ACCURACY IN DESIGN COST ESTIMATING

by

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KEYWORD

Since good decisions can lead to bad outcomes (and vice versa) decision makers cannot infallibly be graded by their results.

Brown, Kahr & Peterson, 1974.

DEDICATION

To LOVE that has brought me this far; and will lead me HOME.

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ABSTRACT

ACCURACY IN DESIGN COST ESTIMATING

The level of achieved accuracy in design cost estimating is generally accepted by researchers as being less than desirable. Low accuracy has been attributed to the nature of historical cost data, estimating method and the expertise of the estimator. Previous researchers have suggested that the adoption of resource based estimating by designers could eliminate data and method-related problems. The work in this thesis has shown that this will not solve the problem of inaccuracy in estimating.

A major problem in assessing accuracy in design cost estimating has been the absence of a generally agreed definition of the 'true cost' of a construction project. Hitherto, studies of accuracy in design cost estimating have relied solely on the assessment of errors using the low bid as a datum. Design cost estimators do not always focus on predicting the low bid. Rather, they may focus on the lowest, second lowest, third lowest or any other bid, mean/median of bids, or sometimes, on just being 'within the collection'. This has resulted in designers and researchers having different views on the level of achieved accuracy in estimating. To resolve this problem, an analysis package, ACCEST (ACCuracy in ESTimating), was developed to facilitate 'fair' assessment of accuracy in design cost estimates.

Tests - using cost data from 7 offices, the ACCEST package and the OPEN ACCESS II package on an IBM PS/2 - have shown that error in design cost estimating (averaging 3.6% higher than the predicted parameter) is much lower than portrayed in construction literature (average13% higher than the low bid). Also, false associations between project environment factors (such as geographical location, market conditions, number of bidders, etc.) and the level of achieved accuracy has been developed by researchers through using the low bid as a datum.

Previous researches have also demonstrated that design estimators do not learn sufficiently from experience on past projects. A controlled experiment on design cost estimating information selection was designed to explain this occurrence. Failure to

learn, and the persistent use of information on one project for estimating, has been shown to result from the method of information storage in design offices, the illusion of validity of inaccurate rules and over-confidence resulting from inaccurate assessment of individual expertise. A procedure for aiding learning from experience in design cost estimating has been suggested.

Finally, the work has shown that by distinguishing between different trades, and selectively applying different estimating strategies, based on the objective evaluation of the uncertainty associated with cost prediction for each trade, error in design cost estimating could be further reduced.

Two formulae for predicting tender prices using data generated from historical cost estimating experience are presented.

DECLARATION

No portion of the research referred to in this thesis has been submitted in support of an application for another degree or qualification at this or any other university or other institution of learning.

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The research described in this thesis has been completed in the area of design phase construction cost estimating as a service to the client and the design process with the help of many.

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GLOSSARY OF TERMS

Accuracy	The closeness of a measured quantity to the real value or the absence of error in a measured quantity.
Contract Estimate	Estimate of construction costs made by a contractor for the purpose of submitting a competitive tender.
Design phase	The period in a project's life when it is being designed. This is usually but by no means limited to the period between project conception and tendering.
Design estimate	A cost estimate prepared to aid the design of a construction project.
Estimate	The process of predicting costs of construction.
Estimate Consistency	A measure of the ability to estimate costs within a specified range of accuracy.
Estimate reliability	The confidence level associated with the expected accuracy of an estimate.
Expert (in estimating)	An experienced estimator possessing knowledge of the method and process of estimating acquired over a long period of time. An expertise is acquired through experience rather than reading only.
Learning from experience	Using information acquired during the course of estimating to improve the accuracy of future estimates.
Low Bid	The lowest bid submitted in a tendering exercise.
Precision (of estimate)	A measure of the the distribution of estimates around the predicted or 'true' cost.
Tender	An offer to build submitted by a contractor comprising estimate of construction cost and a mark-up to cater for profit and overheads.

Tender estimate Estimate of tender prices made by designers or the last design estimate prior to tender.

Chapter 1

GENERAL INTRODUCTION

"Which of you intending to build a tower does not sit down first and estimate the cost whether he has enough to finish it? Lest after he has laid the foundation, and is unable to finish it, all who see it begin to mock him, saying, 'this man started to build and was not able to finish it'"

-The Holy Bible, Luke 14:28-30.

1.0 INTRODUCTION TO THE SUBJECT

History and our daily experiences provide examples of prediction-based decisions that have resulted in fiascoes. America intervened in Vietnam believing that intervention would stop the advance of communism. It didn't. The Soviet Union too have just retreated from Afghanistan after years of fighting. Rain-soaked holidays often result from inaccurate weather forecasts, money is lost on the stock exchange daily and overcrowded highways advertise inaccurate predictions of traffic volume. Such occurrences are common. The underlying theme is uncertainty. Inaccuracies in forecasts derive from uncertainty factors outside the control of the forecaster.

Arguably, construction work suffers the effects of uncertainty more than most human undertakings and construction cost estimating is perhaps the most error-prone construction activity. Cost estimating is error prone for two reasons. First it depends on historical cost data. In construction work, history has a rather unusual tendency of not repeating itself. Secondly, cost estimating attempts to predict future human actions in a world where things are never static. The result has been that accuracy achieved in cost estimating has been less than desirable (see Ashworth and Skitmore, 1982 and Ogunlana and Thorpe, 1987). Industry practitioners and researchers have long recognised this and have expressed concern about cost estimating inaccuracies.

Concern with improving accuracy in cost estimating is so strong that, continually, effort is made to improve the practice and the method of estimating. This concern is appropriate when viewed in light of the performance on some major construction projects in the U.K. and abroad. For example, consider the data in Table 1.1. The cost consultants on the Barbican Arts Centre project may say, "ours was much better than the others." However, the promoters of the project, faced with 371% increase in cost, may think twice before employing the services of the same estimators in future.

Table 1.1: **Estimating performance on some major projects.**

Project	Estimate (£/$m)	Actual Cost (£/$m)	difference (%)
Sydney Opera House	2.5	87	3380
Thames Barrier	23	400	1639
Barbican Arts Centre	17	80	371
Australian Parliament building	$220	$1068*	385

* Estimate collected from the Australian High Commission, London. External works on the project yet to be completed.

The value of accuracy in predictions may be further demonstrated by recent events in the UK economy. The Chancellor's prediction of the level of inflation in October 1988 was 5.8%. The actual figure was calculated as 6.4% at the end of the month. The 9.4% underestimation necessitated introduction of monetary measures to curb inflation. The predicted trade deficit for the same month was £0.5bn while actual trade deficit stood at £2.4bn (80% underestimation). The deficit not only embarassed the government but also cast doubt on the reliability of other government predictions.

Inaccurate predictions on a construction project may not have adverse effects on the whole industry. However, a construction client whose project is plagued with potentially massive cost overrun has three options:

1. to abort the the project and incur loss.
2. to continue with the project while seeking additional funding.
3. to reduce the scope and/or quality of the project.

None of the options listed endears the construction cost consultant to the client who always remembers the initial cost prediction. All are detrimental to the construction industry as a whole and the client's project management effort. However, the cost consultant should not be blamed without a proper understanding of what his problems are. Projects often fall foul of the biblical injuction quoted at the top of this chapter not because realistic cost estimates were not produced, but rather, because the most realistic estimate can not anticipate all eventualities. Cost estimating is simply an inprecise art. There are too many variables in the equation to guarantee accuracy.

The experience of the managers of the Australian Parliamant Building is worth noting as it demonstrates the effects of cost overruns on construction projects. The managers reported that,

> "in order to keep cost within budget, reductions were made in the quality of finishes and the scope of landscaping. Also, significant reductions were made to the sound and vision systems installed and to the quality and amount of furniture acquired for the building." (Australian High Commission, 1988)

Such experiences underly the need for accurate cost predictions at the design phase and illustrate the vagaries of predicting costs in a changing environment.

The value of good estimating to project management is best illustrated by the Freiman's curve presented below. Figure 1.1 can be interpreted thus:

1. the greater the understimate the greater the actual expenditure;
2. the greater the overestimate, the greater the actual expenditure;
3. the most realistic estimate results in the economical project cost.

Understanding what is wrong with cost estimating is a precondition to determining appropriate strategies for accuracy improvement.

1.2 AIM AND OBJECTIVES

In view of the importance of good cost estimating to the project management process, this research concentrates on determining appropriate strategies for improving accuracy in design cost estimates. Achieving this aim necessitated a thorough study of the findings of other researchers and an investigation of the techniques for assessing accuracy in design estimates. The research had the following objectives to realise the aim of improving design cost estimating accuracy:

1. to examine the problems with design cost estimating;
2. to devise a fair procedure for determining accuracy in design estimates;

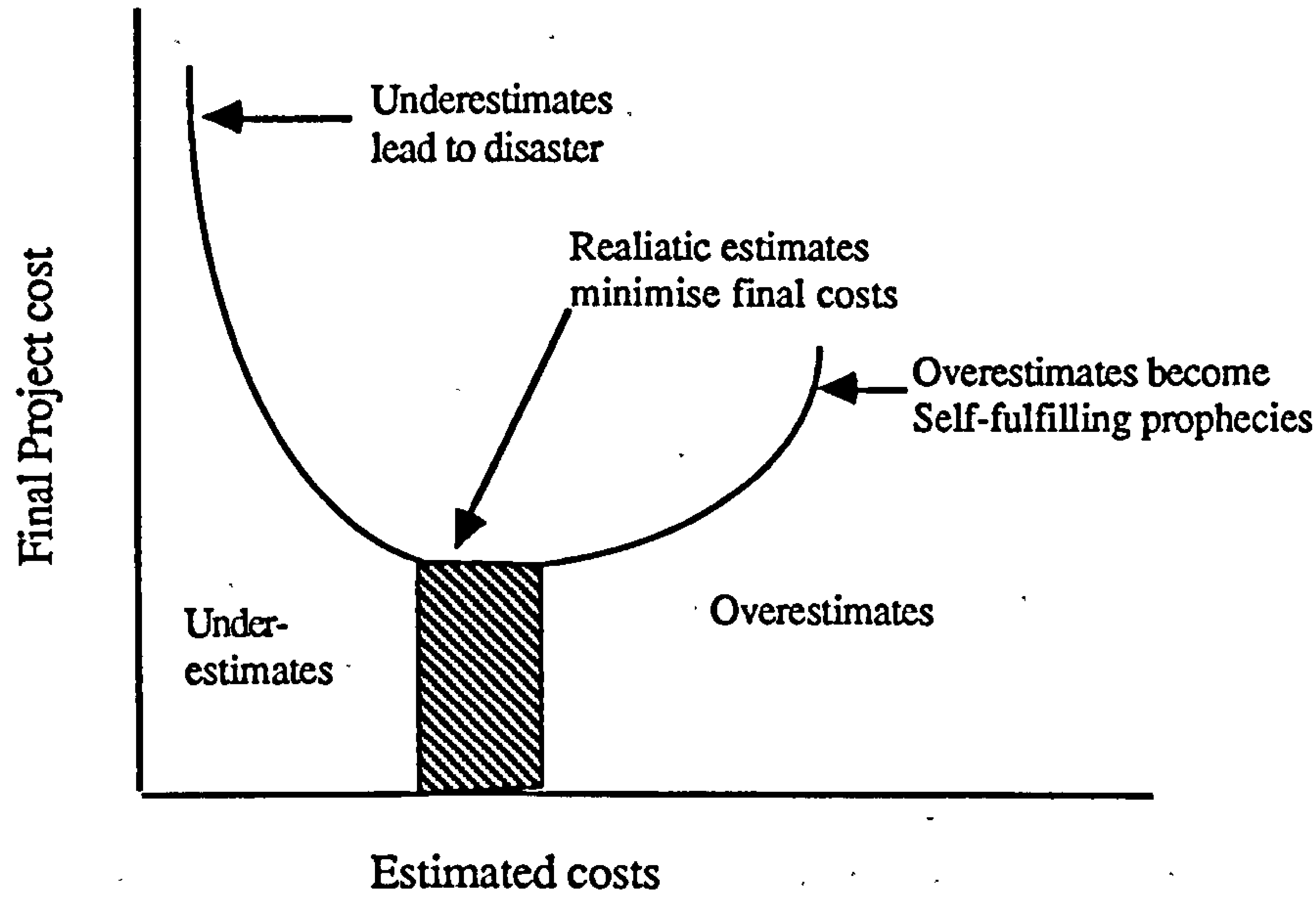


FIGURE 1.1 THE FREIMAN CURVE
Source : Daschbach and Agpar (1988)

3. to provide psychological explanations for the information selection practices of design cost estimators;
4. to determine the level of accuracy currently achieved in the industry; and
5. to suggest ways for improving accuracy in design cost estimating.

1.3 METHODOLOGY AND WORK UNDERTAKEN

The research originated from the apparent need to improve accuracy in design cost estimating. A thorough review of existing literature on cost estimating methods, techniques for assessing accuracy in estimates and previous measures of accuracy in design cost estimates was necessary as a foundation for the research. The rest of the research undertaken can be broadly classified as in Table 1.2.

1.4 MAJOR FINDINGS

The research set out to examine suitable avenues for improving accuracy in design cost estimating. The major findings are :

1. A method for assessing error in design estimates that does not depend on the use of the low bid as datum has been suggested. The method requires that design cost estimates be compared with the parameter predicted by estimators;

2. The method of using the deviation of estimate from the low bid as a basis for assessing accuracy is biased against design cost estimators;

3. The use of resource based estimating at the design stage which is being advocated by some researchers is unlikely to reduce error in estimating;

4. By substituting the appropriate parameter used by design offices for the low bid, error in design estimates reduces significantly (from 12.77% to 3.6%); A package (ACCEST) has been developed to facilitate such testing. The package has also been tested using data from industry;

5. Failure to learn from experience by design cost estimators and persistent use of information from one project for estimating derives from the nature of information stored in design offices, the illusion of validity of sub-optimal rules and overconfidence resulting from incorrect assessment of individual ability;

6. By comparing estimates with tenders at the elemental level on a regular basis, error in estimating the low bid can be minimised.

7. By adopting different strategies for predicting costs for different elements, based on the assessment of uncertainty associated with cost predictions, error in forecasting the low bid can be reduced; and

8. Two equations for predicting tender prices have also been presented. The equations can consistently predict tender prices to within ±10% if used with a suitable data bank.

Table 1.2: **Methodology**

Phase	Method	Aim
Literature Review	Books and journals were reviewed. Experts from industry and academic institutions were also consulted.	To establish a firm basis for research.
Phase II	Pilot study of a current project was made and research aim and objectives formulated.	To formulate a viable direction for the research.
Phase III	Interviews with design cost estimating practitioners.	To determine the approach to error measurement in the industry.
Phase IV	Estimating experiment. Experiment type questionnaire survey of 25 graduate construction and construction management students.	To provide psychological expl-anations for some practices in industry.
Part V	Development of a computer package for measuring accuracy in design cost estimates.	To develop an appropriate method for measuring accuracy.
Part VI	Data collection in industry and interviews with design cost estimating offices.	To collect data for testing the package developed
Part VII	Data analysis and package testing	To test preformance and make suitable recommendations.

1.5 ORGANISATION OF THE THESIS

The various steps taken to realise the objectives of the research are outlined in Table 1.2. The steps are re-classified under 9 chapters forming the major part of the thesis. The contents of the chapters are briefly described below;

Chapter 2 - This chapter contains a review of construction estimating methods used in industry. Information used for both design and contract estimates are also examined.

Chapter 3 - The chapter contains a review of leading researches into design cost estimating in the UK. The methods for assessing errors in estimates are also examined. The sources of errors in estimates are also traced in this chapter.

Chapter 4 - Studies of errors in both design and contract cost estimates are presented in the chapter. The history of construction cost modelling is also traced. The chapter also incorporates a critical examination of the implications of adopting resource based estimating at the design phase.

Chapter 5 - Psychological explanations for some practices noted in industry are provided in this chapter. Also, an estimating experiment involving 25 post graduate students in civil engineering highlighting the psychological processes responsible for the choice of information used for estimating is reported.

Chapter 6 - Factors affecting the accuracy of estimates are examined both theoretically and practically. Reports of opinion surveys, coupled with empirical study are used to verify the factors usually cited in literature.

Chapter 7 - The implications of estimate targetting are discussed. Results of tests undertaken in industry are also presented.

Chapter 8 - The chapter describes the main features of ACCEST - an IBM PC based fortran programme written for assessing accuracy in cost estimates and for testing the research hypothesis.

Chapter 9 - Report of tests of ACCEST using data on 51 projects acquired from 7 offices in the United Kingdom are presented in the chapter.

Chapter 10 - The major conclusions and recommendations from this research are presented. Areas of future research are also discussed.

A Schematic diagram of the relationship of the chapters is shown in Figure 1.2.

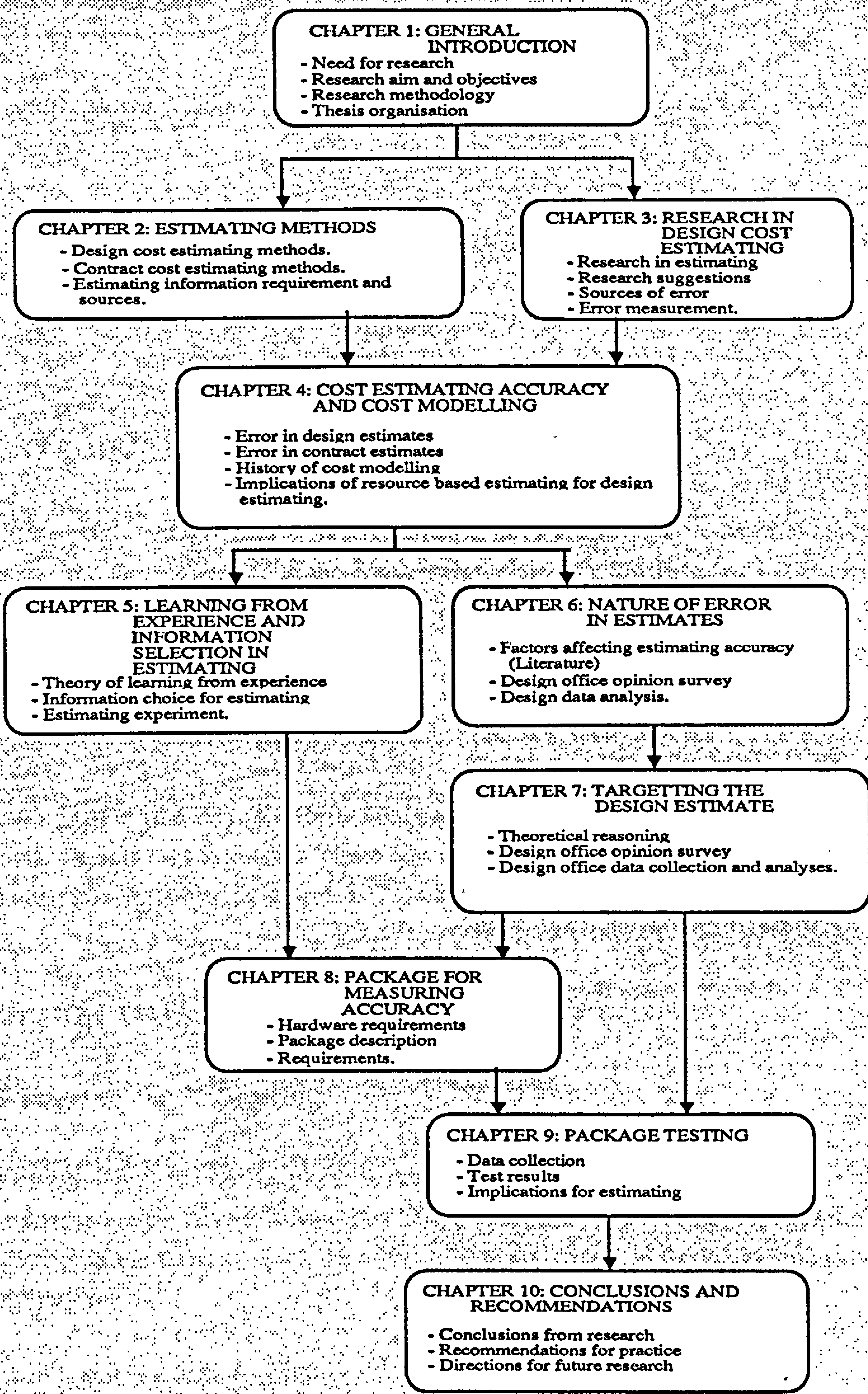


FIGURE 1.2: SCHEMATIC DIAGRAM OF THE THESIS ORGANISATION

CHAPTER 2

CONSTRUCTION COST ESTIMATING METHODS

My intention is not to teach here the method which everyone must follow if he is to conduct his reason correctly, but only to demonstrate how I have conducted my own.
-Descartes, 1637

2.0 INTRODUCTION

Traditional construction management practice divides the project procurement process into two : the design phase and the construction phase. Cost estimating has tended to follow, very closely, this division. Design phase cost estimating is the principal responsibility of the client's cost consultant : the quantity surveyor [for building projects] or the design engineer [for civil engineering works]. Estimating cost for the contractor is seldom started until the tendering process is set in motion.

