742,700.00	6201734.75	414,184.94	384,161.00
10	6,832,370.88	6,459,400.84	5,414,900.00	5,099,280.00	5,099,280.00	5656201.41	372,970.04	315,620.00
11	6,287,245.00	6,087,245.00	5,450,000.00	5,000,033.11	5,000,033.11	5461868.10	200,000.00	449,966.89
12	5,444,843.40	4,998,843.40	5,317,000.00	4,986,998.00	3,699,145.73	4742894.57	446,000.00	330,002.00
13	5,400,904.00	5,000,904.00	5,398,000.00	4,943,434.34	3,621,322.44	4512281.11	400,000.00	454,565.66
14	6,770,500.00	6,450,427.90	6,811,500.40	5,576,256.66	4,639,525.00	5314649.00	320,072.10	1,235,243.74
15	6,247,000.00	5,748,100.00	5,409,000.00	5,039,530.00	4,692,700.00	4912818.65	498,900.00	369,470.00
16	6,765,000.00	6,220,400.00	5,510,000.00	5,129,755.00	4,895,970.00	5158790.05	544,600.00	380,245.00
17	5,185,000.00	4,931,350.00	5,070,000.00	4,788,939.00	3,999,976.00	4656806.73	253,650.00	281,061.00
18	3,163,000.00	2,979,904.00	2,684,000.00	2,513,800.00	1,995,360.00	2416490.92	183,096.00	170,200.00
19	3,402,000.00	3,205,400.00	3,309,000.00	3,015,276.00	2,388,170.00	2833800.60	196,600.00	293,724.00
20	2,747,000.00	2,443,225.00	2,580,000.00	2,383,800.00	2,081,100.00	2364739.25	303,775.00	196,200.00
21	2,647,000.00	2,488,000.00	2,510,000.00	2,295,156.00	2,141,100.00	2361068.50	159,000.00	214,844.00
22	2,747,000.00	2,479,916.00	2,522,000.00	2,255,525.00	2,120,008.80	2217543.23	267,084.00	266,475.00
23	2,917,000.00	2,834,500.00	2,730,000.00	2,467,700.00	2,333,555.00	2450981.88	82,500.00	262,300.00
24	2,937,000.00	2,856,500.00	2,681,000.00	2,502,034.40	2,272,360.00	2398331.18	80,500.00	178,965.60
25	2,567,000.00	2,249,064.00	2,276,000.00	2,027,390.00	1,726,068.00	1890017.31	317,936.00	248,610.00
26	3,395,000.00	3,324,420.00	3,000,000.00	2,775,339.40	2,456,995.00	2709745.40	70,580.00	224,660.60
27	3,040,000.00	2,917,750.00	2,895,000.00	2,676,340.00	2,528,953.00	2698671.13	122,250.00	218,660.00
28	4,467,000.00	4,344,510.00	4,060,000.00	3,788,788.00	3,464,160.60	3877898.73	122,490.00	271,212.00
29	3,013,000.00	2,924,956.00	2,626,000.00	2,380,230.50	2,208,360.00	2333323.31	88,044.00	245,769.50
30	3,421,700.00	3,361,700.00	2,720,000.00	2,507,730.00	2,507,730.00	2765982.85	60,000.00	212,270.00
31	3,270,000.00	3,197,766.00	3,170,000.00	2,936,000.00	2,695,558.00	2948772.15	72,234.00	234,000.00
32	3,985,000.00	3,893,900.00	3,345,000.00	3,118,962.00	2,388,907.00	2947811.75	91,100.00	226,038.00
33	2,617,250.00	2,556,000.00	2,475,000.00	2,296,999.00	2,158,000.00	2281988.38	61,250.00	178,001.00
34	476,648.00	459,648.00	473,650.00	438,250.00	351,794.00	433132.38	17,000.00	35,400.00