For reasons of availability of information, purpose and the speed at which estimates are required, the methods for design phase cost estimating have historically been different from contractor's estimating methods. The methods are described below.

2.1 DESIGN PHASE COST ESTIMATING METHODS

2.1.1 Purpose for Estimating

Cost estimating at the design phase is done for two primary purposes. Firstly, design phase cost estimates serve to advise the client on the probable cost of a proposed facility. Depending on the stage at which the estimate is made, the client (or his agents) may use the estimate to:

1. assess project feasibility;
2. prepare a cost budget for the project;
3. assess the ability to pay for a designed facility;

4. make a decision on continuing with or aborting a project; and
5. make provisions for financing the project.

The second beneficiary of design phase estimates is the design team. Cost estimates are used by the team to:

1. prepare a cost plan for the project;
2. assess the balance of expenditure between the various components of the project; and
3. assess the suitability of a proposed solution to the design problem.

A third use of design phase cost estimates is made during the selection of the contractor. When the project is placed for tender, the contractor's price is compared with the design cost estimate for the project.

The number of cost estimates that may be required at the design phase is unlimited. However two factors which place practical limitations on the number is that cost estimates are costly and the quantity surveyor/cost engineer will have to work according to the plan of work for the project design. The Royal Institute of British Architect's (RIBA) plan of work for project design is shown in Figure Appendix A. However, the design team is not constrained to conform rigidly to the plan. In real life situations, the design process is more flexible than is portrayed in the conventional model.

2.1.2 Methods

There are various methods for preparing design phase cost estimates. The method used will depend on:

(i) the purpose for which the estimated cost is required;
(ii) the amount of design information available for estimating;
(iii) the time available to the estimator; and
(iv) the cost data available to the estimator.

The theory of estimating is well covered in current literature [see Seeley (1976); Ferry and Brandon (1978); Adrian (1981); Smith (1986) and Ashworth (1988) for example].

James (1955) first classified approximate estimates according to their purposes as :

1. <u>Single - purpose estimates</u>. These aim to forecast costs and can be sub-divided into :

(a) preliminary estimates which establish the broad financial feasibility for the project; and
(b) later stage estimates which produce a figure comparable with that of the lowest tender.

2. <u>Dual - purpose estimates</u>. These aim to determine total costs and also various cost - design relationships between possible variants of the project. Such estimates delve into cost planning. Dual - purpose estimates can be further subdivided into:

(a) primary comparative - cost estimates which indicate the relative costs of different solutions which will satisfy the client's requirements; and
(b) secondary comparative - cost estimates which apply financial yardsticks to alternatives of construction, finish and service installations applicable to the selected design.

The problems associated with using each of the main categories of approximate estimating methods are covered by Seeley (1976) and centre on the determination of appropriate relationships between building elements and construction costs.

More often, approximate estimating methods are classified in construction literature according to the procedure used in producing the estimates as :

(i) Unit Method;
(ii) Cube Method;
(iii) Floor Area Method;
(iv) Storey Enclosure Method;
(v) Approximate Quantities Method;
(vi) Elemental Cost Analysis;
(vii) Comparative Estimates; and
(viii) Others.

2.1.1.1 Unit Method

The unit method of approximate cost estimating allocates cost to each accommodation unit of the facility e.g.

Cars parks	Cost/car space
Hospitals	Cost/bed
Houses	Cost/person
Schools	Cost/pupil
Theatres	Cost/seat

The total estimate for the project is determined by mutiplying the total number of units by the unit rate. The unit rate is calculated from information extracted from documentation of previous similar contracts, with costs suitably adjusted for inflation, changes in design, state of the market, etc. (Smith 1986).

Seeley (1976) commented that the weakness of this method lies in its lack of precision, the difficulty of making allowance for a whole range of factors, from shape and size of the buildings, constructional methods, materials, finishings, etc. and that the accuracy is low for majority of purposes. The use of this technique is limited to public projects and/or very early stages of project definition where very little design has been undertaken. However, presenting cost in this format is more meaningful to politicians and the public who may have very limited knowledge of construction.

2.1.1.2 Cube Method

The cubic content of the building is obtained by the use of rules prescribed by the RIBA which provides for multiplying the length, width and height of a building with the volume expressed in cubic metres. The volume of the building multiplied by the cubic rate give the approximate cost of the building. The method for obtaining the height of the building depends on the method of construction and the nature of occupation.

Cost per cubic metre estimates are used for buildings that may have varying floor heights such as warehouses. For such buildings cost per floor area estimates tend to be unreliable because of the differences in floor heights.

Athough calculating the building volume is an essentially simple operation, incorporating various design factors into a cubic rate is difficult. The cube method does not make sufficient allowance for plan shape, storey heights and number of storeys, which all influence cost (Seeley 1976). The method also does not indicate to the client the amount of usable floor area and cannot assist the design team as it is difficult to forecast quickly the effects of changes in specifications on cubic rates.

2.1.1.3 The Floor Area Method

This method involves measuring the total floor area of all storeys between external walls without deductions for internal walls, lifts, stair wells, etc. The total approximate cost is obtained by multiplying the area by an appropriate rate per square metre. The calculation is quick, and straightforward and cost is expressed in floor area which is more meaningful to the client than unit or cubic content.

The major drawback is in determining a suitable rate. The usual approach depends on analysis of similar historical projects. The method for selecting appropriate historical project is subjective. Also, making allowances for plan shape, storey heights number of storeys and changes in specification is not a precise art. However, such allowances are easier to make than in unit or cubic rates.

2.1.1.4 Storey - Enclosure Method

The objective of this method is to devise an estimating system which, whilst leaving the type of strucure and standard of finishings to be assessed in the price rate, would take the following into account:

(1) shape of building;
(2) total floor areas;
(3) vertical positioning of floor areas in the building;
(4) storey heights of buildings; and
(5) extra cost of sinking usable floor area below ground level.

When using the technique, the following works have to be estimated separately (Seeley 1976) :

(1) site works, such as roads, paths, drainage service mains and other external

works;

(2) extra cost of foundations, which are more expensive than those normally provided for the particular type of building;

(3) sanitary plumbing, water services, heating, electrical and gas services and lifts;

(4) features which are not general to the structure as a whole, such as dormers, canopies and boiler flues; and

(5) curved works.

The aim is to obtain a total superficial area in square metres to which a single rate can be attached. Using the method involves using various factors for floor areas depending on the location of the floor and weightings to obtain the storey enclosure units. Its proponents argue that prices thus obtained are much closer to tender figures than using the methods earlier described. The method has had very limited application in industry, due to the volume of work involved and the dearth of published cost data for its application. (Seeley, 1976)

2.1.1.5 Approximate Quantities Method

This method involves pricing approximate building quantities at rates produced at the same time that the quantities are prepared. The procedure is to measure approximate quantities based on drawings produced for the project. The most significant cost items are identified and measured with Royal Institution of Chartered Surveyors guidelines (RICS Pamphlet No.2, Undated) while less important cost items are ignored. Their presence however influence the rates used. Composite price rates are obtained by combining or grouping bill items.

The method is generally accepted to be the most accurate approximate estimating method (Seeley, 1976; Smith, 1986 and Willis and Ashworth, 1987). It can only be used when design has progressed fairly well (i.e. when at least sketch drawings are available from which approximate quantities can be obtained). It may therefore be argued that the accuracy derives from a relatively clearer definition of project scope and the availability of more information.

2.1.1.6 Elemental Cost Analysis

This method utilises elemental cost analysis of previous similar projects as a basis for estimating and is computed according to the format specified by the Royal Institution of Chartered Surveyors' Standard Form of Cost Anaysis (RICS, 1973). The cost is normally computed on a superficial or floor area basis but the overall superficial unit cost is broken down into elements and sub elements. At this lower level of division, it becomes possible to make adjustments for variations in design in the new project as compared with the historical projects from which the data was obtained.
The attraction of this method derives from the relationship between elements and cost which is useful for design purposes. Also the Building Cost Information Service (BCIS) publishes information (Elemental Cost Analysis Data) which is useful to the estimator (RICS Pamphlet No.2, Undated).

2.1.1.7 Parameter Estimating

This method uses unit costs which are allocated to trades or component sytems of a building project. Parameter measures are then chosen to divide into the trade costs, one parameter per trade. For example, structural steel costs may be related to the gross area supported, and dry wall costs to the internal area.

The merit of this technique is that, in determining a measure of preliminary costs, the designer has merely to take off the parameter measured quantities and use a historical library of parameter costs by trade.

2.1.1.8 Factor Estimating

This method is best used for projects with a single predominant cost component (especially in heavy engineering and process plant projects e.g. oil refineries, foundries, etc.). The factor estimate develops factors for each component as a function of a predominant cost. Often this component is the purchased equipment cost for the project. The theory is that components of a given type of project will have the same relative cost as a function of a key or predominant component cost which hardly varies for different projects. Factor cost data accumulated over time is used to determine a preliminary cost estimate for a project. A component cost is determined by multiplying the historical factor for that component by the estimated purchased equipment cost for the proposed project.

A major shortcoming in using this method is that relationships between components usually vary across projects. However, when equipment costs can easily be determined and a suitable relationship between equipment cost and other cost components can be calculated, the factor method is a fast way of arriving at a project cost estimate.

2.1.1.9 Range Estimating

This estimating technique sets out a range of possible project costs or probabilities of possible project costs within a range. An expected range of total project cost is calculated as a function of the range of expected costs for individual work packages or phases. The user of this method can equate risks with various possible project budgets. The method sets out critical phases or work packages that can greatly affect the project either adversely or favourably. The estimate is thus not limited to a single cost. Usually, a target cost is set, then low and high estimates and the likelihood that the actual cost will be lower or higher than the target cost. Although a certain amount of subjectivity is involved in calculating low and high estimates, they are possible assuming the original target cost is drawn from a known distribution of possible costs.

Adrian (1981) argued that knowledge of the range of project costs and the likelihood of over-running a single cost helps the designer to equate risks; to budget for contingencies or to redesign aspects of the project to decrease the potential range of costs. DeGoff and Friedman (1985) commented that it represents more accurately the probabilistic nature of estimating.

2.1.1.10 Tender Estimate

A tender estimate is prepared prior to receiving construction bids form contractors. The object is to give the client and the design team an indication of probable tender prices for the project. The procedure involves attaching rates to a detailed bill of quantities. The rates are usually calculated from historical cost data and adjustments made for prevailing market conditions to cater for the contractors' reaction to the market.

The tender estimate differs from the contractor's estimate of construction costs (ref. section 2.2.7). Whereas the contractor's tender comprises the estimate of construction costs and a mark-up added, the tender estimate is a prediction of tender price. Thus, the contractor's estimate of construction costs and the mark-up are contained in the tender estimate. The work covered in the subsequent part of this thesis concentrates more on the tender estimate than on the other estimates.

2.1.1.11 Cost Modelling

Cost modelling involves the construction of mathematical models to describe project costs. A model is a mini representation of reality.

Models can be constructed to cover live situations provided some facts are available to trace the detail of the existing problem (Rowe, 1975). A model is built up from currently available data and from factors related to previous performance. This information is analysed in model form so that the trends can be correlated. Predictions can then be made about the future. In a sense, most of the other cost estimating methods may be regarded as cost models.

2.1.1.12 Life Cycle Costing

Life Cycle Costing stems from a realisation that the best service to the client is provided not by merely estimating project capital costs, but by forecasting in addition the cost in use. An attempt is then made to compare construction and capital costs of different design solutions. This comparison of costs attempts to incorporate all the costs that are associated with a building; e.g. (Cartlidge and Mehrtens, 1982)

1. the cost of the site - a purchase price (a capital sum), or an annual rent (an annual sum);
2. cost of construction and associated professional fees (a capital sum);
3. annual running costs, for example heating and annual maintenance (an annual sum);
4. periodic expenditure for replacement of elements (capital sums at intervals); and
5. premiums paid to landlords if any.

Life cycle costing is mostly used while design is evolving or while a choice of materials for members are being considered. Ashworth (1988) commented that the primary use of life cycle costing is in the evaluation of alternative solutions to specific design problems.

The use of the technique in practice is demonstrated in Flanagan et al. (1987).

Whilst construction costs are relatively predictable, at the design phase, costs in use are not. They are therefore subject to considerable errors in their assessment. A factor which to some extent mitigates against these errors is the fact that future costs need to be discounted in order to bring them into the same time scale as the initial costs. However, this does not lessen the uncertanity in predicting future costs.

2.1.3 Information Requirement for Design Phase Cost Estimating

Estimating by the client's cost adviser essentially relies on information from three sources:

- information supplied by the client;
- information from other members of the design team; and
- information acquired directly by the quantity surveying office - historical cost information.

The amount of information available from the client and the design team will depend on the stage of design. The details of information required from each source is also constrained by the estimating method.

2.1.3.1 Client

The estimator will require details of requirements, relating to accommodation, building quality and probable construction time from the client.

2.1.3.2 From the Design Team

The design team may be able to supply drawings, location of public services, floor and ground loadings, engineering services, etc. depending on the stage of design.

2.1.3.3 Cost Information Acquired Directly

The RICS Handbook (Pamphlet No.2) lists three major sources of cost data :

1. Cost Analyses
   - (a) Building Cost Information Service (BCIS)
   - (b) Professional Journals : Chartered Quantity Surveyor, Architects Journal, Building etc..
   - (c) In-house cost analyses of previous projects.

2. Price Information Handbooks :
   - (a) Spon's Price Books;
   - (b) Laxton's Price Books;
   - (c) Griffiths Price Books;
   - (d) Wessex Database;
   - (e) Building Market Research;
   - (f) Building Magazine;
   - (g) Cost Data file for the building industry (BWS Ltd);
   - (h) In-house priced Bill of Quantities; and
   - (i) Specialist suppliers' quotations.

3. Published Indices
   - (a) BCIS cost and tender statistics;
   - (b) DoE (Housing and Construction Statistics);
   - (c) NEDO;
   - (d) Architect's Journal;
   - (e) Building;
   - (f) CIBSE Journal; and
   - (g) Building Services Research and Information Association (BSRIA) Statistical Bulletin.

2.1.4 Procedure for Design Phase Cost Estimating

Depending on which estimating technique is adopted, the procedure for design phase cost estimating can be broken down into four steps:

- Calculating quantities and units for estimating.
- Determination of the unit rates to be used.
- Adding up to arrive at a total cost estimate.
- Making necessary adjustments to the estimate.

Calculating the quantities is a technical and fairly straightforward process. The quantities are determined from information supplied by the client or the design team.

Determination of unit rates combines technical expertise with subjective evaluations. Usually, a unit rate is abstracted from a historical project, the rate is then adjusted to cater for inflation, variations in design, market condition, etc.. The factors that contribute to the determination of appropriate unit rates are: (Ashworth and Willis, 1987)

(1) Market condition - Past data is interpreted in the light of present circumstances; allowances being made for contract conditions, client, labour availability, workload etc.

(2) Design economics - Variations in shape, height, rise, etc. are considered.

(3) Quality - Differences in quality requirements are considered although effort is made to select data from 'similar' projects.

(4) Engineering services - The quality of engineering services and the level of specialist services required will greatly affect rates.

(5) Differences in external works requirements.

(6) Price and design risks - Allowances are made for possible price flunctuations, changes in design etc.

(7) Exclusions - The estimator will need to state the items that are not covered in the unit rates.

Adding up sectional prices is a technical process. It incorporates summing all element costs to arrive at a total estimate.

Adjustments may be made to the total estimate of cost to cater for items not covered in any section of the estimate. Alternatively, adjustments are made to: (a) quantities calculated, (b) cater for changes in design quality and (c) prices indices used for calculation. Also a lump sum addition may be made to cater for contingencies.

2.2 CONTRACTOR'S ESTIMATING METHODS

Estimates produced by the contractor are based on relatively complete sets of plans and specifications, and they involve much more than simply applying historical unit costs to a completed quantities. The contractor's bid estimate is his foundation for a successful project. He must bid low enough to obtain the work, yet high enough to make a profit.

The methods available for contractor's estimating derive from the nature of his work. The contractor needs to price resources that are used for construction. His methods are therefore referred to as resource based estimating or analytical estimating. The items covered by the contractor's estimate are: (The Institution of Civil Engineers (ICE), 1979)

Direct Costs
- Labour and materials
- Plant and transport
- Subcontracts

Indirect Costs
- Erection and dismantling of plants
- Temporary works
- Temporary buildings
- Store and yard labour
- Tools and tackle
- Welfare
- Insurance
- Notices and fees
- Site management and supervision
- Contingencies
- Special conditions of contract
- Head office overheads
- Finance and profits.

The differences between the two methods lie in how rates are calculated. The methods are described below.

2.2.1 Unit Rate Estimating

In unit rate estimating, the calculation of a labour, plant or material rate is based upon a predetermined output or wage rate and the quantity of work stated against the bill item. "The estimator selects historical rate or prices for each item in the bill of quantities using either information from recent similar contracts, or published information, or 'built up' rates from his own analysis" (Thompson, 1989). The composition of the unit rate suggested by the CIOB is shown in Appendix C (CIOB, 1983).

The technique is most suited to building and repetitive works where the sequences of operations are well defined. To provide a good estimate using the unit rate technique, "it is essential that the rates are selected from an adequate sample of similar work with reasonably constant levels of productivity and limited distortions arising from construction risks" (Thompson, 1981).

2.2.2 Operational Estimating

Operational estimating is the calculation of a direct cost rate of labour and plant based upon the total quantity of work involved and the total period that resources will be required on site [McCaffer and Baldwin (1986)]. Thompson (1989) defined operational estimating as "the fundamental technique wherein the total cost of the work is compiled from consideration of the constituent operations or activities defined in the construction method statement and programme and from the accumulated demand for resources". He also stated (Thompson, 1981) that the technique is by far the best method of evaluating uncertainties and risks, particularly those likely to cause delay.

Most civil engineering contractors use operational estimating methods combined with unit rate estimating methods for calculating rates. Cost estimating using operational estimating tehniques is relatively painstaking and time consuming compared with other techniques.

2.2.3 Combination of Unit Rate and Operational Estimating

In some cases the estimator may combine a unit rate and an operational estimating rate. For example, the provision of concrete may be priced by a unit rate while placing concrete (involving labour and plant) is on an operational basis.

2.2.4 Spot Rates

A method for less significant items is to estimate the cost rate for each cost code category. The rates for each cost category are included in the item rate based upon the estimator's experience.

The estimate may be calculated in several ways including:

(i) Approximate quantities which may be taken off and unit rates used to calculate a lump sum estimate for the item.

(ii) The description may be analysed into its constituent operations and an estimate of cost made for each.

The rates thus calculated are then included in the rates based on the estimator's previous experience.

2.2.5 Included In

The price for some items may be included under other items of cost. This is done when the estimator does not consider it necessary to provide for a cost item separately.

2.2.6 Item Sum

Where there are items in the bill of quantities for which there are no quantities given, the estimator would be required to provide a single sum of money to cover the sum involved. This method is used to price general items covering contractual arrangements and specified requirements such as testing of materials and the provision of temporary works.

2.2.7 The Contractor's Tender

The price submitted by the contractor is more than an estimate of construction costs for the project. Bainbridge (1976) presented two alternative structures of the tender price as shown in Figure 2.1.

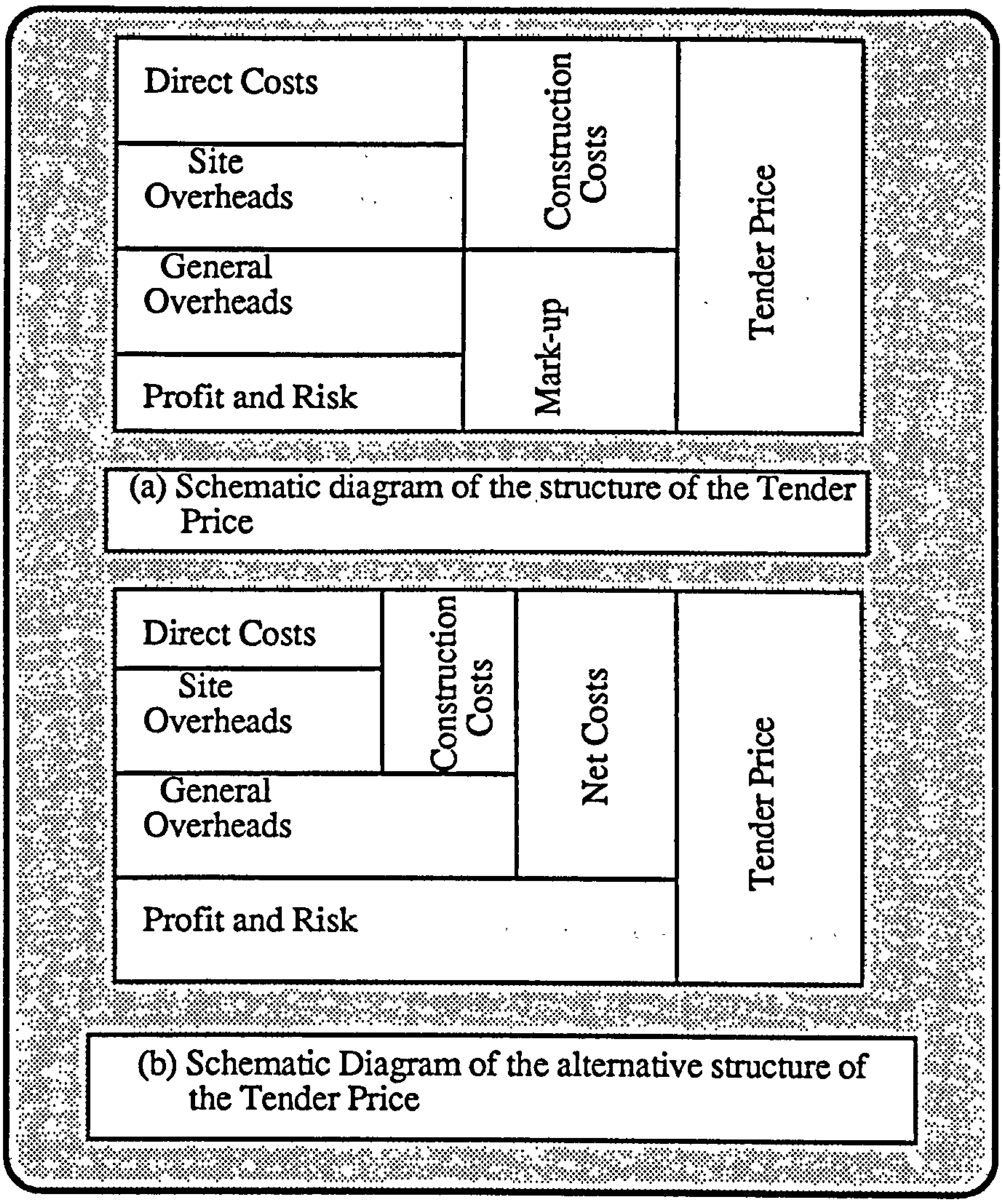


Figure 2.1 : STRUCTURE OF THE TENDER PRICE

Source : Bainbridge (1976)

Figure 2.1(a) illustrates that the contractor's tender has two major components : **an estimate of construction cost** and **mark-up**. The mark-up comprises profit and risk and, depending on whether Figure 2.1(a) or 2.1(b), general over head. The construction cost estimate represents the contractor's prediction of how much the cost of materials, labour, plant and other resources that will be consumed by the project. The contractor's mark-up comprises:

- general overheads - a proportion of head office running costs allocated to a project; and
- risk assessment and profit desired from the project.

The mark-up is applied as a purely commercial decision requiring consideration for many factors such as the state of the market, the client type, the desirability of wining the contract, risk assessment, etc.. Since the mark-up is applied due to considerations not necessarily related to actual construction on site, the contractor's tender may often give a distorted view of construction cost. A lot of biases may be introduced into the assessment of the mark-up (see McCaffer, 1976). Thus design cost etsimators using tender prices as basis for cost predictions are using biased figures.

2.2.8 Information Requirement for Contractor's Estimating

To enable the contractor's estimator to arrive at a suitable cost estimate for a project the following information is required:

- drawings
- specifications
- schedules
- technical reports
- programme of work periods for subcontracted trades
- bill of quantities

The estimator may obtain, for the project, information details which:

- relate to the contractor's intended method of working
- impose restrictions
- affect access
- interrupt the regular flow of trades
- affect the duration of the project
- require specialist skills and materials
- have significant effect on the programme.
- are of major cost significance.

The contractor's estimate therefore benefits from relatively complete information on the project.

2.3 COST ESTIMATING IN INDUSTRY

It is necessary to state here that although the work presented in this thesis concerns design cost estimating in general, difficulties in acquiring data for building projects precluded analyses (as will be seen in later chapters) on building contracts. All analyses relate to road contracts but are deemed to be valid for building works also.

2.3.1 Design Cost Estimating

The foregoing discussion represent the theory of design and contract cost estimating. However, there may be slight differences in the practice in industry. The procedure used in a County Council design office for road construction projects is now described.

2.3.1.1 Information Used

Two levels of historical data are available from each contract analysed:

i) cost per square metre of wearing surface
ii) bill rates

The former is used for preliminary estimates. The latter is of limited use until a bill of quantities is produced at the pre tender estimate stage. The information is all based on tender figures - the final account figure may not be available for some years.

2.3.1.2 Information Treatment

1. The 3 lowest tenders are analysed to produce an "all in" rate for a library of Method of Measurement for Roads and Bridgeworks (MMRB) standard items.
2. The system is run on a micro computer and the rates are updated when the output is printed using the Road Construction Price Index.
3. The latest Road Construction Price Index is inevitably rather out of date and in times of price inflation, allowance is made for this based on Baxter Indices. Although the Baxter index is not based on tender prices it is a reasonably upto date index and is convenient to use. Typical tender analysis forms are shown in Appendix B.

A major deviation from the published literature is that the design office uses the average of three lowest tenders updated through tender indices for predicting prices rather than the lowest tender only.

2.3.2 Contractor's Estimating

Two contractors were approached to gain an understanding of how estimates are prepared in industry. There is no fundamental departure, in method, from the procedures outlined in Section 2.2. Combinations of unit rate estimating, spot rates and operational estimating are used depending on the peculiarities of each project. However one contractor has computerised the estimating procedure.

A new development was noticed in one of the construction firms. The contractor, because of the pressure of work, sometimes contracts out the cost estimating function to 'freelance estimators'. Freelance estimating, planning, site management and quantity surveying are products of two recent developments in the construction industry. First the development of management contracting and project management have in turn resulted in other similar functions springing up. A steady move towards de-organisation in construction work has been noticed by Naoum and Langford (1983) and Abdel-Razek and McCaffer (1987). The later study noted that more construction works are being subcontracted while the traditional contractors concentrate on management contracting and project management services. Secondly, the recent boom in the construction industry has meant that more work is available and shortages in manpower in the industry have encouraged the use of freelancers to make up for the shortfall in contracting organisations. Freelancers are currently used mainly by small and medium sized contractors. It can be speculated that further moves towards de-organisation may lead to some large firms using freelancers.

Freelance estimators are unable to use operational estimating techinque because of the restrictions in access to cost data. They therefore rely mainly on unit rate estimating and other less analytical procedures. Alternatively, such estimators may rely on information in published price books. The traditional image that contractor's estimates are built up from the 'first principles' is no longer completely true, at least for the small contractor. However, the use of freelancers is still restricted to small and medium sized firms.

2. 4 SUMMARY

The treatise in this section have shown *inter alia* that:

1. traditionally, there are distinctions between contractor's estimating methods and the methods for design phase cost estimating.

2. whereas providing cost advice to the design process is the *raison d'etre* for design phase cost estimating, contractor's estimates are made for the primary purpose of enabling the contractor to submit a competitive tender.

3. the choice of method for design phase cost estimating is constrained by the information available, the need for the estimate, the stage in the design process at which the estimate is prepare, the quality of advice to the design process required, etc.

4. contractors' estimates benefit from relatively more complete information than design phase cost estimates.

5. whereas the contractor's method of estimating is analytical or resource based, design phase cost estimates rely on unit rates calculated from historical projects.

6. there exist slight differences between office procedures for design cost estimating and procedures detailed in literature.

7. the traditional belief that contractors' estimates are always derived from first principles is no longer true.

CHAPTER 3

ACCURACY IN DESIGN COST ESTIMATING

The strategic aim of a business is to earn a return on capital, and if in any particular case the return in the long run is not satisfactory, then the deficiency should be corrected or the activity abandoned for a more favourable one.
-Alfred P. Sloan, Jr.

3.0 INTRODUCTION

The major aim of this research is to improve the quality of design cost estimates. A major requirement for the achievement of this aim is a thorough understanding of the problems with design cost estimating. This chapter therefore, identifies the problems associated with design phase cost estimating and presents a review of recent research aimed at improving estimating practice. A discussion of the methods for measuring accuracy in estimates is also presented.

3.1 RESEARCH IN COST PLANNING AND ESTIMATING

In this section, the works of several major research centres in the U.K. are reviewed to establish the direction of research in cost estimating and cost planning.

3.1.1 Research at the Property Services Agency (PSA)

A pioneering effort to improve estimating practice was made by Derek Beeston at the Property Services Agency of the Department of Environment. In 1973, Beeston assessed the level of accuracies of estimating obtained using traditional/current methods and the levels achievable using improved methods. His research suggested that estimating accuracy could be improved through the use of 'improved methods'. He also investigated the current practice of quantity surveying and concluded that the use of previous cost analyses of bills of quantities was the most common technique used in cost planning and estimating. Using this approach, the variability of predictions would be that of the original analysis combined with that of the index used for updating the cost information. He concluded that estimating accuracy could be improved by the inclusion of more projects as a basis for predicting costs. His efforts were reported in two major works (Beeston 1974 and Beeston 1983).

He made a distinction between 'black box' models and 'realistic' models in construction cost representation. The quantity surveyor's methods, which he subdivided into 'in-place materials related' and 'area-related' methods, are classified as 'black-box' models while contractor's methods, which tend to relate cost to the way in which they are incurred on sites, are designated as 'realistic' models.

The major contributions from Beeston's efforts can be summarised as follows:

1. Current estimating practice can be improved by inclusion of more cost analyses as a basis for predicting costs.
2. Realistic methods are more beneficial to design as the construction consequences of design decisions can be easily evaluated.
3. The client's cost consultant should move towards adopting realistic models for cost estimating.
4. The contractors work can be simulated at the design stage.
5. The database needed to achieve (4) can be stored in computers.
6. Contractor's methods do not vary much from firm to firm. Where there are minor departures from the norm, a simulation model can incorporate the deviations.

Beeston developed a model to monitor the cost of contractor's operations (COCO). The model is based on decision criteria governing the choice of construction methods and choice of plants, performance data for plant and labour and procedures for smoothing resources. The use of the model in practice has not been reported.

3.1.2 The Fair Tender and Statistical Unit Estimating

The Department of Civil Engineering, Loughborough University of Technology, has undertaken much research into cost estimating and tender price prediction. A chronology of the major research work is presented below:

(1) In 1976, the Fairtender system was introduced by McCaffer for predicting continental building prices. The FAIRTENDER system comprised a library

of individual unit prices obtained from tenders of construction works and a suite of computer programs which "simulates tenders by selecting unit prices from the price library, correcting these prices for inflation, analysing the variability of the prices and predicting the likely mean and standard deviation of the tender price."

(2) In 1978, McCaffrey adapted the Fairtender system for use with U.K. building cost data. The system was then renamed the Statistical Unit Estimating (SUE) system.

(3) In 1979, Gichuki carried out feasibility tests into the accuracy of the SUE system.

(4) In 1982, Lavelle investigated the best way of developing a suitable database that would enable the SUE system to be utilised on micro-computers.

(5) Also in 1982, Thorpe reported the results of stability tests on the SUE system using 32 alternative statistical treatments of the cost data.

The system has remained undeveloped further since 1982. The SUE system is a computer based tender price prediction system comprising:

1) Files of quantity data in the form of elemental cost analysis and descriptions.
2) Files of price adjustment data in the form of indices.
3) Computer programs which abstract and manipulate data from (1) and (2) to create the basis for an estimate.
4) A facility for the quantity surveyor to supply information on the proposed project specifically, the tender date and a list of elements and their unit quantities.
5) Computer programmes which update the prices from (3) and statistically analyse the data according to the method chosen by the quantity surveyor.
6) A simulation program which calculates the expected tender prices based on statistics, together with a number of simulations which measure the reliability of the estimate.

Lavelle recommended in his report that, to develop the SUE system beyond its present level and to enhance its use by the quantity surveyor the following should be done :

1) More project data should be stored and the efficiency of the system in manipulating this information should be tested.
2) The criteria for selective choice of estimate information should be investigated.
3) The statistical program of the SUE system should be adapted for use on the new database he developed.
4) The feasibility of implementing the system on the micro-computer should be investigated, as a step towards commercial application.

3.1.3 Research at Reading University for the Property Services Agency (PSA)

In 1978, Professor Bennet of the Department of Construction Management, Reading University, was awarded a research contract by the PSA to assess the feasibility of providing the quantity surveyor with the construction cost data they require for effective cost planning. The final report was published in June 1981 under the title "Cost Planning and Computers."

Bennet et al (1981) used computer models to simulate practice and acquired live data to validate the model developed. They made "a very careful selection of the important characteristics in quantity surveying estimating, tendering and contractors pricing" (Bennet, 1982). The computer based model suggested in the report has been developed by the BCIS into an Online system comprising a cost data bank and estimating system.

3.1.3.1 Procedure for Using the Model

The system assumes that each quantity surveyor in his own office builds up cost analyses of his own projects in a standard format which identifies the 100 most cost significant items on each project. Each practice builds up its own database of its own projects and at the same time, cost analyses are transmitted over the British Telecom network to a central database. Here each new analysis is matched and compared with others. The centre produces sets of unit rates in a form which makes choosing the right one for any particular item on a new project relatively straightforward. These unit rates are transmitted back to the individual quantity surveyor as they are needed.

A very important development from the research is the need to subdivide cost into 100 work sections of roughly equal value. The research proposed a hierarchical data structure which allows individual projects to be analysed to the required depth in a consistent yet flexible manner.

Since the completion of the research, the BCIS has developed such as computer database and a computer aided estimating program capable of using the database.

3.1.4 Estimating Expertise - Salford University

A third research project of interest was undertaken at the Department of Civil Engineering of Salford University. Skitmore (1987) reported on research partly funded by the Science and Engineering Research Council into the influence of expertise on estimating performance.

In the research, the performance of 'expert' estimators was compared with 'novices'. The estimates for both groups were compared with actual costs for the projects used for the experiment.

The results show that those subjects exhibiting the greatest expertise were generally :

- more relaxed and confident;
- more concerned with maintaining familiarity with the market and overall price levels than others who were more concerned with careful analysis; and
- able to recall the overall price of the projects undertaken.

'Experts' when provided with very little project information produced estimates comparable with average practitioners pricing a full bill of quantities.

Although the result of the research was not conclusive, it suggested that a relationship exists between expertise and estimating performance. The expert was defined as a quantity surveyor with many years of experience in estimating and a flair for estimating. Thus, the development of Expert Systems and other artificial intelligence procedures may have potential for improving the performance in design phase cost estimating (see RICS/ALVEY, 1988).

3.1.5 Cost Planning in Practice

Chapter 2 of this thesis contains the theory of estimating as a service to the client's cost planning effort. Often however, there is a gap between theory and practice. Morrison and Steven's (1981) research demonstrated that in practice, the design process is more complex than is portrayed by the conventional model. Rather than working within a rigid framework, the quantity surveyor is faced with a system of work which requires him to choose the nature and sequence of the processes which he undertakes during the design of buildings. Factors, other than personal preference, which may influence the choice are:

- the relationships within the design team;
- the characteristics of the project (e.g. familiarity with the type of project, client imposed system of work and the amount of innovation in the design);
- the time available to carry out the process; and
- the amount of information available to undertake the process.

Their research revealed that the quantity surveyor in a separate practice, as opposed to public office surveyor, is often less involved in cost planning than previously thought; in many cases the design process is well underway before he is appointed. Consequently, the extent of his involvement is limited to giving advice on less cost significant items involved in the choice of construction alternatives while major items may have been agreed by the client and the architect.

3.1.6 Problems with Design Cost Estimating

The problems associated with design cost estimating as identified in recent research may be summarised as follows:

- quantity surveyors are not as accurate in estimating as they can, ought to and expect to be (Morrison and Stevens, 1981; Thorpe , 1982 and Beeston, 1983).

- quantity surveyors are unaware of the magnitude of the errors made in estimating and cost planning (Morrison and Stevens, 1981; Thorpe , 1982).

- in estimating costs for new works, quantity surveyors prefer using cost data with which they are familiar i.e. cost analysis of projects in which they have been involved, cost analysis of other projects within the same practice, etc. (Morrison and Stevens, 1981).

- the quantity surveyor and the contractor use different methods in estimating construction costs. While the contractor uses analytical or resource based methods, the quantity surveyor depends on historical cost data in preparing estimates and cost plans for new projects. The difference in methods contribute to the inaccuracies in design phase cost estimating (Morrison and Stevens, 1981; Beeston, 1983).

- quantity surveyors usually use the cost analysis of only one historical project in preparing cost plans for a new project irrespective of the error in the original data (Morrison and Stevens, 1981).

- it is unusual for the cost analysis of the lowest tender to be compared element by element with the cost plan should the overall tender figure become acceptable. Only when the tender figure differs significantly from the cost plan will the quantity surveyor examine the cost analysis and cost plan together in order to establish reasons for the differences (Morrison and Stevens, 1981).

- where differences are found between the cost plan and the cost analysis within individual elements, no adjustments are made to any of the data. The most recent cost analysis is almost invariably used as the basis for estimating and cost planning future projects. This is the case irrespective of any differences between the unit rates it contains and the earlier cost data (Morrison and Stevens, 1981).

3.2 SUGGESTED APPROACHES FOR IMPROVING ESTIMATING PRACTICE

The contributions of the reported research work have been beneficial to the evolution of estimating and cost planning practice. Many of the research works have made prescriptions for the futherance of estimating practice. While some of the suggestions have been implemented and are now standards of acceptable practice, others remain subject to controversy and the feasibility of them being incorporated into the industry still appear remote. The options are discussed in detail below.

3.2.1 The Use of Computers in Estimating

Computers and Information Technology in general are causing major changes in the way we work. In many ways the computer revolution has introduced significant improvements in the ability to store, retrieve and manipulate data necessary for professional practice.

The research works reported in the foregoing sections of this chapter touch on three major inlvovements of computer in estimating. These potential applications of computers are:

a. To speed up the process of producing cost estimates, cost plans and cost checking.
b. To store more data to aid estimating and cost planning.
c. To introduce statistical treatments into predictions of construction costs.
d. Modelling construction process and/or cost simulation.

These are now examined in detail under three headings: Databases, Statistical treatments and Simulation.