35	2,981,000.00	2,917,480.00	2,675,100.00	2,480,036.40	2,230,245.00	2387590.86	63,520.00	195,063.60
36	2,328,000.00	2,034,600.00	2,318,000.00	2,177,718.90	1,747,470.00	2150952.74	293,400.00	140,281.10
37	2,333,240.00	2,097,240.00	2,325,360.00	2,208,795.08	2,008,330.00	2182297.93	236,000.00	116,564.92
38	365,000.00	348,300.00	334,000.00	307,177.40	268,800.00	327818.16	16,700.00	26,822.60
39	378,000.00	338,000.00	329,780.00	304,680.00	238,986.00	300610.25	40,000.00	25,100.00
40	3,160,000.00	2,978,000.00	3,055,200.00	2,886,700.00	2,737,760.00	2902473.13	182,000.00	168,500.00
41	476,648.00	459,648.00	461,750.00	430,250.00	430,250.00	448440.00	17,000.00	31,500.00
42	459,500.00	415,500.00	361,000.00	338,800.00	328,700.00	353000.00	44,000.00	22,200.00
43	2,435,492.00	2,415,492.00	2,573,000.00	2,446,000.00	2,199,900.00	2306316.00	20,000.00	127,000.00
44	4,217,700.00	3,975,200.00	3,290,000.00	3,079,900.00	3,010,250.00	3310316.63	242,500.00	210,100.00
45	3,538,000.00	3,056,116.00	2,940,000.00	2,765,734.50	2,123,396.00	2690363.56	481,884.00	174,265.50
46	3,779,000.00	3,279,690.00	3,139,010.00	2,888,848.00	2,591,256.00	2738623.41	499,310.00	250,162.00
47	3,335,249.15	3,063,512.80	2,539,000.00	2,382,233.00	2,238,315.20	2478712.17	271,736.35	156,767.00
48	4,019,500.00	3,789,500.00	3,346,700.00	3,118,880.00	3,020,000.00	3251978.09	230,000.00	227,820.00
49	549,517.32	499,540.30	529,900.00	487,780.00	487,780.00	527267.60	49,977.02	42,120.00
50	1,620,478.70	1,495,694.00	1,509,000.00	1,412,400.00	1,119,710.00	1453754.63	124,784.70	96,600.00
51	3,550,000.00	3,322,000.00	3,414,000.00	3,202,222.22	2,478,311.00	3004385.12	228,000.00	211,777.78
52	3,912,550.00	3,682,550.00	3,345,500.00	3,137,197.00	2,864,175.00	3195358.13	230,000.00	208,303.00
53	349,405.00	293,405.00	360,000.00	337,850.00	320,050.00	340899.35	56,000.00	22,150.00
54	361,450.00	309,450.00	383,000.00	367,963.60	303,330.00	350597.80	52,000.00	15,036.40
55	420,420.00	371,800.00	398,000.00	345,200.00	337,047.00	359369.38	48,620.00	52,800.00
56	4,112,980.00	3,428,980.00	3,792,000.00	3,549,992.00	2,741,120.60	3310792.42	684,000.00	242,008.00
57	3,225,500.00	3,035,945.00	2,502,000.00	2,378,000.00	2,271,915.00	2412456.65	189,555.00	124,000.00
58	343,000.00	320,400.00	401,000.00	367,350.00	276,000.00	341914.20	22,600.00	33,650.00
59	2,058,925.10	1,913,262.00	1,975,000.00	1,847,700.00	1,507,370.00	1776143.88	145,663.10	127,300.00
60	403,470.00	347,470.00	421,000.00	388,000.00	380,000.00	390226.54	56,000.00	33,000.00
61	414,000.00	379,400.00	389,000.00	358,662.00	320,000.00	373966.55	34,600.00	30,338.00
62	335,000.00	313,500.00	388,000.00	350,120.00	284,000.00	340746.75	21,500.00	37,880.00
63	3,001,500.00	2,981,500.00	3,365,000.00	3,118,684.00	3,118,684.00	3365001.76	20,000.00	246,316.00
64	2,281,450.00	2,081,450.00	2,010,100.00	1,769,100.00	1,769,100.00	1870080.83	200,000.00	241,000.00
65	944,000.00	844,000.00	805,000.00	740,272.80	603,669.00	707121.85	100,000.00	64,727.20
66	3,794,000.00	3,443,900.00	3,266,000.00	3,086,400.00	2,777,700.00	3118437.50	350,100.00	179,600.00
67	2,835,000.00	2,667,500.00	2,422,000.00	2,267,700.00	2,000,000.00	2221049.38	167,500.00	154,300.00
68	3,772,400.00	3,422,400.00	3,503,000.00	3,304,800.00	3,046,695.00	3301299.31	350,000.00	198,200.00
69	4,728,650.00	4,378,650.00	4,300,000.00	4,012,900.00	3,550,600.00	3939769.13	350,000.00	287,100.00
70	2,319,300.00	2,144,300.00	2,500,000.00	2,335,100.00	2,102,500.00	2339334.69	175,000.00	164,900.00
71	2,770,000.00	2,624,790.00	2,320,000.00	2,157,520.00	1,707,978.00	2088745.95	145,210.00	162,480.00
72	2,764,000.00	2,604,520.00	2,418,000.00	2,262,485.00	2,102,102.00	2227809.81	159,480.00	155,515.00
73	3,376,100.00	3,232,100.00	3,230,000.00	3,009,160.00	2,336,717.00	2761631.35	144,000.00	220,840.00
74	2,926,000.00	2,714,300.00	2,620,000.00	2,437,370.00	2,381,381.00	2551547.52	211,700.00	182,630.00
75	3,888,270.00	3,798,270.00	3,367,000.00	3,120,750.00	3,120,750.00	3631190.43	90,000.00	246,250.00
76	3,357,074.00	3,087,074.00	2,811,000.00	2,635,691.36	1,956,875.76	2405136.96	270,000.00	175,308.64
77	4,414,200.00	4,134,200.00	3,565,800.00	3,340,700.00	3,340,700.00	4034497.00	280,000.00	225,100.00
78	363,068.50	327,068.50	325,000.00	296,866.00	295,000.00	338127.58	36,000.00	28,134.00
79	581,540.00	481,540.00	417,000.00	395,000.00	321,532.00	365127.60	100,000.00	22,000.00
80	2,922,925.00	2,722,925.00	2,385,000.00	2,183,452.00	2,183,452.00	2434304.25	200,000.00	201,548.00
81	3,570,000.00	3,399,900.00	3,290,000.00	3,079,900.00	3,010,250.00	3310316.63	170,100.00	210,100.00
82	2,689,580.00	2,409,580.00	2,341,980.00	2,184,980.00	1,796,040.00	2127601.67	280,000.00	157,000.00
83	5,151,123.32	4,858,188.88	4,456,000.00	4,125,166.00	3,982,500.00	4179898.50	292,934.44	330,834.00
Total	280,470,476.45	262,976,229.74	250,539,830.40	232,508,387.06	207,883,635.64		17,494,246.71	18,031,443.34

VOP in the estimate	%	VOP at tender stage	%	Contingencies in the estimate	%	Contingencies at tender stage	%	Bias Accepted Bid + (C+V)	Bias Accepted Bid - (C+V)	Bias Lowest Bid