3.2.1.1 Databases

The SUE (1978) system, the Reading Report (1981) and Beeston (1983) advocated the use of more data in the preparation of cost estimates and for cost planning. They all suggested that data could be stored in computers because of their ability to store, retrieve and manipulate large quantities of data quickly and accurately.

A database, in the broadest sense, is a file of information or 'data', or a collection of such files (Broomer, 1982). The data need not all be of the same type from file to file. The characteristics that distinguishes a database from the collections of data is the fact that all points of the data can be accessed in a common manner. This is usually, but not limited to, a computer program or a related group of programs.

Since the Reading report was prepared, the BCIS has established an 'On-line' system which consists of cost data banks and software for quantity suveyor's estimating and cost planning. A quantity surveyor can link up his computer with the BCIS data bank to access material prices, unit element costs, cost analysis of different projects, cost indices and information on market conditions. The computer software on the BCIS computer may also be used for cost planning by the subscribing quantity surveyor.

The BCIS On-line system facilitates the use of more data for estimating and cost planning projects. However, although this facility is available, the use of more data through using the system has not been reported.

3.6.1.2 Statistical Treatments

The SUE system uses staistical treatment to measure the reliability of estimates. The idea is that, with the aid of computers, the quantity surveyor can predict how reliable estimates prepared are. Also, more than one estimate can be prepared at the same time. Most of the cost models suggested in the 1970s are regression models (see Chapter 4). Regression models are now being used in the industry both to monitor and to predict construction costs. However, it has been acknowledged that their use in industry is very limited (Raftery, 1987).

3.2.1.3 Simulation of Construction Projects

The designers of the SUE system, Beeston and Bennet all sugested that simulation of constuction costs is possible with the aid of computers. The SUE system uses this procedure to produce several estimates for a single project.

Bennet and Ormerod (1984), described how construction processes can be simulated using computers. Construction projects are fraught with uncertainty. The underlying hypothesis of the simulator is that uncertainty is considered to be made up of two major components : variability and interference. Interference are those external factors which affect the project causing work to stop on a particular task. This may result from such things as; inclement weather, delivery problems, sub-contract non-attendance, plant breakdowns and the many other influences of the project environment which cause delay. Variability refers only to variations in the rate of productivity with which work is executed. Using simulation, the duration and cost of each building operation is considered variable and represented by a population of fixed possible values, not just one fixed value. During simulation the value of an operation is influenced by the effects of uncertainty by being chosen at random from a range of possibilities. The total project duration and costs are calculated from these randomly chosen values. This represents only one possible way in which the project may proceed. The whole process of choosing duration and cost under uncertain conditions is repeated and the result calculated to produce a family of solutions.

Each simulation is known as an 'iteration'. In the Construction Project Simulator, the simulation is complete when 100 different answers for project execution are obtained. This, it is said, gives an objective assessment of the range and pattern of possible solutions to a project under realistic but uncertain conditions.

Bennet (1985) suggested that the quantity surveyor should move from traditional systems of cost estimating to the simulation of construction processes. This, he proposes, will prepare ground for doing without databases. He opines that cost can best be estimated using contractors' knowledge of construction and hence its inherent risks.

3.2.1.4 The Development of Expert Systems

The results of Skitmore's research on the influence of expertise on estimating performance are not conclusive. However, they provide a good indication that the development of expert systems may have potential in estimating. Others (see Warzawski 1985 and Abdullah, 1989) have also suggested that Expert systems are quite suited to esimating work.

The Expert Systems Group of the British Computer Society defined Expert Systems thus :

> An expert system is a means of capturing the knowledge of experts in the form of programs and data where disagrements among the experts are settled by mediation and results refined so as to extract the essence of their knowledge in such a way that it can be used by less experienced people within the field. The usage of such a system can be monitored so that adjustments may be made semi-automatically under the guidance of the experts. The expert system is a tool and means of coherent communication of the latest views of the experts to the users who may be the experts themselves. The use of the system combined with a measure of importance of provided by the experts gives a measure of the utility of what is being communicated. This recorded utility may be used by a program to vet the

knowledge so that the channel does not get closed with redundant material. (BCS special group on expert systems, 1981)

Proprietary expert system shells are already in existence. The application of expert systems in construction management is being accepted as a viable option. However little has been done in the commercial application of expert systems in cost planning and estimating. Exploratory work by the Expert Systems Group of the RICS/ALVEY Research Project (1988) suggest that there is good potential for using Expert Systems in cost estimating.

There has been no study as yet into the characteristics of the individual which enhances expertise in estimating. Until that is ascertained, training in estimating and cost planning will still continue along the traditional lines of evaluating applicants based on academic achievement.

3.2.1.5 Resource - Based Estimating for Design Estimates

Flanagan (1980) suggested that cost prediction should be related to construction time. This approach would seem to necessitate the use of contractor's methods. Also, inherent in the Construction Project Simulator is the need to introduce resource-based estimating at the design phase. Morrison and Stevens (1981), Beeston (1983) and Bennet (1985) were more direct in advocating the use of contractor's methods in design phase estimating. Although the idea has not been incorporated into estimating practice, it represent a great departure from traditional methods. There is a need for caution in this respect. Novelty does not necessarily imply suitability. Two issues need to be resolved before resource based estimating can be advocated at the design phase: Firstly it must be determined whether the accuracy of resource based estimates are higher than those obtained by unit rate methods. This is considered in detail in Chapter 4. The second issue is to assess the practicalities of using resource based estimating methods at the design phase.

3.3 ACCURACY IN COST ESTIMATING

The studies presented above were made with the premise that inaccuracies exist in design phase cost estimates. We have tentatively assumed the validity of the assertion.

However, 'accuracy' or 'inaccuracy' in cost estimates has not been defined.

Studies of accuracy in cost estimating [for example, those presented in Chapter 4] rely wholly on the assessment of errors. Because of the limitations of the methods used, accuracy per se cannot be assessed. Therefore accuracy is defined as 'the absence of error'.

3.3.1 Error in Estimates

The notion of error in measured quantity stems from the acceptance that there is a 'correct' or 'true' value of the quantity. For instance, assuming an architect specifies that the length of a building should be 25m we assess the error in the engineer's setting out by the deviaton of his measurement from the value 25. If the true quantity to be measured is represented by X, error exists if the actual quantity measured is $X \pm dx$ (where $dx > 0$). The error in the measurement being dx; the deviation from the true quantity desired. We can now represent the actual quantity measured by Y and relate Y to X. The mathematical equation relating Y to X is

$$Y = X \pm dx \qquad \text{--} \quad (3.1)$$

Equation 3.1 assumes that there is equal probability to undermeasure as to overmeasure. Thus,

$$P[Y>X] = {}^1/_2 \quad \text{and} \quad P[Y<X] = {}^1/_2 \quad \text{----------------------} \quad (3.2)$$

However, in certain measurements, the probabilities are not equal. In such cases

$$P[Y>X] \neq P[Y<X] \neq {}^1/_2 \qquad \text{-------------------------------} \quad (3.3)$$

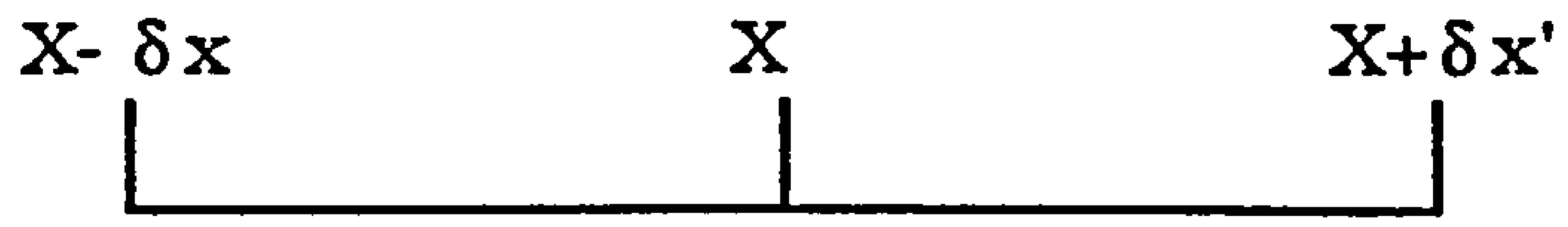
If there is a greater likelihood to overmeasure,

$$P[Y>X] > P[Y<X] \qquad \text{----------------------------------} \quad (3.4)$$

else,

$$P[Y>X] < P[Y<X] \qquad \text{---------------------------------} \quad (3.5)$$

Y, then, can occur within the boundary



dx > dx' or dx < dx'

dx = dx' if and only if there is equal probality to undermeasure or overmeasure.

If the assertion that 'even the finest scientific measuring device can never be accurate' (Heisenberg 1969) is true, the magnitude of error, dx in the measured quantity X can never be 0 (i.e. $dx \neq 0$).

3.3.2 Error Appreciation

The value of error in the mesurement above, dx, has been expressed in **absolute** terms. However, this form of expression give very little understanding of the relationship between the error and the measured quantity X. Thus it can be very misleading. For instance, a supplier delivering 9 windows to site to fulfil an order for 10 windows has supplied 1 window short. If however he supplied 97 windows for an order for 100 windows, he has supplied 3 windows short. In absolute terms 3 is greater than 1 (3>1). To aid appreciation, error is often expressed in **relative** terms i.e. relative to the measured quantity. In the windows example, the first error is

$$\frac{1}{10} = \text{Abs}\left(\frac{9-10}{10}\right) = 0.1 \text{ or } 10\%$$

The second error equally expressed is

$$\frac{3}{100} = \text{Abs}\left(\frac{97-100}{100}\right) = 0.03 \text{ or } 3\%$$

In relative terms, the first error is greater than the second. The picture becomes clearer if the relative expressions use the same denominator. The first error represents 1 out of 10 or 10 out of 100; the second error being 0.3 out of 10 or 3 out of 100. Thus expressing error in relative terms helps to improve appreciation of error.

3.3.3 Accuracy Measurement

3.3.3.1 Accuracy Measurement in Design Estimates

The error in cost estimates is measured relative to the 'actual value' and expressed as a percentage. For most purposes, the low bid is taken as the actual or true cost desired when estimates are compared with contractors' bids. Its suitability will be examined further in Chapter 5 of this thesis. Thus:

$$\text{Accuracy of Estimate} = \frac{\text{Estimate value - Low Bid}}{\text{Low Bid}} \times 100\,\% \quad \text{--- (3.6)}$$

Sometimes, the true value may be represented by the final account value. Thus:

$$\text{Accuracy of Estimate} = \frac{\text{Estimate Value - Total Cost}}{\text{Total Cost}} \times 100\,\% \quad \text{--- (3.7)}$$

Another method often employed in the assessment of error in estimates is the value of the coefficient of variation (CV) of estimating errors across contracts. A coefficient of variation is a measure of consistency rather than a direct measure of accuracy. The procedure for measuring CV for design phase estimates is to calculate the CV of residuals. An example is given to illustrate its use.

For n contracts, let the estimate be represented by Y_i, i= 1, 2, ... , n and the low bid values be represented by X_i, i=1, 2, ... , n. The residual and D-values (deviation of estimates) are calculated as follows:

Y_1	X_1	$D_1 = Y_1 - X_1,\ R_1 = X_1 / Y_1$
Y_2	X_2	$D_2 = Y_2 - X_2,\ R_2 = X_2 / Y_2$
Y_3	X_3	$D_3 = Y_3 - X_3,\ R_3 = X_3 / Y_3$
.	.	. .
.	.	. .
Y_n	X_n	$D_n = Y_n - X_n,\ R_n = X_n / Y_n$

From these figures, the mean R_{mean}, Standard Deviation (SD) and the CV are calculated as follows.

$$R_{mean} = \frac{\sum_{1}^{n} R}{n}, \qquad SD = \sqrt{\frac{\sum_{1}^{n} R^2 - \frac{(\sum_{1}^{n} R)^2}{n}}{n}}$$

$$C.V. = \frac{SD}{R_{mean}} \times 100\%$$

An alternative procedure utilises the D-values in calculating coefficient of variation. The two approaches produce different values of CV in estimates. The ratio technique seems more appropriate since it produces more consistent figures. It is also more widely used than the D-values.

It is noted that as a useful service to the design process, consistency in cost predictions rather than accuracy is more relevant. The client and the design team require that the cost consultant be able to give 'accurate' cost predictions consistently. The relationship between accuracy and consistenty is expressedby Flanagan (1980). The choice as expressed in Fig: 3.1 is between four alternatives:

1 High accuracy and high precision (a)
2. Low accuracy and high precision (c)
3. High accuracy and low precision (b)
4. Low accuracy and low precision (d)

In real terms the higher the accuracy and the higher the precision the better the service to the design function. However, consistency can only be measured for a range of estimates while accuracy can be assessed for every single estimate. Thus, effort is devoted to seeking ways of improving accuracy as an aid to making predictions consistent.

3.3.3.2 Contractor's Estimates

Errors in contractor's estimates can be related to the total construction cost to the contractor. When contractors estimate cost, an attempt is made to determine the cost of resources that will be consumed by the project. In Chapter 2 it is stated that the tender is made up of the cost estimate and the mark-up. Appropriately, the contractor's estimate of cost should be compared to the actual cost incurred. However, most contractors do not have a cost reporting system capable of assessing accurately how much cost is

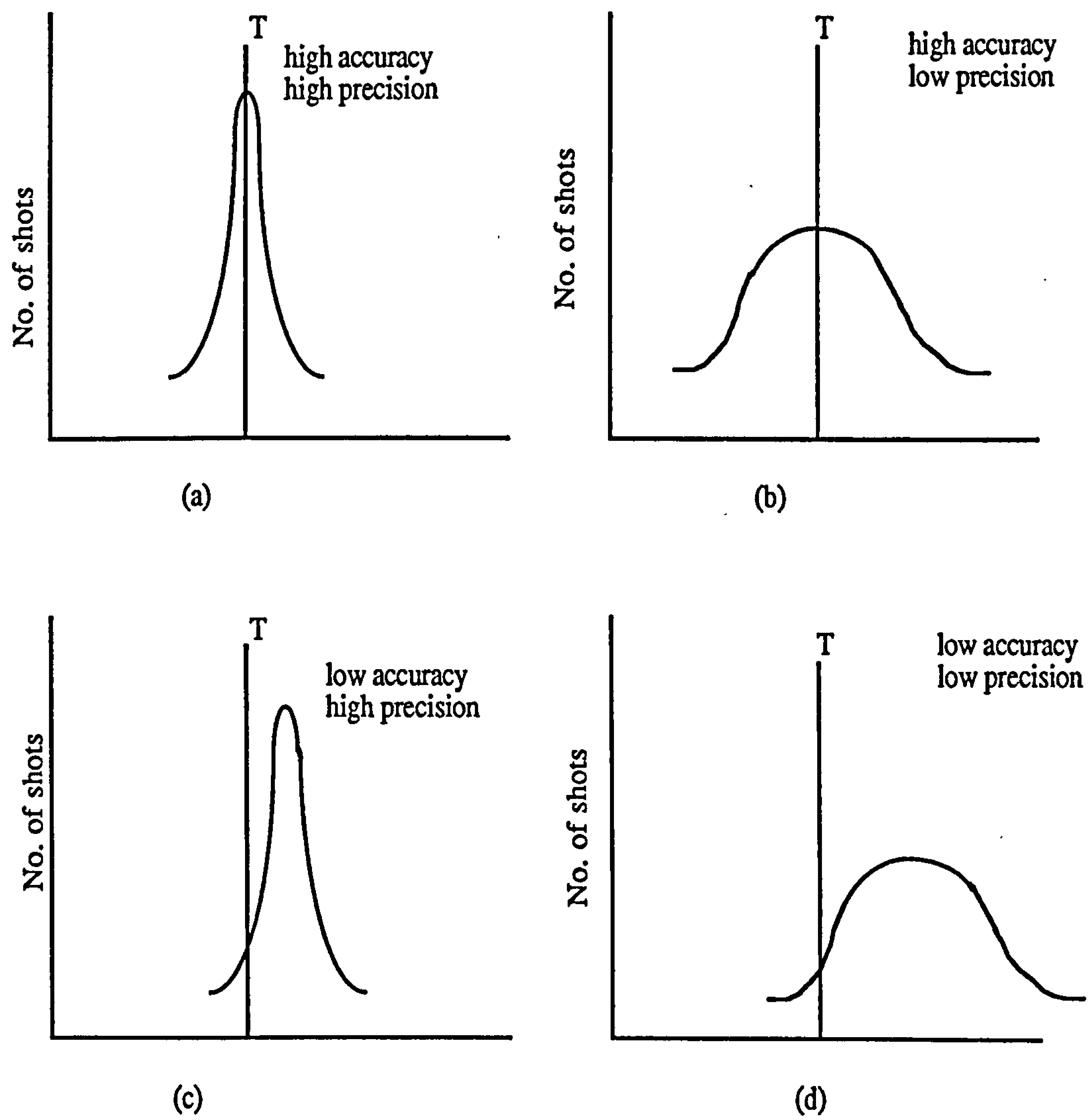


FIGURE 3.1 : RELATIONSHIP BETWEEN ACCURACY AND PRECISION
(Adapted from Flanagan 1980)

incurred on a particular contract (Abdullah, 1989). Thus the only viable alternative is to calculate the coefficient of variation of contractor's bids. It should be noted however that the variability thereby determined will also include the variability of the mark-up.

3.3.3.3 Comparing Accuracy in Design Estimates with Contractor's Estimates

To aid the evaluation of whether contractor's estimates are more accurate than design estimates, the errors in the estimates must be compared. Since it was stated that measuring errors in contractors estimate is not feasible, cvs are calculated over a range of projects and the average is compared with the cv calculated for design estimates.

3.3.4 Sources of Error in Estimates

In Chapter 2, a clear distinction was made between contractor's estimate and design estimate. Errors in contractor's estimate originate from the individual components of the analytical process of estimating. Thus the overall error will be as shown in Fig. 3.2. The contribution of each component to the overall tender error is well documented by Abdel-Razek (1987). It suffices to state that error in the contractor's tender will arise from the error in the basic cost estimate and the error in determining an appropriate mark-up.

3.7.4.1 Error in Design Estimates: Analytical Concept

Error in design phase cost estimates derive from the procedure for estimating. The errors can be classified as :

1. measurement errors;
2. unit rate errors;
3. addition errors; and
4. adjustment errors.