50,000.00	0.86	185,066.00	3.49	291,785.02	4.92	140,614.00	2.53	9.80	10.10	15.81
345,000.00	3.94	289,100.00	3.74	150,000.00	1.62	209,780.00	2.58	12.65	13.52	29.55
96,000.00	1.92	178,600.00	3.85	359,000.00	7.00	125,818.00	2.60	10.42	7.86	18.98
284,379.50	4.03	271,000.00	4.05	195,030.50	2.63	184,810.00	2.60	5.51	5.54	55.34
150,000.00	2.74	174,600.00	3.73	103,861.00	1.84	120,612.61	2.47	14.92	16.75	32.54
100,000.00	1.59	269,000.00	5.29	100,000.00	1.56	210,000.00	3.85	16.31	23.33	25.73
150,000.00	2.19	234,480.00	4.26	200,000.00	2.85	187,565.00	3.18	21.39	24.34	28.50
200,000.00	2.95	221,900.00	3.87	300,000.00	4.28	147,840.00	2.47	19.50	18.48	27.86
50,000.00	0.69	225,599.45	3.76	364,184.94	4.95	158,561.55	2.52	20.59	21.41	26.83
50,000.00	0.77	179,579.00	3.52	322,970.04	4.95	136,041.00	2.55	26.18	26.67	26.67
100,000.00	1.64	250,001.66	5.00	100,000.00	1.61	199,965.23	3.78	15.36	21.74	21.74
86,000.00	1.72	193,300.00	3.88	360,000.00	7.04	136,702.00	2.62	2.40	0.24	35.14
150,000.00	3.00	248,000.00	5.02	250,000.00	4.83	206,565.66	3.95	0.05	1.16	38.10
220,000.00	3.41	1,158,000.00	20.77	100,072.10	1.49	77,243.74	1.14	-0.60	15.68	39.03
200,000.00	3.48	202,411.80	4.02	298,900.00	5.00	167,058.20	3.17	15.49	14.06	22.49
200,000.00	3.22	211,896.75	4.13	344,600.00	5.33	168,348.25	3.12	22.78	21.26	27.05
130,000.00	2.64	147,595.95	3.08	123,650.00	2.42	133,465.05	2.68	2.27	2.97	23.28
89,390.00	3.00	97,875.00	3.89	93,706.00	3.02	72,325.00	2.73	17.85	18.54	49.34
160,000.00	4.99	126,106.56	4.18	36,600.00	1.08	167,617.44	5.29	2.81	6.31	34.22
90,000.00	3.68	95,076.00	3.99	213,775.00	8.36	101,124.00	4.01	6.47	2.49	17.40
80,000.00	3.22	114,687.36	5.00	79,000.00	3.05	100,156.64	4.09	5.46	8.40	16.20
80,000.00	3.23	98,421.06	4.36	187,084.00	7.25	168,053.94	7.03	8.92	9.95	16.98
10,000.00	0.35	111,606.00	4.52	72,500.00	2.53	150,694.00	5.75	6.85	14.86	21.47
60,000.00	2.10	103,983.11	4.16	20,500.00	0.70	74,982.49	2.83	9.55	14.17	25.71
100,000.00	4.45	80,661.00	3.98	217,936.00	9.18	167,949.00	7.82	12.79	10.93	30.30
30,000.00	0.90	134,972.36	4.86	40,580.00	1.20	89,688.24	3.04	13.17	19.78	35.30
80,000.00	2.74	113,030.40	4.22	42,250.00	1.40	105,629.60	3.73	5.01	9.02	15.37
89,000.00	2.05	138,000.00	3.64	33,490.00	0.75	133,212.00	3.37	10.02	14.67	25.41
30,000.00	1.03	130,000.00	5.46	58,044.00	1.94	115,769.50	4.54	14.74	22.89	32.45
30,000.00	0.89	117,610.80	4.69	30,000.00	0.88	94,659.20	3.55	25.80	34.05	34.05
30,000.00	0.94	142,740.00	4.86	42,234.00	1.30	91,260.00	2.93	3.15	8.92	18.63
60,000.00	1.54	130,458.36	4.18	31,100.00	0.78	95,579.64	2.91	19.13	24.85	63.00
30,000.00	1.17	87,249.95	3.80	31,250.00	1.19	90,751.05	3.74	5.75	11.28	18.44
17,000.00	3.70	16,000.00	3.65	0.00	0.00	19,400.00	4.02	0.63	4.88	30.66
30,000.00	1.03	91,991.82	3.71	33,520.00	1.13	103,071.78	3.95	11.44	17.64	30.81
141,722.00	6.97	78,208.50	3.59	151,678.00	6.88	62,072.60	2.72	0.43	-6.57	16.43
130,000.00	6.20	81,564.83	3.69	106,000.00	4.70	35,000.09	1.51	0.34	-5.05	4.43
10,000.00	2.87	9,041.37	2.94	6,700.00	1.77	17,781.23	5.37	9.28	13.39	29.58
15,000.00	4.44	9,100.00	2.99	25,000.00	6.85	16,000.00	4.68	14.62	10.94	41.43
112,000.00	3.76	92,500.00	3.20	70,000.00	2.25	76,000.00	2.53	3.43	3.16	8.78
17,000.00	3.70	12,600.00	2.93	0.00	0.00	18,900.00	4.01	3.23	6.83	6.83
24,000.00	5.78	6,200.00	1.83	20,000.00	4.40	16,000.00	4.47	27.29	22.64	26.41
0.00	0.00	63,000.00	2.58	20,000.00	0.82	64,000.00	2.54	-5.34	-1.25	9.80
137,485.00	3.46	89,440.00	2.90	105,015.00	2.53	120,660.00	3.74	28.20	29.07	32.06
152,805.80	5.00	92,485.60	3.34	329,078.20	10.09	81,779.90	2.80	20.34	10.50	43.93
159,434.50	4.86	59,887.40	2.07	339,875.50	9.81	190,274.60	6.39	20.39	13.53	26.57
104,513.98	3.41	87,400.00	3.67	167,222.37	5.23	69,367.00	2.82	31.36	28.60	36.87
80,000.00	2.11	142,400.00	4.57	150,000.00	3.85	85,420.00	2.61	20.10	21.50	25.48
25,000.00	5.00	19,639.00	4.03	24,977.02	4.59	22,481.00	4.21	3.70	2.41	2.41
50,000.00	3.34	46,620.00	3.30	74,784.70	4.78	49,980.00	3.28	7.39	5.90	33.58
126,450.00	3.81	120,000.00	3.75	101,550.00	2.82	91,777.78	2.69	3.98	3.74	34.04
80,000.00	2.17	123,000.00	3.92	150,000.00	3.95	85,303.00	2.61	16.95	17.38	28.57
18,000.00	6.13	10,000.00	2.96	38,000.00	11.54	12,150.00	3.32	-2.94	-13.16	-8.33
18,000.00	5.82	8,036.40	2.18	34,000.00	9.84	7,000.00	1.80	-5.63	-15.90	2.02
18,620.00	5.01	34,000.00	9.85	30,000.00	7.61	18,800.00	4.73	5.63	7.71	10.31
186,000.00	5.42	150,000.00	4.23	498,000.00	13.75	92,008.00	2.47	8.46	-3.41	25.09
70,000.00	2.31	70,000.00	2.94	119,555.00	3.83	54,000.00	2.19	28.92	27.67	33.63
10,000.00	3.12	13,100.00	3.57	12,600.00	3.77	20,550.00	5.16	-14.46	-12.78	16.09
50,000.00	2.61	66,985.00	3.63	95,663.10	4.82	60,315.00	3.05	4.25	3.55	26.93
18,000.00	5.18	14,000.00	3.61	38,000.00	9.91	19,000.00	4.52	-4.16	-10.45	-8.56
17,600.00	4.64	12,600.00	3.51	17,000.00	4.24	17,738.00	4.68	6.43	5.78	18.56
9,000.00	2.87	17,500.00	5.00	12,500.00	3.83	20,380.00	5.28	-13.66	-10.46	10.39
20,000.00	0.67	155,934.20	5.00	0.00	0.00	90,381.80	2.74	-10.80	-4.40	-4.40
100,000.00	4.80	126,000.00	7.12	100,000.00	4.55	115,000.00	5.95	13.50	17.66	17.66