3.3.4.1.1 Measurement Errors

The design estimate relies on the measurement of quantities which may be floor areas, cubic content, element quantities, etc. depending on the method of estimating adopted. Inability to measure quantities correctly may originate from the use of incomplete information for estimating as well as the limitations imposed by the instrument. Except for the preparation of the tender estimate, construction drawings are rarely completed before estimates are prepared. Measurement errors associated with incomplete

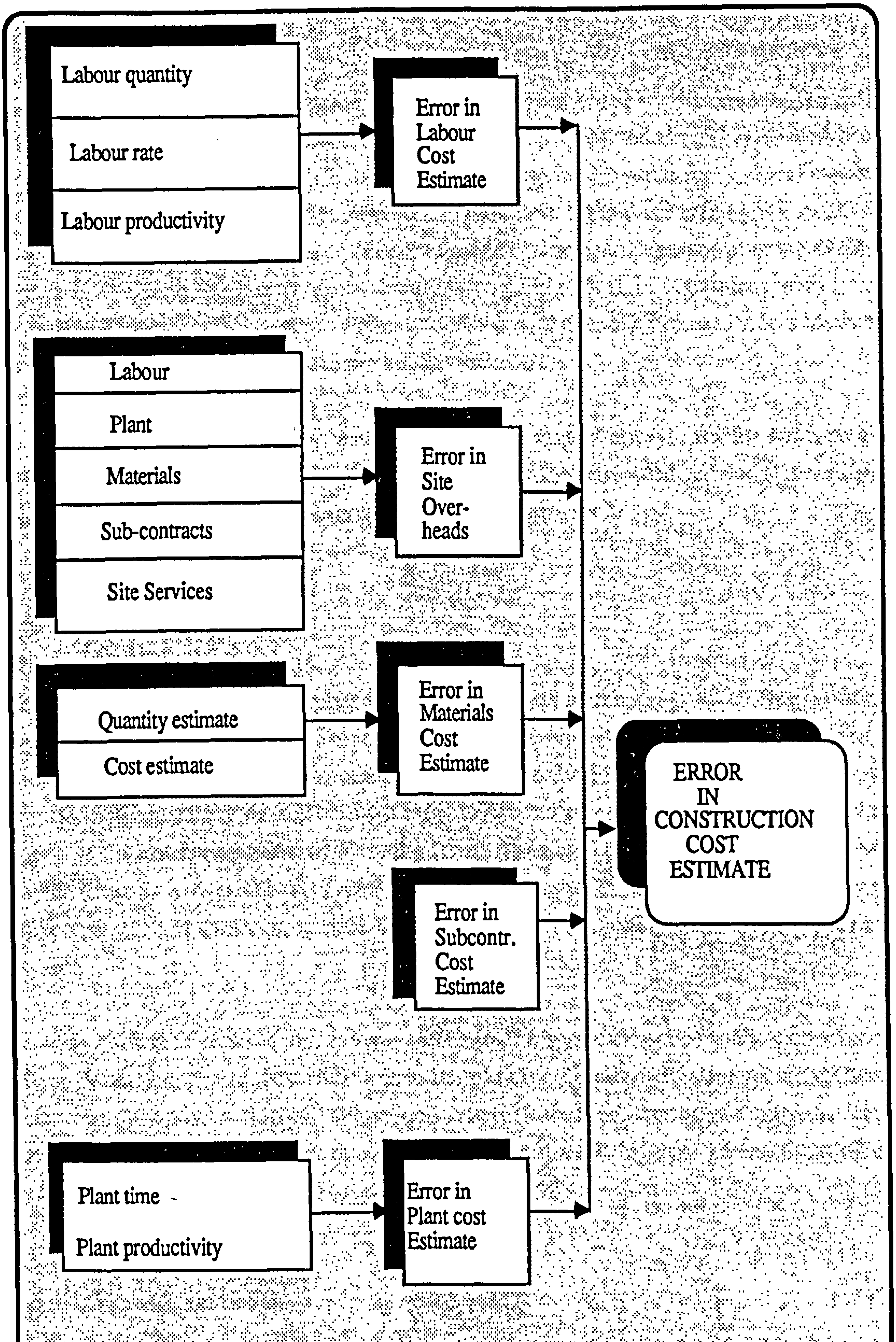


FIGURE 3.2: SOURCES OF ERROR IN CONTRACTOR'S COST ESTIMATE

information may originate from:

- **Scope changes :** Inadequate definition of project scope by the client at the early stages in design contribute to estimating error. As Merrow et al (1979) observed on energy process plants, changes in conceived project size between the budget estimate and the final design and construction correlate with time lag and are usually the results of changing exogenous conditions or demands made on the agency performing the design. The error picture in construction literature (e.g. Fig. 6.1) is consistent with these changes. Therefore, for reasons of clearer definition, the tender estimate is less likely to be affected by scope changes than the budget estimate.

- **Design changes:** These usually, but by no means always, results from scope changes and correlate with time. Such changes can be attributed to inadequacies and incompleteness in preliminary survey and design information.

3.3.4.1.2 Unit Rate Errors

The unit rate used for design phase cost estimating is usually abstracted from data on past projects. Morrison and Steven (1981) observed that "when differences occur between the cost plan and the cost analysis within individual elements, no adjustments are made to any of the data. The most recent cost analysis is almost invariably used as the basis for estimating and cost planning future projects. This is the case irrespective of any differences between the unit rates contained in the earlier cost data." If the validity of this observation is assumed, error in the original data is invariably transferred to the new project.

Another source of error in unit rates is the estimator's assessment of market conditions which determine the adjustment made to the old rate. Usually adjustments are made to cater for changes in design, shape construction method, economic climate, etc.. Incorrect interpretation of the market situation can result in gross overestimation or underestimation.

3.3.4.1.3 Addition Errors

The total cost estimate for a project is the summation of cost estimates for different items of cost or parts of the project. Although cost estimates are often checked and double checked before being presented to the client or design team, errors in addition often escape detection and thus affect the total cost estimate. However, addition errors are not as serious as other types of errors. Also, the advent of electronic calculators and computers have helped to reduce addition errors to the bearest minimum.

Rounding errors can also be associated with addition. They occur more frequently in fractions. Because the estimator works with large sums of money, rounding errors may not be so large as to have adverse effects on estimate accuracy.

3.3.4.1.4 Errors in Adjustments

A design estimate is adjusted for market conditions using a tender price index and the estimator's knowledge of the local industry. Indices are constructed from data from various projects and are designed to be representative of the industry as a whole. Three sources of adjustment errors can therefore be identified. Firstly, the estimator's knowledge of the local market relative to the national market can never be perfect. Secondly, errors originate from the data used in the construction of indices. These errors are transferred via the index to the estimate.

The third, and perhaps most serious, source of error in using price indices is the representativeness principle. Aggregating data from different parts of the country and from different projects pose a problem in itself. When a project deviates slightly from being 'typical', a particular index may not be suitable for making adjustments. Also, national economic phenomena such as the North/South divide in economic prosperity, which increase difficulties in recruiting construction workers in the South, may render a 'representative' index unsuitable for use in a place like the East Midlands area, which is neither North nor South. When indices are being constructed, different weightings are given to cost items. A quantity surveyor may need to estimate cost for a project on which the items given low ratings in the representative index are prominent. In such instances, his estimate is likely to suffer from lack of representativeness of index. Familiarity with the method of constructing a particular index will serve to improve their suitability in making adjustments to cost estimates.

3.3.4.2 Errors in Design Cost Estimates: Qualitative Concept

Ashley et al. (1988) present a conceptualisation of error in design cost estimate similar to, but not the same as, that presented in the foregoing discussions. They distinguished between accuracy and reliability of estimates. An estimate of error, the ratio of the difference between the estimate and a reference value, is used to assess accuracy. They identified the factors that affect estimating accuracy as: scope quality, information quality, uncertainty level, estimator performance and quality of estimating procedure (see Figure 3.3).

Estimate reliability is defined as a confidence level associated with the expected accuracy of an estimate. Factors affecting estimate reliability is portrayed in Figure 3.4. They recognise that prediction of the reliability of design estimates is an uncertain task. Ashley's et al's approach gives prominence to the influence of the design cost estimator on the accuracy of estimates.

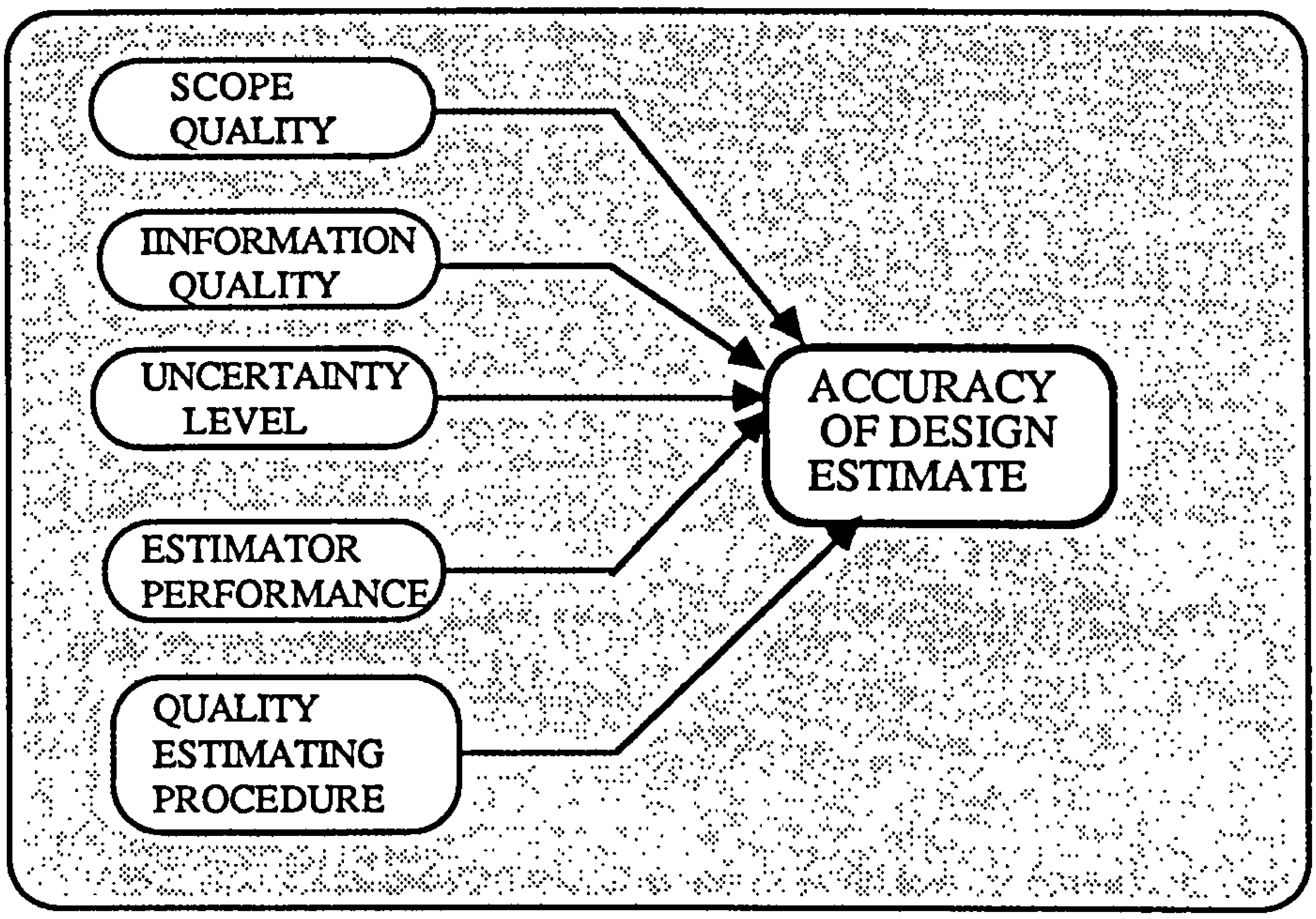


FIGURE 3.3: INFLUENCE DIAGRAM OF THE EXPECTED ACCURACY OF AN ESTIMATE

Source: Ashley et al. 1988.

3.4 SUMMARY

The major conclusions from the foregoing discusions can be summarised as follows :

1 Improving estimating accuracy is beneficial both to the industry and to the project management team.

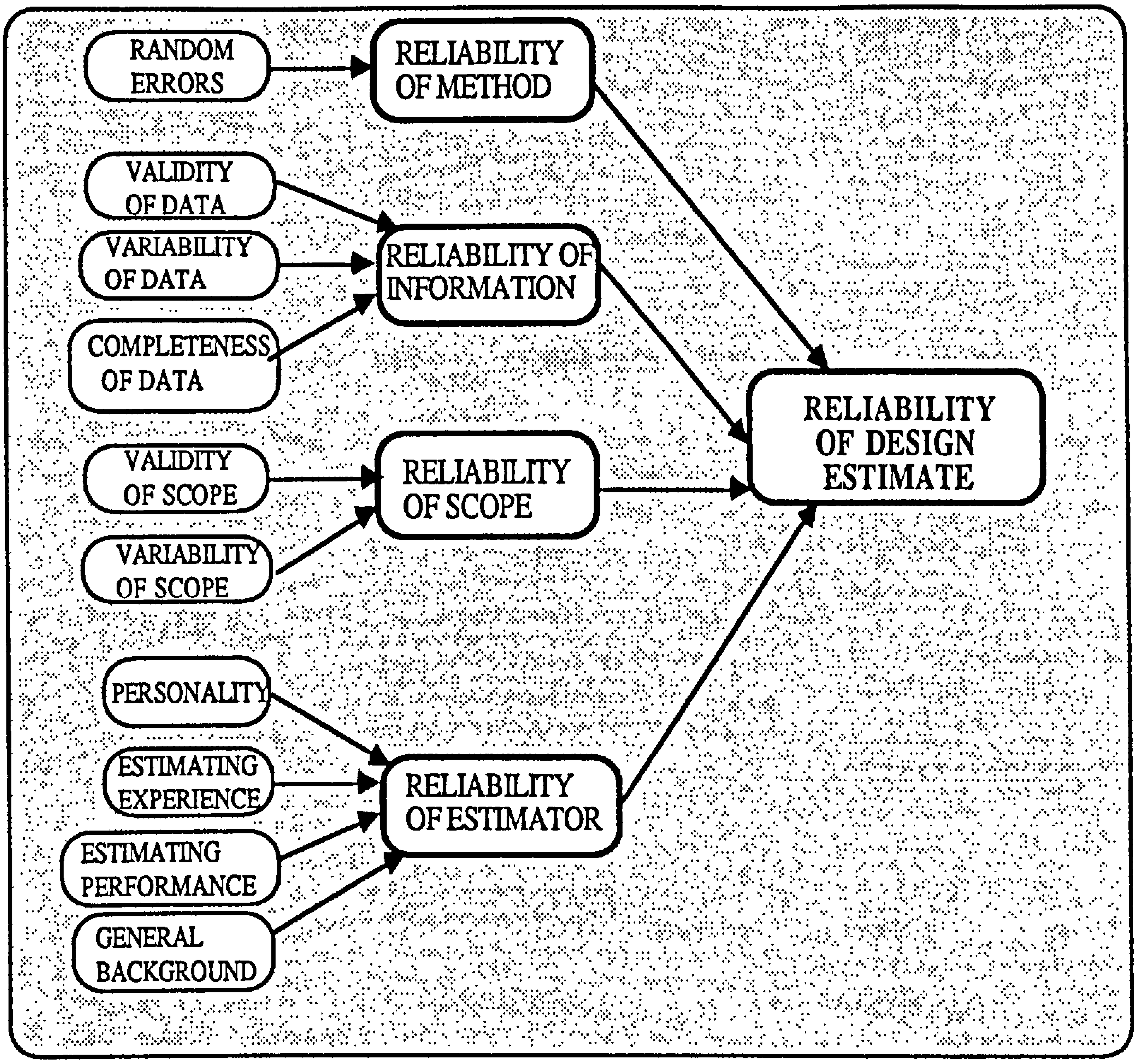


FIGURE 3.4: INFLUENCE DIAGRAM OF CONCEPTUAL ESTIMATING RELIABILITY.

Source: Ashley et al. 1988.

2 Research has established that there is scope for improving estimating accuracy. The major areas for improvement has been identified as:
- increased information use for estimating
- computer applications
- development of expertise and expert systems for estimating
- construction simulation
- resource based estimating at the design phase;

3 Error in design estimates originate mainly from the use of incomplete or unreliable information for estimating and inaccurate predictions about the construction environment;

4 Accuracy in estimating can only be studied by assessing errors; and

5 The methods for assessing accuracy in design estimates rely on the use of low bid as datum.

Chapter 4

ESTIMATING ACCURACY AND DESIGN PHASE COST MODELLING

There is a degree of speculation in all construction cost estimates, for no estimator, regardless of how capable, can accuractely forecast all material costs, let alone the cost of equipment, and particularly the cost of labour.
-W.S. Douglas, 1963.

4.0 INTRODUCTION

A major proposition from the research works reviewed in Chapter 3 is the introduction of resource based estimating at the design phase. Bennet (1985), Morrison and Stevens (1981) as well as Beeston (1983) appear to support the view that the way forward for improving accuracy of design estimates lies in the use of resource based methods.

Morrison and Stevens (1981) stated that "quantity surveyor's methods of estimating are not capable of producing significantly better levels of accuracy than those currently achieved in practice". They, therefore, suggested that "to improve accuracy of quantity surveyor's estimating requires research which should include, amongst other approaches, a consideration of methods which explicitly consider construction method, resource use and construction time." Although this does not seem a categorical statement that contractor's methods should be adopted at the design phase, it does suggest that current methods have limited scope for improving accuracy. Beeston (1983) is more explicit in suggesting that "the best hope for improvement in advice to designers and in accuracy of estimating is to calculate costs in the way in which they arise or as closely as possible to this ideal." His position is that the 'ideal' lies outside current methods. Also calculating costs in "the way in which they arise" will require resource based estimating since construction cost is incurred by using construction resources.

Ref? 1983?

Ashworth and Skitmore (1982), however, suggested that accuracy could be improved by exploiting the intuition of experienced cost forecasters. This represents less deviation from the current position. Before making a definitive statement on the best approach for improving accuracy in design estimates, it is necessary to establish if there is sufficient justification, in current literature, to suggest that contract estimates are more accurate than design estimates and to assess if resource based estimating will appeal to design estimators. This is the focus of this chapter.

4.1 DESIGN ESTIMATES

It was stated in Chapter 3 that measuring accuracy relies on the assessment of errors. Also, assessing errors presupposes the existence of a 'correct' or 'true' value and that error is a deviation from this 'true' value. In assessing error, design estimates of construction costs are compared with tender prices. The system in the United Kingdom is to award contracts to the contractor with the lowest reasonable bid [at least on public contracts]. A consequence of this is that design estimates are usually compared with the low bid when errors are being assessed. Most studies considered in this chapter compare the design estimate with the low bid or the winning bid in cases where the low bidder is not awarded the contract.

The accuracy of design estimates is thought to correlate with the stage of design at which the estimate is prepared. In theory, there is no limitation to the number of estimates that may be prepared on a construction project. However practical limitations are imposed by the cost of producing estimates and the need of the client and the design team. It is appropriate to assume that the client will require an estimate of cost for budgeting purposes and for arranging for project finance. Also, forecasts of tender prices are usually needed to advise the client on appropriate contract price. This is consistent with Morrison and Stevens (1980) study. Accuracy improves with the development of design because of better scope definition and completeness of information. Thus, there is sufficient justification for dividing studies of accuracy into: (1) early stage estimates; and (2) estimates based on detailed design. This approach has been adopted in Ashworth and Skitmore (1983) and Ogunlana and Thorpe (1987). To make later discussions clearer, these studies are further divided along quality lines and arranged in chronological order.

4.1.1 Early Stage Estimates

4.1.1.1 Opinions, Suggestions, etc.

1963 In the book, Chemical Engineering Handbook (J.H. Perry ed.), Weaver et al suggested 4 stages of accuracy for cost estimates in the Chemical industry: order of magnitude (over ±30%), study estimate (±30%), budget authorisation (±20%), and project control (±10).

1973 Park remarked that there is usually a choice between 3 levels of accuracy in estimating: 'order of magnitude forecasts' range between ±50% and ±30%, while 'semi detailed' or conceptual estimates prepared from rough quantity take-offs and suppliers' quotations should be accurate to within ±10% and 'detailed' estimates prepared from complete engineering specifications, drawings and site surveys should be accurate to within ±5% of actual cost.

1974 Barnes and others suggested that an accuracy of ±33% will include most estimates made for feasibility purposes. Barnes further suggested that, with contract estimates having accuracy between 5-7%, it is unlikely that design estimates can be better than 15-20% (when prepared by professionals) or 20-30% (when prepared by students). He produced a figure relating accuracy to design stage/information which suggest that estimates generally improve from -40% or +20% at the commencement of feasibility studies to -20% or +10% at the commencement of detailed design.

1977 Keating was of the opinion that 'the experienced estimator provided with complete process design and equipment specification can confidently arrive at costs within 10-25% accuracy. Marr specified 5 levels of accuracy adequate for construction cost forecasting as: planning control estimate (20-40%), budget control estimate (15-30%), schematic stage contol estimate (10-20%), and preliminary drawing stage control estimate (8-15%) and construction drawing stage control estimate (5-10%).

1979 Bennet and Barnes used figures of ±7% and ±10% cv in developing arguments for including less items in bills of quatities without indicating the source of the figures.

4.1.1.2 Empirical Studies

1980 Flanagan analysed data from 2 County Councils on forecasts made at the inception and outline stages. His analysis suggested a cv of 15% with 25-30% of predictions falling within ±5%.

1981 Greig interviewed 32 client organisations and produced accuracy figures for forecasts made in the early and late stages of design ranging from less than -20% to

+20% with 75% of forecasts within ±5% of final account. This result produced cvs of roughly 6-7% in the early stages and less than 5% in prior to tender.