50,000.00	5.92	31,057.97	4.20	50,000.00	5.38	33,669.23	4.15	17.27	14.01	39.81
150,100.00	4.36	94,370.00	3.06	200,000.00	5.50	85,230.00	2.63	16.17	11.58	23.98
82,000.00	3.07	88,285.00	3.89	85,500.00	3.07	66,015.00	2.76	17.05	17.63	33.38
150,000.00	4.38	107,580.00	3.26	200,000.00	5.53	90,620.00	2.61	7.69	3.56	12.33
150,000.00	3.43	133,040.00	3.32	200,000.00	4.37	154,060.00	3.66	9.97	9.11	23.32
100,000.00	4.66	72,775.00	3.12	75,000.00	3.28	92,125.00	3.73	-7.23	-8.17	1.99
70,000.00	2.67	76,851.00	3.56	75,210.00	2.77	85,629.00	3.76	19.40	21.66	53.68
77,200.00	2.96	89,609.25	3.96	82,280.00	3.03	65,905.75	2.76	14.31	15.12	23.90
70,000.00	2.17	125,928.00	4.18	74,000.00	2.22	94,912.00	2.99	4.52	7.41	38.32
80,000.00	2.95	99,968.50	4.10	131,700.00	4.65	82,661.50	3.21	11.68	11.36	13.98
50,000.00	1.32	156,037.50	5.00	40,000.00	1.03	90,212.50	2.73	15.48	21.71	21.71
110,000.00	3.56	95,500.00	3.62	160,000.00	4.95	79,808.64	2.89	19.43	17.13	57.76
80,000.00	1.94	133,000.00	3.98	200,000.00	4.71	92,100.00	2.64	23.79	23.75	23.75
12,000.00	3.67	5,500.00	1.85	24,000.00	6.94	22,634.00	6.96	11.71	10.17	10.87
50,000.00	10.38	7,000.00	1.77	50,000.00	9.23	15,000.00	3.50	39.46	21.91	49.76
100,000.00	3.67	108,922.60	4.99	100,000.00	3.52	92,625.40	3.93	22.55	24.71	24.71
90,000.00	2.65	89,440.00	2.90	80,100.00	2.27	120,660.00	3.74	8.51	10.39	12.94
80,000.00	3.32	92,800.00	4.25	200,000.00	7.93	64,200.00	2.78	14.84	10.28	34.16
50,000.00	1.03	155,943.30	3.78	242,934.44	4.90	114,890.70	2.64	15.60	17.77	21.99
7,158,700.78	3.20	10,145,450.81	4.10	10,335,545.93	4.20	7,825,992.53	3.52	$\bar{x}$ = 10.82	11.18	25.05
								sd = 10.23	10.71	13.92
								cv = 9.23	9.63	11.13

Bias Lowest Bid	Bias Lowest Bid only	Bias - Mean of the bids	Size (m2)	PI (/m2GFA) - Accepted bids	PI (/m2GFA) - lowest bids	PI (/m2GFA) - mean of bids	Storey Height	Contract Period	No of Tender	State	Type of School	Class of Project
15.81		5.24	3,609.18	1,468.57	1,396.13	1,536.41	4	60	7	Johor	M	P
29.55		18.84	6,794.90	1,136.16	995.60	1,085.32	4	52	19	Johor	M	X
18.98		0.93	2,643.45	1,754.75	1,590.72	1,875.18	2	52	13	Johor	M	X
55.34		12.02	5,567.00	1,201.76	816.49	1,132.19	4	65	10	Melaka	M	X
32.54		25.18	3,047.00	1,537.05	1,353.86	1,433.50	4	30	21	N9	M	X
25.73		16.30	2,498.00	2,037.23	1,998.24	2,160.39	4	45	11	Johor	M	X
28.50		22.59	3,349.00	1,643.94	1,590.64	1,667.37	4	60	10	Johor	M	X
27.86		21.19	3,852.40	1,486.93	1,377.84	1,453.66	3	61	14	Johor	M	X
26.83		17.45	4,635.40	1,294.22	1,238.88	1,337.91	4	65	4	Johor	M	P
26.67	26.67	14.20	3,129.97	1,629.18	1,629.18	1,807.11	3	32	4	Johor	M	P
21.74	21.74	11.45	3,023.30	1,653.83	1,653.83	1,806.59	4	50	15	Johor	M	X
35.14		5.40	2,636.20	1,891.74	1,403.21	1,799.14	4	62	14	Johor	M	X
38.10		10.83	4,703.40	1,051.03	769.94	959.37	3	55	26	N9	R	X
39.03		21.37	3,344.15	1,667.47	1,387.36	1,589.24	2	56	16	N9	M	X
22.49		17.00	4,254.00	1,184.66	1,103.13	1,154.87	4	60	23	Kedah	M	X
27.05		20.58	4,066.00	1,261.62	1,204.12	1,268.76	3	42	17	Kedah	M	X
23.28		5.90	2,917.40	1,641.51	1,371.08	1,596.22	2	60	15	Kedah	M	X
49.34		23.32	2,098.00	1,198.19	951.08	1,151.81	4	42	20	Kedah	R	P
34.22		13.11	2,149.00	1,403.11	1,111.29	1,318.66	4	52	29	Kedah	M	P
17.40		3.32	1,310.00	1,819.69	1,588.63	1,805.14	3	52	20	Kedah	R	P
16.20		5.38	1,458.00	1,574.18	1,468.52	1,619.39	3	52	14	Kedah	R	P
16.98		11.83	1,146.20	1,967.83	1,849.60	1,934.69	1	60	27	Kedah	R	S
21.47		15.65	1,836.00	1,344.06	1,271.00	1,334.96	3	52	25	Kedah	M	P
25.71		19.10	1,836.00	1,362.76	1,237.67	1,306.28	3	52	33	Kedah	M	P
30.30		19.00	1,146.00	1,769.10	1,506.17	1,649.23	1	60	30	Kedah	M	S
35.30		22.68	2,607.00	1,064.57	942.46	1,039.41	4	42	22	Kedah	M	P
15.37		8.12	2,094.00	1,278.10	1,207.71	1,288.76	3	56	14	Kedah	M	X
25.41		12.03	2,905.00	1,304.23	1,192.48	1,334.90	4	52	10	Kedah	M	P
32.45		25.36	2,420.00	983.57	912.55	964.18	3	42	20	Kedah	R	P
34.05	34.05	21.54	2,751.00	911.57	911.57	1,005.45	4	48	21	Kedah	R	P
18.63		8.44	2,510.00	1,169.72	1,073.93	1,174.81	4	56	6	Kedah	R	P
63.00		32.09	2,958.00	1,054.42	807.61	996.56	4	52	26	Kedah	M	P
18.44		12.01	1,315.00	1,746.77	1,641.06	1,735.35	1	42	21	Kedah	M	S
30.66		6.12	300.00	1,460.83	1,172.65	1,443.77	1	26	14	Perak	R	S
30.81		22.19	2,567.00	966.12	868.81	930.11	4	56	26	Kedah	R	P
16.43		-5.41	1,350.00	1,613.13	1,294.42	1,593.30	3	42	16	Kedah	M	P
4.43		-3.90	1,388.00	1,591.35	1,446.92	1,572.26	3	42	16	Kedah	R	P
29.58		6.25	88.00	3,490.65	3,054.55	3,725.21	1	32	10	Perak	M	S
41.43		12.44	67.50	4,513.78	3,540.53	4,453.49	1	26	15	Perak	M	S
8.78		2.60	2,401.00	1,202.29	1,140.26	1,208.86	2	65	18	Perak	R	X
6.83	6.83	2.50	270.72	1,589.28	1,589.28	1,656.47	1	26	18	Perak	M	S
26.41		17.71	67.50	5,019.26	4,869.63	5,229.63	1	36	8	Perak	M	S
9.80		4.73	2,631.00	929.68	836.15	876.59	3	52	24	Perak	R	P
32.06		20.09	2,474.00	1,244.91	1,216.75	1,338.04	2	52	9	Kedah	M	P
43.93		13.59	1,272.24	2,173.91	1,669.02	2,114.67	1	42	16	Kedah	M	S
26.57		19.76	2,513.70	1,149.24	1,030.85	1,089.48	4	42	17	Kedah	R	P
36.87		23.59	1,910.70	1,246.79	1,171.46	1,297.28	4	50	15	Johor	M	X
25.48		16.53	2,007.60	1,553.54	1,504.28	1,619.83	3	52	13	Johor	M	X