Jupp and McMillan also reported on an opinion survey of 49 quantity surveying practices. The results suggest accuracy figures of ±5% in most cases. Finally, McCaffrey and McCaffer's survey of forecasting accuracies on 15 schools produced figures for 4 stages of design: forecast (17%), brief (10%), sketch (9%) and detailed design (6%).

Table 4.1: Accuracy of Design estimates (at the early stages)

Source	Estimate Stage	Accuracy	Cv	Source Data
Weaver et al. [1963)	Order of magnitude	over 30%	-	Suggested values for
	Study estimate	±30%	-	the chemical industry
	Budget asthorisation	±20%	-	
	Project Estimate	±10%	-	
Park [1972]	Order of magnitude	±30%	-	Park's opinion
	Semi-detailed	±10%	-	
Barnes [1974]	Feasibility structure	+20% to -40%	-	Barnes' suggestions
	Detailed Design	+10% to -20%	-	
Keating [1977]	Order of magnitude	±25%	-	Keating's opinion
	Appropriation grade	±15%	-	
Marr [1977	Planning	±20 to ±40%	-	Marr's suggested
	Budget	±15 to 30%	-	standards
	Schematics	±10 to ±20%	-	
	Before construction	±5 to 10%	-	
Flanagan [1980]	Inception and outline	-	15%	Data from 2 County councils
Greig [1981]	Early stage	over ±20%		Opinion survey
	Final forecast	86% achieve ±5% accuracy		
Jupp and McMillan [1981]	-	±5%	-	Opinion survey of 49 QS practices
McCaffrey & McCaffer [1981]	Forecast	-	17%	Data on 15 schools
	Brief	-	10	projects
	Sketch plan	-	9	

4.1.2 Detail Design

The view in construction literature is that the accuracy of estimates should improve as design progresses. The estimator has more information on which to base predictions and project is better defined than at the early stages of design. Ideally, the studies in this section should reflect the improvements by showing less values of error than in the previous section.

1950 Alchian made 4 studies of the reliability of cost estimates using data from several sources. The results are as follow: (1) Aircraft wing weights (±10%); an estimator's predictions of aircraft component cost for a 2 year period (±23%); and cost predictions on public works (±15%).

1971 Perry et al. reported estimation errors in weapon acquisition projects over two decades : (1) 1950s mean of actual/estimated cost on 55 projects show a cv of 72%, (2) 1960s mean of actual/estimated cost on 25 projects show a cv of 27.9%.

1972 Merewitz reported cost overruns on public works with special reference to Urban Rapid Transport Projects as : (1) 49 Highway projects (50% cv); (2) 49 water projects (50.4%); (3) 59 Buildings (50.1%) (4) 15 Ad hoc (63.6%).

Park analysed engineer's cost estimates on nearly 100 projects reported in the Engineering News Records in 1971 using the low bid as the true cost: 94% of the estimates were within ±20%; about three quarters were within ±5%; more than half were within ±10% and about one third were within ±5%.

1974 Beeston reported that, from the analysis of Property Services Agency contracts, a cv of 7% is the best the quantity surveyor can hope to achieve using current methods. He calculated that this will produce 85% of the estimates within ±10% of the low bid. Also, Mitchell considered that ±10% was normal for forecasts based on detailed design.

1975 McCaffer reported on various studies at Loughborough University indicating cvs as follows: (1) 34% for electrical services, (2) 26% for Heating and Ventilating, (3) over 15% for office buildings, and over 20% for roadworks.

1976 McCaffer analysed estimating performance on 132 building contracts and 16 road contracts in Belgium. The results show an average overestimation of 7.5% and 1.45%. The corresponding cvs were calculated as 13.13% and 18.37% respectively. Also, Hanscomb Roy Associates claimed to achieve a cv of 7.71% on 52 contracts between 1975 and 1977.

1977 Mead et al. analysed estimating errors on 12 major construction works in the gas industry which show a cv of 73%.

1979 Merrow et al. analysed data on 10 energy process plants showing significant underestimation of the mean. The cv for the projects was 20%. Also, Brown reported an average 7.8% overestimation of the low bid on 273 NASA construction contracts awarded between 1973 and 1981.

1980 Bowen conducted an attitude survey which revealed an accuracy of ±9% for framed structures. In the same year, Morrison and Stevens analysed estimates for 915 construction projects let between 1973 and 1979. The results revealed standard deviation ranging from 7.57 to 11.76 and an average cv of 13%. Also, Kennaway investigated tender price levels associated with 'abnormal conditions'. The range of errors for the 25 Railway projects was -30% to +40.60%. Brown too analysed 22 projects showing engineer's forecasts to be, on average, 7.49% higher than the low bid, with a cv of 16.77%. Finally, Jupp and McMillan rerpoted the result of an estimating experiment involving 3 quantity surveyors pricing bills of quantities of similar projects. Cvs of 18% and 24% were calculated depending on the information used for estimating.

1981 Merrow et al. reported that the experience in pioneer process plants show underestimation of costs in 5 stages as : stage 0 (51%), stage 1 (38%) stage 2 (22%), stage 3 (17%) and stage 4 (7%).

1982 Thorpe collected data on projects undertaken in 2 government departments which show mean errors of ±7% with standard deviation up to 26.

1985 Darko analysed data on 33 projects which show: (1) cv between estimates and tenders to be 12%; (2) cvs between tenders and actual costs to be 19%, and (3) cvs between estimates and actual costs to be 14%. Also, Skitmore conducted an experiment in estimating which involved 12 quantity surveyors pricing 2 projects from a pool of 5 projects. The results show that mean error increases from -12.71% to +16.98% for 'non-experts' and from -0.57% to 5.17% for 'experts', depending on the amount of information supplied. The corresponding standard deviations were 37.07 improving to 28.61 and 14.08 changing to 14.23 for the 2 projects respectively.

Table 4.2: **Accuracy of design cost estimates (Detailed design)**

Source	Accuracy (%)	Cv (%)	Source Data
Merewitz [1972]	-	50	49 highway projects
		50.4	49 Water projects
		50.1	59 Buildings
McCaffrey and McCaffer [1981]	-	6	Data on 15 school projects
Park [1972]	-	10-15	100 projects
Beeston [1974]	-	7	Large sample of PSA projects
Mitchell [1974]	+10	-	-
McCaffer [1975]	-	34	Electrical services
		26	Heating and Ventillating
		> 15	Office buildings
		> 20	Road works
McCaffer [1976]	+7.5	13.31	132 Belgian buildings
	+1.45	18.37	16 Belgian roads
Mead [1977]	-	73	12 major construction works
Merrow et al. [1979]	-	20	10 energy process plants
Hanscomb Roy Associates [1976]	-	7.7	52 North American contracts
Brown [1979]	+7.8	-	273 NASA constrn projects
Bowen [1980]	+9	-	Attitude survey
Morrison and Stevens [1981]	-	13	915 construction projects
Kennaway [1979]	-30 to +40	-	25 railway projects
Brown [1979]	+7.49	16.77	22 projects
Jupp and McMillan [1981]	-	18 and 24	Estimating experiment with 3 QSs and 9 projects
Thorpe [1982]	±7	-	41 government projects
Darko [1985]	Estimate/tender	12	33 projects
	Tender/constn cost	19	"
	Estimate/constn cost	14	"

4.2 CONTRACT ESTIMATES

Three approaches are generally taken in assessing the accuracy of contract estimates:

- the estimated construction cost may be compared with the actual cost of construction. This approach suffers from the problem of contractors' cost reporting systems being unable to provide accurate figures of actual construction cost (Abdullah, 1989);

- a contractor's losing bid may be compared with the winning bid. Although this does not provide a measure of error in the winning bid, developers of competitive bidding models favour it;

- a coefficient of variation may be calulated for the distribution of tenders.

Most of the studies in this section use the first approach despite its limitations.

4.2.1 Views, Opinions and Limited Studies

1966 Rubey and Milner proposed that contractors should estimate with error considerably less than 10% of their final cost. Park is however of the view that, given engineering specifications, drawings and site survey, estimating errors should generally be about ±5%.

1969 Morin and Clough's analysis of a limited sample of data with symmetrical distribution yielded a cv of 2%. They built a model on the assumption that the cost estimate is equal to the true cost.

1970 Fine and Hackemar reported that Monte Carlo simulation model indicated errors between ±8% and 14%. Fine later rounded the figure to ±10% while Hackemar quoted ±5% from the same model.

1972 Willenbrock noticed a mean 3% increase in actual over estimated cost while Case suggested a mean figure of 5.5% cv for engineering services whereas cvs may vary in extreme cases between 0% and 33%.

1973 Moyles conducted an opinion survey of contractors and others at a seminar in Loughborough where ±5% accuracy was accepted as being appropriate.

1977 Keating reported that experienced estimators in process engineering contracts can achieve accuracy within 10-25% of total installed cost when provided with complete process design and equipment specifications.

1979 Ashworth's experiment involving contractors estimating manhours on building jobs for 9 projects showed a mean error for each estimator to be between -3% and +46% with standard deviation ranging from 17 to 30 and cvs for each project ranging from 13 to 20%.

1979 Barnes referred to examples varying from 2% to 15% cv without indicating the source.

4.2.2 Empirical Studies

1967 Gate analysed bidding performance of a large contractor on 110 Highway contracts let by the same client between 1963 and 1965. The actual/estimated construction cost ratio appear normally distributed with a cv of 8%. He calculated that the probability of estimating within ±10% of the actual cost is around 0.80.

1971 Barnes analysed 160 contracts using the ratio of actual total cost/estimated cost multiplied by the ratio of tender sum/final account to assess accuracy. His study indicated a cv of 5.8%.

1974 Beeston analysed a large sample of PSA contracts giving a cv between 5.2% and 6%.

1976 McCaffer compared bids to designer's estimates on 185 building and, 16 bridges and 168 road contracts in Belgium. The results show cvs of 6.5%, 7.5% and 8.4% respectively. Grinyer and Whittaker analysed data from 153 contarcts indicating cv around 6.0%.

1976 Associated Industrial Consultants Ltd and Business Operations Research Ltd analysed 213 Motorway contracts for the Ministry of Transport which showed a cv of 6.8%.

1979 Benjamin and Meador's analysis of 131 contracts show a mean cv of 6.6%.

Table 4.3: **Mean Coefficient of Variation of Construction Bids**

Author	Source of Data	Mean cv (%)
Gate [1967]	110 Highway Contracts	8
Fine and Hackemar [1970]	Adequate sample of construction contracts	5.0
Beeston [1974]	Large sample of PSA contracts	5.2 to 6.0
Grinyer and Whittaker [1973]	153 government construction contracts	6.04
Skitmore [1986]	269 building contracts	6.4
Barnes [1971]	160 construction contracts	6.5
McCaffer [1976]	185 Belgian building contracts	6.5
AICBOR [1976]	213 Motorway contracts	6.8
McCaffer [1976]	16 belgian bridge contracts	7.5
McCaffer [1976]	385 road contracts	8.4
Benjamin and Meador [1979]	131 Contracts	6.6
Runeson [1988]	1046 Building projects	4.9

1988 Runeson analysed bid distribution on 1046 Australian building contracts showing a cv of 4.9%.

Measures of coefficient of variations of construction bids are shown in Table 4.3.

4.3 DISCUSSIONS

The foregoing review contains available literature on the measurement of errors in estimates. It provides a useful basis for establishing whether design estimates are less or more accurate than contract estimates.

It is noticed that a large proportion of the 'studies' are views and reasonable generalisations. A salient characteristic of this category of literature is that the figures tend to be genarally more optimistic than those in empirical studies. This agrees with previous observations (see Thorpe, 1982 and Morrison and Stevens, 1980) which suggest that quantity surveyors are not aware of the magnitude of the errors they make in estimating. There is also a divergence of opinion regarding the achievable level of accuracy in estimating. It seems generally acceptable to quote figures between 5% and 10% for later stage estimates and 10-20% for early estimates. Alternatively, it may be argued that considering the results of Skitmore's (1987) experiment, experts produce figures less than 10% while the shortfall in error originates from estimates made by non-experts. This conclusion cannot be substantiated from empirical data.

Also, the studies are neither confined to any particular sector of the construction economy nor are they restricted to any country. The results do not indicate that quantity surveyors and design engineers in the UK are less or more accurate than design phase cost estimators in other countries.

As stated earlier, design estimates are compared with the low bid in most cases. It is doubtful however, if while making predictions, design estimators consciously predict the low bid. It seems more appropriate to assume that, at the early stages in design, estimates of likely project cost are required. The estimator does not have information on which predictions of low bid can be made. He is therefore more likely to forecast a probable cost for the project while accepting that that the actual cost can be below or above the predicted value.

On the other hand, contractors' bids are compared with actual cost/final account figures in some studies. It is a truism that a competitive bid does not represent the contractors opinion of the actual cost of the project. In competitive tendering, contractors try to outbid each other while ensuring that they can safely make profits on projects. In some cases, profit may have lower priority than winning. Evidence suggests that some contractors bid high in anticipation of negotiation (see Runneson 1988). Except for the technical purpose of apportioning error, the bid is not a measure of cost.

Because contractors are generally not required to forecast construction costs at the early stages in design, it is inappropriate to compare early stage design estimates with contractors' estimates. Design estimators realise that accuracy in the early stage estimates are much lower than for later stage estimates. A fair comparison can only be made between estimates made from detailed design and contract estimates.

The studies in Table 4.2 and 4.3 seem to suggest that the general variability of contractor's estimates is within the range 5.0-6.5% while cvs measured for design estimates average 12.41% at the detailed design stage. It is noticed however that no studies have been made to directly compare design estimates of construction cost with the contractor's cost estimate. The reason is obvious; the contractor's tender is not a measure of construction cost. Rather, as earlier stated in Chapter 2, the tender consists of a cost estimate plus a mark-up representing general overhead costs and profit. Unlike the contractor, the design estimator does not forecast construction costs and mark-up separately. While the contract estimator forecasts the likely cost of construction, he may not be responsible for adding the mark-up, his role being often limited to advising the tender adjudication panel. The achievable level of accuracies in estimates should be examined at this juncture. Assuming the ratio of construction cost to the mark-up is 80:20 (for the purpose of this discussion) and similarly, that the total error in the tender follows this proportion. If errors in mark-up and the cost estimate are assummed to be mutually exclusive, the alternatives are (Figure 4.1):

(1) Positive error in both estimate and mark-up - in which case errors are additive and positive taking the maximum value 1.0e (a).
(2) Positive error in estimate combined with negative error in mark-up - error in tender is positive but reduced having the maximum value 0.6e (b).
(3) Negative error in estimate and positive error in mark-up - error in tender is negative but reduced having the maximum value 0.6e (c).
(4) Negative error in both estimate and mark-up - negative error in the tender having a maximum value 1.0e (d).

Thus the design estimator's target flunctuates between T-1.0e and T+1.0e (T being the target cost) making his overall error value to be ±1.0e. On the other hand, the contract estimator's target flunctuates between T-0.8e and T+0.8e; the theoritical maximum value of his error being ±0.8e since he only estimates the cost to the contractor. Irrespective of the method of estimating, the design estimator's error band is 25% wider than the contract estimator's. The greater the proportion of error attributable to mark-up the more the difference between the design estimator and the contract estimator's achievable accuracy.

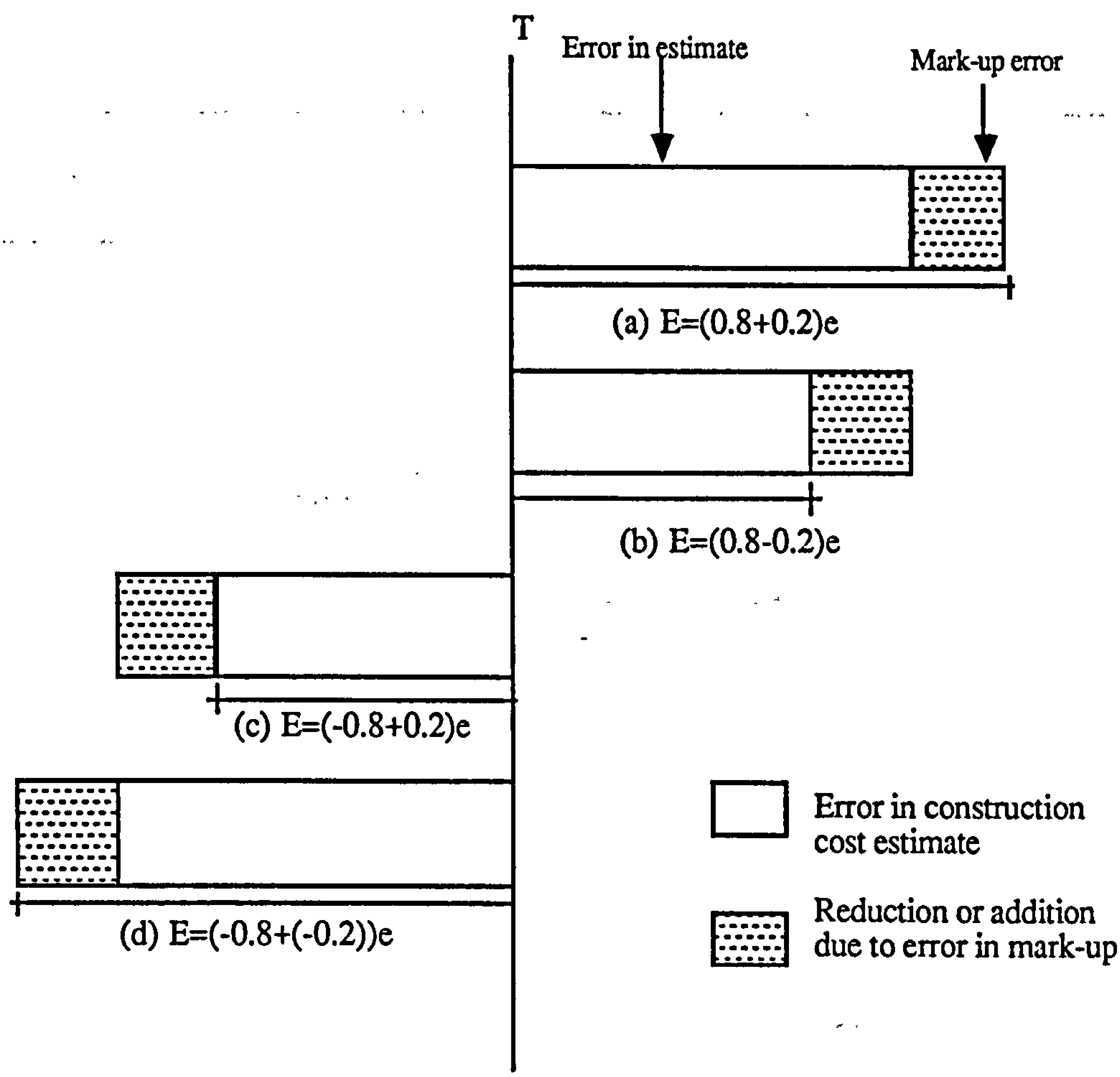


FIGURE 4.1 : CONTRIBUTION OF ERROR IN ESTIMATE AND MARK-UP ERROR TO OVERALL TENDER ERROR (Theoretical Model).

Also, the studies do not specify what estimating methods where involved. A picture of the estimating process and the feedback that may be received is presented in Figure 4.2. The task performer uses cost data and estimating method (or a combination of methods) in the process of estimating. Estimators are well aware that different methods have limits of accuracy and that the quality of the data used for estimating affects their abilities to predict cost. The ability of the task performer as well as the the conditions under which the estimate was made also affect accuracy. As Einhorn (1982) observed, outcome information without knowledge of task structure can be irrelevant in providing self correcting feedback about poor heuristics. Thus, knowledge of the method employed, the quality of data, under what conditions they were used, etc. is essential to assessing the predictive ability of each method. The studies presented provide no such information.