2.41	2.41	-5.26	279.00	1,748.32	1,748.32	1,889.85	2	24	5	Johor	R	S
33.58		2.88	838.00	1,685.44	1,336.17	1,734.79	2	44	8	Johor	R	S
34.04		10.57	2,530.00	1,265.70	979.57	1,187.50	4	68	17	Melaka	M	X
28.57		15.25	2,076.00	1,511.17	1,379.66	1,539.19	3	52	11	Johor	M	X
-8.33		-13.93	67.50	5,005.19	4,741.48	5,050.36	1	30	16	Melaka	R	S
2.02		-11.74	67.50	5,451.31	4,493.78	5,194.04	1	12	14	Melaka	R	S
10.31		3.46	67.50	5,114.07	4,993.29	5,323.99	1	28	9	Melaka	M	S
25.09		3.57	2,319.00	1,530.83	1,182.03	1,427.68	4	52	18	Melaka	M	X
33.63		25.84	1,241.00	1,916.20	1,830.71	1,943.96	1	32	17	N9	M	S
16.09		-6.29	67.50	5,442.22	4,088.89	5,065.40	1	20	9	Melaka	M	S
26.93		7.72	1,117.00	1,654.16	1,349.48	1,590.10	2	63	12	Johor	R	S
-8.56		-10.96	67.50	5,748.15	5,629.63	5,781.13	1	28	14	Melaka	R	S
18.56		1.45	67.50	5,313.51	4,740.74	5,540.25	1	26	7	Melaka	R	S
10.39		-8.00	67.50	5,186.96	4,207.41	5,048.10	1	28	9	Melaka	R	S
-4.40	-4.40	-11.40	2,160.00	1,443.84	1,443.84	1,557.87	4	46	5	Melaka	R	P
17.66	17.66	11.30	810.00	2,184.07	2,184.07	2,308.74	4	48	6	Johor	R	P
39.81		19.36	317.00	2,335.25	1,904.32	2,230.67	1	32	22	Kedah	M	S
23.98		10.44	2,366.40	1,304.26	1,173.81	1,317.80	4	52	12	Kedah	M	P
33.38		20.10	1,750.00	1,295.83	1,142.86	1,269.17	3	42	23	Kedah	M	P
12.33		3.67	2,433.90	1,357.82	1,251.77	1,356.38	4	52	14	Kedah	M	X
23.32		11.14	3,001.50	1,336.96	1,182.94	1,312.60	4	56	16	Kedah	M	P
1.99		-8.34	1,363.50	1,712.58	1,541.99	1,715.68	3	42	11	Kedah	M	X
53.68		25.66	1,799.60	1,198.89	949.09	1,160.67	4	42	20	Kedah	M	P
23.90		16.91	1,625.80	1,391.61	1,292.96	1,370.29	3	42	28	Kedah	R	P
38.32		17.04	2,223.00	1,353.65	1,051.15	1,242.30	4	42	17	Kedah	R	P
13.98		6.38	2,065.00	1,180.32	1,153.21	1,235.62	4	42	24	Kedah	R	P
21.71	21.71	4.60	2,610.60	1,195.41	1,195.41	1,390.94	3	52	6	Johor	M	X
57.76		28.35	2,283.90	1,154.03	856.81	1,053.08	4	60	13	Johor	M	P
23.75	23.75	2.47	2,738.00	1,220.12	1,220.12	1,473.52	2	52	6	Johor	M	X
10.87		-3.27	67.50	4,398.01	4,370.37	5,009.30	1	26	10	Johor	M	S
49.76		31.88	67.50	5,851.85	4,763.44	5,409.30	1	24	5	Johor	M	S
24.71	24.71	11.86	1,237.50	1,764.41	1,764.41	1,967.11	4	40	13	Johor	M	X
12.94		2.71	2,366.40	1,301.51	1,272.08	1,398.88	4	52	9	Kedah	M	P
34.16		13.25	1,101.14	1,984.29	1,631.07	1,932.18	3	56	6	N9	R	X
21.99		16.23	2,720.43	1,516.37	1,463.92	1,536.48	4	84	4	Johor	M	P
25.05	17.51	10.88	Note: R = Primary school, M = Secondary school, P = Mainbuilding, S = Ancillary building. X = Mix buildings and (C+V) = Contingencies + VOP									
13.92	12.05	10.58										
11.13	10.25	9.54										