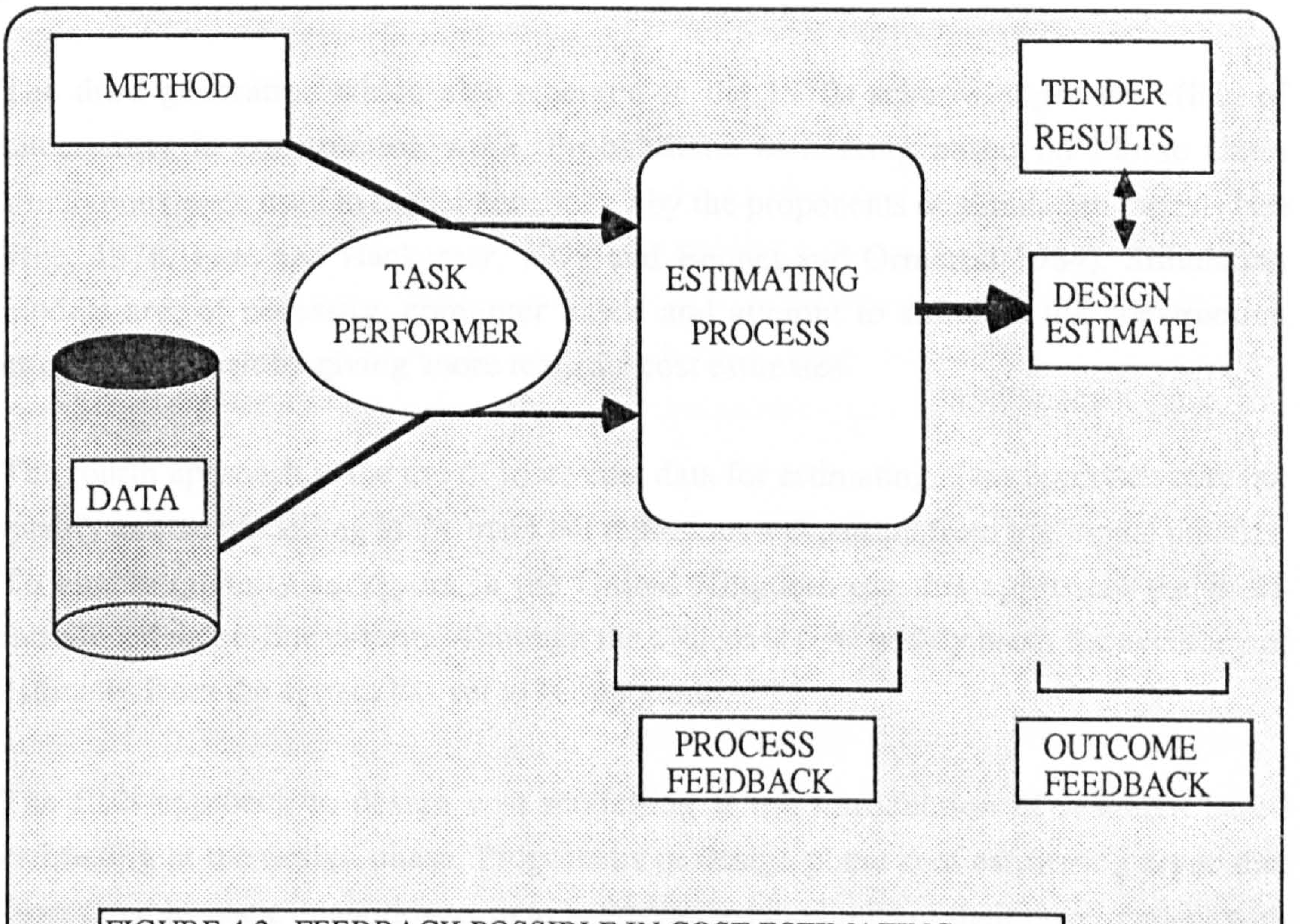


FIGURE 4.2 : FEEDBACK POSSIBLE IN COST ESTIMATING

4. 4 DESIGN COST MODELS - PAST, PRESENT AND FUTURE

Raftery (1987) first identified three generations of cost models. Other approaches to construction cost modelling are now available in addition to those identified by Raftery.

First there was the procedural approach (elemental cost analysis) introduced in the 1950s (see James, 1954 for example). The procedure relates cost to unit area and adjustments are made for quality based on professional intuition. The drawback in this approach derives from the inability to arrive at suitable relationships between elements and projects on which cost forecasts can be based.

The second generation of models were regression models. These models emerged in the 1970s and were usually computer based due to the amount of information used in the models (Kouskoulas and Koehn, 1974 and McCaffer 1976). When first developed, the models were reported to be capable of producing better cost estimates than the procedural models.

The third generation which also emerged in the 1970s acknowledges the effect of uncertainty in construction work. Probabilistic estimating based on Monte Carlo simulations were used to model uncertainty by the proponents of simulation models (see Fine, 1978; Fine and Hackemar, 1978 and Bennet and Ormerod 1984). Simulation models are, of necessity, computer based and attempt to simulate the construction environment thereby giving 'more realistic' cost estimates.

The fourth approach is the use of more cost data for estimating. This approach may not qualify as cost modelling in the main but represents a departure from traditional practice. To enable quantity surveyors in the United Kingdom use this approach, the BCIS introduced an on-line system. Although the system is now widely used, the accuracy of estimates from the system has yet to be reported.

The fifth approach to design cost modelling is the introduction of resource based estimating at the design phase. Proponents of design phase cost estimating argue that "measured in-place quantities seem to have reached the limits of their development with an accuracy insufficient either for estimating or for cost advice at the design phase (Beeston, 1987). Based on this assumption, they suggest that costs should be measured in the way in which they arise. However, it has yet to be demonstrated that resource based estimating at the design phase will be feasible.

Bennet and Barnes (1979) remarked that ideal cost models would comprise a set of factors and relationships which responded to variations in projects by changing valuations of works in the same manner as contractors' actual costs. They observed that since cost depends on many variables including contractor's selection of methods and resources and the timing and sequence of operations, getting the ideal is impossible.

They suggested that the bill for pricing individual projects should be related to the contractor's method of costing even though they accepted that neither contractors nor design estimators have demanded such pricing methods.

A look at the data in Table 4.3 will reveal no increase in measured accuracy since the various models mentioned above were developed. The models developed by researchers do not seem to have affected the accuracy of estimates in the construction industry. Two hypotheses have been proposed to explain this development (Ogunlana and Thorpe, 1987):

(i) the models may not have been adopted by professionals in the industry, or
(ii) the models may not be capable of producing better estimates as claimed by their developers when subjected to real world situations.

There is no empirical data to support the second hypothesis. The first is consistent with Morrison and Stevens' (1980) research. Two questions that demand answers are: Why have the models not been adopted by the "real world practitioners" if indeed that they are capable of producing better cost estimates? Is there any guarantee that resource based estimating will be used by design cost estimators and used effectively if introduced?

Information for answering the first question comes from three unrelated studies, two of which originate outside U.K. construction. Pohlman et al. (1988) surveyed the cash flow estimation practices of large firms (Fortune 500 American firms). The results show a preference for simple cash flow forecasting models. More than 90% of the firms surveyed use management's subjective estimates for cash flow forecasting even though some of them may use other models in addition. Other subjective estimates such as consensus of expert opinion are highly rated too. Models that are sensitive to temporal variations in factors affecting costs are reported to be complex in structure and time consumming to calibrate and apply. The additional effort required to implement the models are substantial and incapable of producing corresponding increase in model accuracy and reliability.

Another similar study under the National Cooperative Transit Research and Development Program (1988) show that mass transit agencies in America use simple, one- or two-variable cost allocation methods having limited accuracy. More complex models are said to be too difficult and time consumming to apply and, therefore, are not adopted by the transit agencies. The research therefore concluded that simple but fairly accurate models are better from the industry's point of view than complex methods.

1988?

A third, and perhaps most relevant, study was conducted by Perera (1989) into the use of optimisation techniques for cost effective reinforced concrete design. A mathematical model (Chou model) which was claimed to be capable of reducing cost of concrete beams by 14% was tested on 24 projects. Actual reductions in cost by using the model were measured as 6%. 15 design organisations interviewed on the use of mathematical models for cost reduction insisted that unless a model could lead to cost reductions higher than 10%, their companies would not consider it. The result is that since the Chou model could not give such guarantees, it has not been adopted.

As Miesl (1988) stated, the key demands on cost models are that they should be acceptable to intuition and experience, should be simple and transparent with traceable logic and ground rules, and have an applicable database. Miesl reasoned that those who use models are more interested in making decisions that are readily explainable to themselves and others in common sense terms. He concluded that it may be easier to live with a good justification than with the dictates of a complex and perhaps unintuitive mathematical models. Miesl's reasoning, and the results of the three previous studies may be used to explain the situation in the construction industry. Complex models are not used because they do not appeal to the real-world practitioners. The procedure for resource based estimating is more involving without the necessary guarantee of better results. Rather than advocate that design estimators should abandon familiar methods and adopt other seemingly better methods of cost estimating without adequate guarantee of yielding better results, the problems with existing estimating practices which contribute to errors in estimates should be examined and rectified.

The second question may be answered by recourse to what is known about the two alternative procedures: Cost in place techniques and resource based estimating. McCaffer and Baldwin (1986) outlined the process of preparing contract estimates thus:

- programming the estimate.
- preliminary project study.
- materials and subcontractor's enquiries.
- project study, construction method and planning.
- calculating labour and plant costs.
- estimating the direct cost.
- calculating on-costs.
- preparing reports for tender meeting.

The additional process of arriving at the tender figure in a construction firm involves: (McCaffer and Baldwin, 1986)

- the assessment of the estimate and evaluation of adjustments.
- the assessment of general overheads.
- the assessment of risk and profit allowances.
- the writing up of bill for submission.

On the other hand, the estimating process in design offices involves the following steps:

- calculating quantities and units for estimating.
- determination of the unit rates to be used.
- adding up to arrive at a total project estimate.
- making adjustments to the total estimate.

The two procedures are different and require different cost data for implementation.

To achieve optimum results from resource based estimating techniques at the design phase, the estimator must be able to apply the technique exactly like the contractor. Calculating construction cost will involve using the following cost data : materials cost, plant cost, labour productivity, labour costs, etc. Such data are not readily available to the design cost estimator. Other alternative sources exist outside the organisation. Cost data books have the all too familiar problem of being different depending on which office they originate from (See Bennet, 1988). Unlike the contractor who sometimes use these cost data books, the design cost estimating office has no facilities for generating in-house cost data with which plant and labour productivity rates can be compared. The reluctance amongst design estimators to use data with which they are not familiar has been widely reported (Morrison and Stevens, 1980 and Thorpe, 1982). It can thus be speculated that design estimators will not be favourably disposed to using such data.

Having calculated costs analytically, how does the design estimator add a suitable mark-up? To arrive at a suitable mark-up will require the design office replicating the contractor's thinking process without being able to provide in-house justifications for his opinions. This will be quite an unprofessional approach to estimating. We can only conclude that the introduction of resource based estimating at the design phase will receive strong opposition from professionals.

4.5 SUMMARY

From the studies in the foregoing sections in this chapter it has been concluded that:

1. There is a divergence of opinion on the level of achievable accuracy in estimating.
2. Indeed, there exist a difference between the accuracy achieved in design estimates (range: 6 - 73, and average: 12.41% cv) and those achieved in contract estimates (range: 4.9 - 8.4% cv).
3. There is also a difference (theoretical) between the design phase estimator's achievable accuracy and that of the contract estimator.
4. The difference between the accuracy levels achieved in design estimates and contract estimates is partly attributable to the theoretical differences and partly due to the quality of cost data used in estimating.
5. The feedback currently received from estimating is limited to outcome rather than process feedback.
6. Cost models proposed in research have not made significant impacts on accuracy in the real world. This is due to the fact that most of the 'paper models' have not been adopted in industry.
7. It is axiomatic that many new models suggested by researchers are not adopted in industry because they require more effort to implement and are time consumming without significant increases in accuracy.
8. Design estimators are not currently in a position to use resource based estimating procedures to advantage.

CHAPTER 5

LEARNING FROM EXPERIENCE AND THE USE OF INFORMATION IN ESTIMATING

What experience and history teach is this - that people and governments never have learnt anything from history, or acted on principles deduced from it.
- G. W. F. Hegel, 1832

5.0 INTRODUCTION

Research findings on current estimating practices and their results that contribute to error were presented in Chapter 3. Specifically, estimators are said to be: (1) unaware of the magnitude of error made in estimating, (2) unable to achieve accuracy levels expected, (3) in favour of information with which they were connected, (4) failing to compare predictions with actuals on a regular basis, (Comparisons are made only when significant deviations of tender from the estimate are noticed) (5) using information on a single project for making predictions and (6) using most recent cost data irrespective of the error in the information. These practices evince a lack of learning (from experience) on the part of design cost estimators and contribute to estimating error.

The work in this chapter provides psychological explanations for design cost estimators' failure to learn. The underlying reasons for choice of information used in design cost estimating are also examined both theoretically, and through an estimating information selection experiment.

5.1 LEARNING AND CHOICE OF INFORMATION

Siegler (1975) presents five generalisations about cognitive development that may aid the understanding of estimating practices detailed above and provide a useful basis for developing a strategy for improving accuracy in estimates. The generalisations as intepreted in Feldman (1986) are:

"1. The rule is the basic unit for characterising knowledge.
2. Rules are adopted in order of predictive accuracy within the range of environment in which the rule is applied. (Partially correct rules are used only if they improve predictions in particular settings).
3. Reasoning across different concepts is more homogenous the less knowledge about the concepts is possessed by an individual. (The less knowledge the more the tendency to make inappropriate generalisations).
4. Learning is determined by the interaction of knowledge and experience, and experience that contradicts existing rules promote the most learning.
5. When contradictions are presented by experience, encoding plays a large role in constructing new rules. (i.e. existing salient category systems influence how events are perceived and relationships inferred)."

These generalisations are supported by other research literature (Feldman, 1981 see also Ilgen and Feldman, 1983). Feldman remarked that, if Siegler's generalisations are accepted, "learning from experience may be said to occur when inaccuracy in predictions is made salient, and the resultant feedback is usefully encoded. These conditions are likely to exist when there is already substantial knowledge about the phenomena in question."

Siegler's generalisations coupled with Feldman's interpretations help to improve understanding of the psychological processes that produce the reported observations on estimating practice. From Feldman's postulate, a useful basis is provided for answering the following questions that arise from previous observations:

1. Why is the estimator unaware of the magnitude of the error made in estimating?
2. Why are tender values not routinely compared with estimates?
3. Why do estimators prefer information with which they are familiar?
4. Why do estimator's use the information on one project for making prediction?
5. Why is the most recent cost information used irrespective of the error it might contain?

The issues involved are psychological in nature, it is necessary therefore to examine current knowledge available in relevant psychology literature.

5.1.1 Learning from experience

5.1.1.1 Awareness of errors and recognition of the need for learning.

The findings of Morrison and Stevens (1980) and Thorpe (1982) show that ignorance of the magnitude of estimating error is prevalent in the industry. The consequence of lack of awareness of errors is that inaccuracies in estimating persist when corrective actions could have been taken to reduce the magnitude of errors (Morrison 1984). In other words, estimators do not recognise the need to learn from experience.

Social psychologists recognise that barriers exist that may prevent recognition of the need to learn. Pryzczynski and Greenberg, (1981) and Feldman, (1986) have demonstrated that when events that disconfirm expectations are made salient, an active process of searching for information may begin. On the other hand, when expectancies are observed, there is no search for information that may be useful for improving knowledge. Weiner (1985) identifies two factor that promote spontaneous attribution activity: (i) the observation of unexpected, novel events and (ii) non achievement of goal. If this proposition is accepted, the behaviour of design estimators will become understandable. Unless an event occurs that brings inaccurate predictions to the attention of the estimator, the need for learning will not be recognised. Events that may threaten the project (abortment, redesign, etc,) or the estimator (rebuke from a superior, rebuke from the client, etc.) will result in the recognition of the need for learning. For such an event to occur, the deviation of the estimate from predicted values must be perceived as significant. This is consistent with the fourth observation on estimating practice: *comparisons of estimate with tender prices are made when there is significant difference between the two.* It may then be that the reason why corrective procedures are not sought (no adjustment made to cost data) is that significant deviations are seldom noticed. Why are significant deviations of estimates from tender seldom noticed when indeed there exist data suggesting so? The possible answers are:

1. Estimates are not compared with tender.
2. Estimates are accurate enough.

To accept the second proposition, a limit must have been set regarding how accurate an estimate has to be to qualify as being "accurate enough". There is no limit of acceptance set by any professional body concerned with estimating. However, there seem a general agreement, in literature (see chapter 4) and by practitioners that a figure of ±10% accuracy at the detailed design stage is appropriate. This figure is also used in some

Australian public works departments for determining the need to resubmit a project for re-approval or redesign (Wilson et al. 1987). Since the measured values are well above the figure of ±10%, it may tentatively be assumed that the second proposition is not justifiable.

Greig (1981) suggest that client dissatifaction with the standard of accuracy in design phase cost estimates is not strong. Bodily et al. (1981) however, present contradicting evidence. They suggest that client's have strong opinions about firms' ability to prepare "better cost estimates." But Bodily's study concerned a client that has many similar projects to execute while Greig's study may be limited to clients who were willing to respond to an opinion survey. The disparity between the two studies explain the conflicting results. Since a conclusive study of client attitude towards estimating performance is not available, the conclusion in Morrison and Stevens (1980) and Thorpe's (1982) surveys (that estimates are not accurate enough but are thought to be accurate) may be the only safe position. This makes the first proposition plausible. This in turn leads to another question. Why are inaccurate estimates thought to be accurate?

This development is termed "illusion of validity" in social psychology - a phenomenon first recognised by Einhorn and Hogarth (1978) as a barrier to learning. A wrong assumption is made by an individual, who, because of certain 'other factors', is able to provide sufficient reinforcement for his position. The explanations provided in literature for this development are: (Feldman, 1986)

1. frequencies are represented in memory rather than probabilities.
2. action taken on the basis of a hypothesis blocks information on the outcome of an alternative decision.
3. people tend not to be sensitive to information unless it has causal significance (Ross and Anderson, 1982). This is described in Hogarth (1981) as the amount of pychological regret associated with making decision.
4. attentional bias direct attentions to expectations - confirming events when disconfirming evidence is available (Darley and Gross, 1983)
5. hindsight bias - people tend to remember favouring correct alternatives when provided with outcome feedback (Fischhoff, 1982).
6. categorical bias - Systematic errors in memory occur as a result of impressions stored. A scan of memory tend to turn up confirming instances (Feldman, 1981).
7. Since much of the reinforcement obtained daily come from others and

people are reluctant to transmit bad news (Allen, 1975), social reinforcement may lead to "group think" (Janis, 1972). In such situations, feedback indicating a need for learning is unlikely.

8. Since information about single events is usually encountered in daily life, general beliefs are slow to change; "exceptions" are dismissed as unrepresentative (Hoch and Deighton, 1989).

From the foregoing explanations, it would seem that the opinions one holds about events, activities or situations will depend on: (a) how information about the event/activity is encountered, (b) how information encountered is treated, (c) how processed information is stored, (d) how stored information is retrieved from memory, (e) how information retrieved from memory is processed prior to its application, and (f) how the processed information is used.

By assuming that a figure of ±10% accuracy is acceptable to all parties to a construction contract, most of the foregoing explanations can be used as a framework for explaining why failure to learn persists in construction cost estimating. First, construction projects are one-off events (8). Clients, other designers or superiors, may not have a chance or, be willing to express their disatisfaction about a prediction that is say ±13% (A figure of ±13% is used as it represent the average error in design cost estimates. See chapter 4) outside the real value (7) since it may not adversely affect the project (2). Since estimators, and others have the impression that ±10% accuracy is the standard achieved, instances where this ideal is achieved readily come to mind (6) because attention is drawn to them (4), their occurencies (1) are thus stored in memory and easily recalled. Research by Wilson et al. (1987) and Runeson (1988) on the practice in the Australian industry provide support for this position. They reported that in public projects, when the low tender exceeds the stage D estimate (estimate prepared about 21 days prior to tender used for setting budget for the contract) by more than 10%, tenders need to be resubmitted for approval or redesign. This requirement draws attention to instances where the figure is not achieved. Estimators are therefore careful to ensure that stage D estimates are as accurate as possible. It is noticed, from the Australian example, that the need to prevent re-approval or redesign (3 - causality or psychological regret) focuses attention on disconfirming evidence (4,8). This focus of attention is occasioned by the system that prevents group think through making outcome feedback mandatory (7). The same system also prevents categorical bias (6). This is possible because the client has many projects to execute (8) and has set up a system that does not depend solely on human memory to provide justification for achievement. It is axiomatic that, to facilitate learning from experience, a limit of acceptable level of estimating performance is necessary and an incentive (reward or punishment) system for good (or bad) perfomance will help the effective functioning of such a system. Implicit in this statement is that outcome feedbacks are received within the system frequently.

5.1.1.2 What learning is necessary?

Having tentatively accepted the notion that learning is necessary and awareness of errors is useful, there exist the need to decide what should be learnt. It was stated that *when tenders differ significantly from estimates, cost comparisons are made on the element level.* Thus, design cost estimators tend to identify the need for learning at the overall tender level while learning is done (at least partially) at the element level. Design estimators assume that estimating performance is 'good enough' when the tenders received suggest so. This assumption is neither necessarily correct nor sufficient for providing good cost advice to construction clients. The learning requirement is best identified by considering the task involved in estimating.

Hammond's (1980, 1981) cognitive continuum model is useful in identifying three types of tasks: analytical tasks (mathematical calculations for example), intuitive tasks (probability judgements) and semi-rational tasks (combining analysis with intuition). Feldman (1986) observed that in intuitive and semi-rational task environments, the events that capture one's attention may be strongly influenced by existing category systems. Under Hammond's classification, construction cost estimating is a semi-rational task: combining intuitive judgements of the market and cost relationships with analytical task of calculating quantities and rates. This task environment relative to performance is shown in Figure 5.1. A tender estimate is more analytical than a budget estimate; but all estimates combine analysis with intuition. Chapman (1967) demonstrated that in such task environments "illusory correlation" may develop which is often strong enough to hide real associations existing in ones data. In construction work, overall cost figures are obtained by summation of costs for all elements. Given that there is equal probability to overestimation and underestimation at the element level, errors may cancel out to give an overall figure that falls within acceptable limits even when there are large errors in individual elements (Beeston, 1974). This development results in the illusion that the cost figures for individual elements are accurate - especially since human psychological processes tend to draw attention to instances where this is so and dismiss contrary evidence as unrepresentative. Hamilton and Rose (1980) remarked that people pay too much attention to positive "hits" and neglect other sources of information. This is also consistent with Hoch and Deighton's (1989) study of consumer behaviour. They observed that consumers' interpretation of datum is not conditionally independent of previous data. Not only are people likely to see what they expect to see, they may also not be motivated to accommodate discrepant evidence, choosing either to re-interprete it so it fits the rule or to explain it away as an exception to the rule. What is learned depends on the magnitude of error made salient by the interpretation of data and the error level expected by the estimator. We may conclude by saying that if the error value in a design estimate is ±13%, the estimator may treat it as being close enough to ±10% or dismiss it as atypical. To facilitate learning, the estimator should analyse every result from estimating exercises and study all deviations carefully.

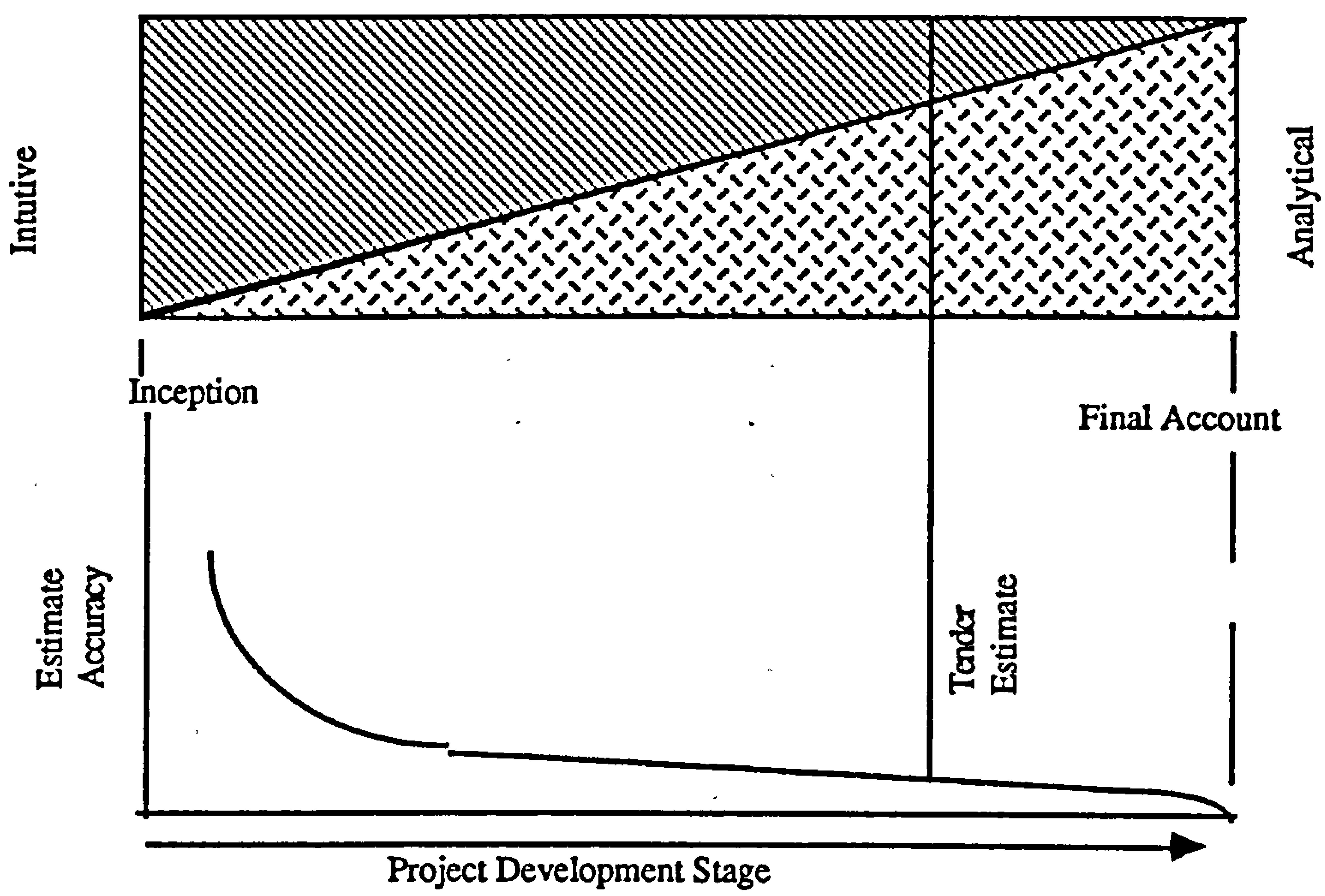
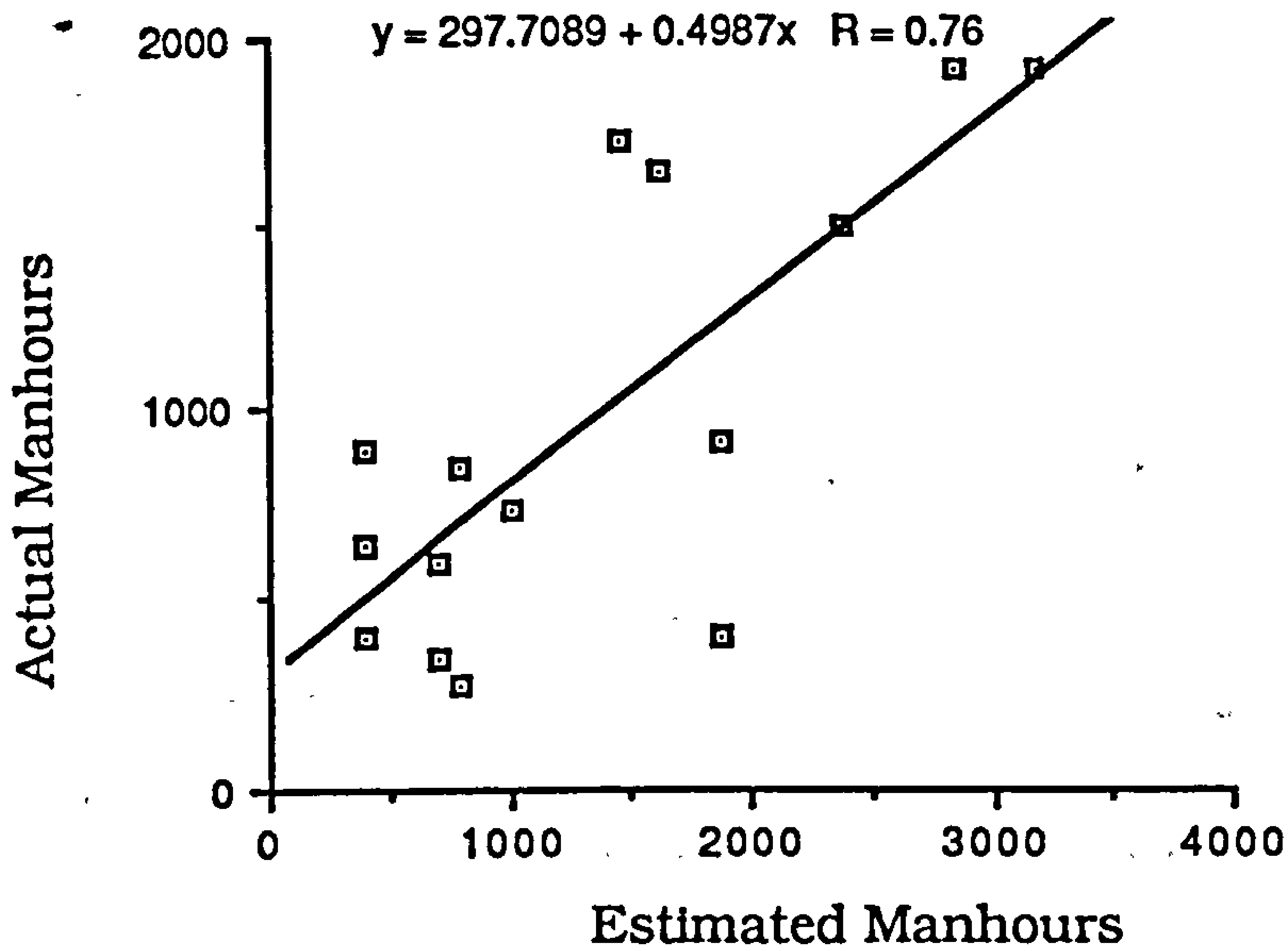


FIGURE 5.1: RELATIONSHIP BETWEEN TASK ENVIRONMENT AND ACCURACY IN DESIGN COST ESTIMATING

At what level should learning occur in design cost estimating? Again, Feldman (1986) stated that "what is learnt depends on the salience or intensity of information in the environment and the kind of relationship one expects". The same experience which assists cost predictions should also help to explain unfavourable outcomes. If cost relationships are developed at the element level, cost variances should also be determined at that level. This will make learning easier since outcome feedbacks are more relevant to expectations of design estimators. This is best illustrated by the result of an experiment in estimating.

FIGURE 5.2: ESTIMATED/ACTUAL MANHOURS FOR A PROJECT



Source : Freeman (1982).

Not Relevant ??

Freeman (1982) presented the results of an experiment involving contractors predicting resource usage. Activity sampling was used to calculate resource used by a contractor on a construction project. Figure 5.2 shows the plot of actual man-hours against estimated man-hours for principal activities. The correlation coefficient is 0.76: suggesting good correlation between actual and estimated man-hours. However, individual data plots show very significant differences between estimates and actual values. The results demonstrate that in instances where overall tender estimating results show good accuracy, estimates for individual elements may contain very large errors. Since designers are mainly interested in cost reduction possibilities at the element level, the best option for improving accuarcy in design cost estimating and advice to design is to encourage learning at the element level. Cost relationships should be studied and reasons for differences between expectations and outcomes thoroughly examined.

5.1.1.3 When Has Learning Taken Place and How can Learning be Accomplished?

It is safe to generalise by saying that when predictions fall within "acceptable" limits, or when feedback suggest satisfactory performance, learning is sufficient. To arrive at the conclusion that learning has taken place, tests that direct attention to disconfirming events should be performed. However it is necessary that the tests be performed at the level where real associations between outcome and predictions can be usefully developed. In design estimating, tests revealing correct relationships between predicted prices and tender values at the element level will be more beneficial for understanding variances between predictions and outcomes.

5.1.1.4 Procedure for Learning from Experience

Four steps are involved in learning from experience: (after Feldman, 1986)

1. Increasing the amount and immediacy of useful feedback.

It has been observed that the predictions of weather forecasters and horse racers are well calibrated due to availability and rapidity of useful feedback (Fischoff, 1982b). Also, Daschbach and Apgar (1988) reported that the British Aerospace Corporation made tremendous improvement in cost estimating through tracking estimated and actual costs of projects. Careful monitoring over four years (on 4395 projects) show dramatic improvement in performance after the first year, "reflecting increased skill by the parametric cost modeller and improved accuracy in the models used through continual calibration. The company has used parametric cost modelling and instantaneous feedback mechanism to assist design teams to achieve, not only more accurate estimates, but also reduced production costs!" Making outcome feedbacks mandatory and putting the results of tendering exercises within the reach of the design estimator is a precondition for improving performance. An additional question arises at this juncture. What type of feedback will be beneficial to design cost estimating?

Two possible feedbacks in design cost estimating were identified in chapter 4: (i) process feedback and (ii) outcome feedback. Although it was observed that process feedback will benefit design cost estimating more than outcome feedback, the need for learning can only be recognised through outcome feedback. Outcome feedback can either be positive or negative and the motivation to learn is related to feedback sign (whether positive or negative). The foregoing discussion has shown that attention directed towards positive feedback prevents the recognition of the need for learning by making estimators develop false confidence in their ability. In such instances, the motivation to learn is low. Podsakoff and Farh (1989) have shown in an experiment setting that, when negative feedback is received, performance tends to improve. The level of performance instigated by the feedback is also related to the source of feedback. Their experiment show that people who receive more credible negative feedback set higher goals and perform at higher levels than people who receive less credible negative feedback. It may thus be deduced that, if design estimators receive credible negative feedback, the motivation to learn will be higher and consequently, performance will improve. This in turn poses the question of how to make feedback credible to design cost estimators. An appropriate approach will be to allow estimators to generate feedback data themselves i.e. let each estimator test his/her performance using an objective model.

2. Creating a social environment that requires learning.

By setting up a system requiring that outcome feedbacks be transmitted to task performers, information will be used to the optimum. It is essential that estimators see tests as a means for improving their performance.

The Australian system requires resubmission of projects for approval when estimates differ more than 10% from tenders. This system encourages learning. If design estimators are aware that not every estimate is good enough, motivation to perform will increase. In line with Hoch and Deighton (1989), when estimators have modest goals they are less likely to experience the negative feedbacks that trigger the learning process.

3. Hiring and training estimators to be experts both in substance and process.

An understanding of the factors that improve predictions, coupled with a thorough knowledge of the technical task of estimating, will lead to increased performance. Process data recording and analysis is necessary to aid learning in design cost estimating.

4. Not expecting infallibility.

Learning from experience requires one to be wrong for some of the time. Emphasis should not be on solutions but on the seriousness of the problem (Campbell, 1969) and how sound the decisions were in the light of available knowledge. According to Peters and Waterman (1982), the 'excellent' company must make a lot of tries and consequently suffer some failures or the organisation won't learn. This observation is true for individuals too; people learn more from past mistakes. Others have stated that it is 'pain' that makes people learn, (De Geus, 1988) and 'failure is essential to learning' (Klein, 1989). Design offices must be willing to accept that not all estimates will fall within the acceptable limit. Failure enhances the recognition of the need for learning.

A Learning from experience model

A model that describes an appropriate procedure for learning from experience in design cost estimating is shown in Figure 5.3. Emphasis is on recording all data relating to the process and substance of estimating and tender exercises and using the analyses derived from outcome and process feedbacks to improve performance.

An analysis package that enables the design cost estimator to learn from experience, in line with the model in Figure 5.3 is presented in chapter 8 of this thesis.

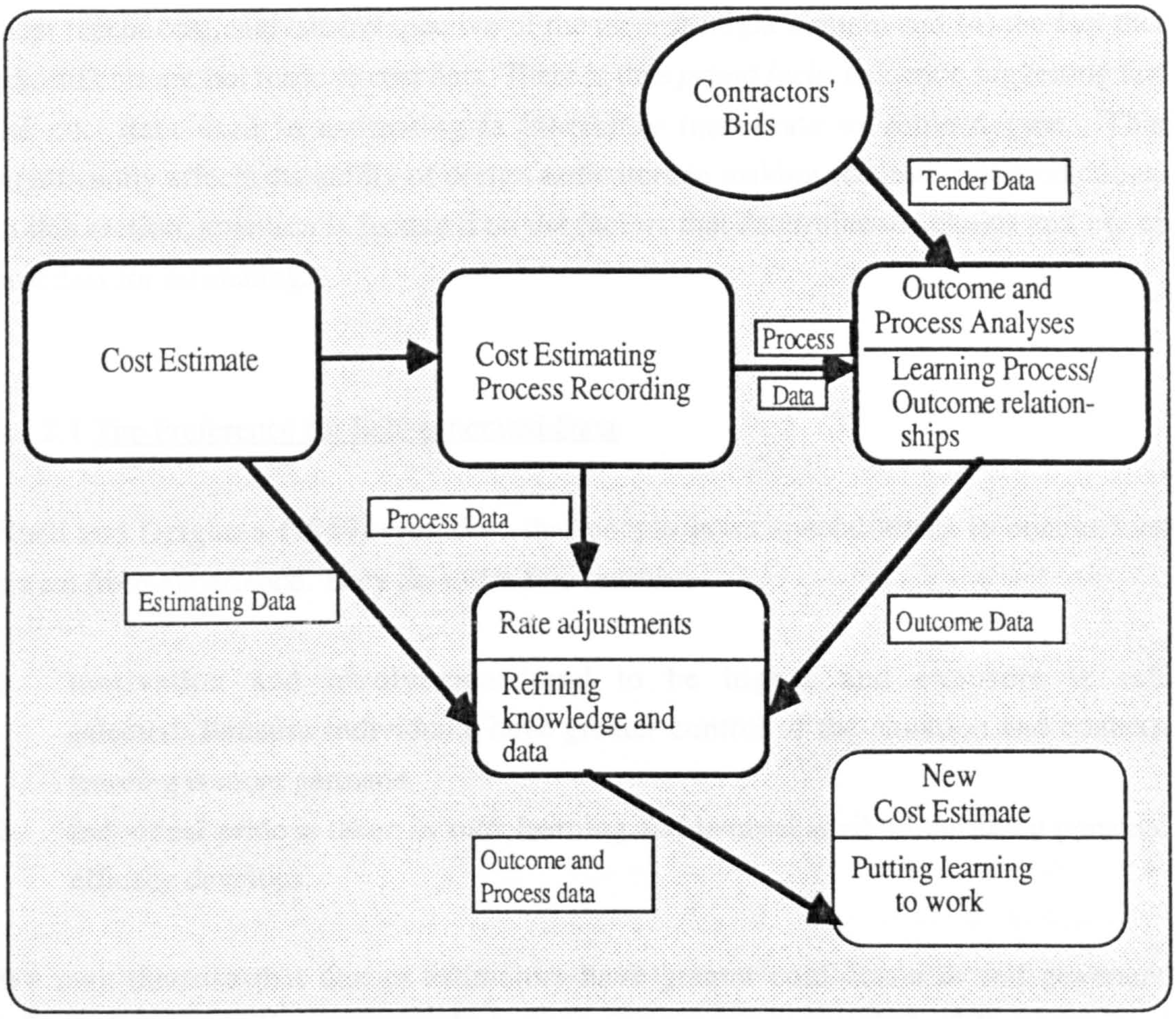


FIGURE 5.3: MODEL FOR LEARNING FROM EXPERIENCE IN DESIGN COST ESTIMATING

5.1.2 Information Usage

Three sources of design cost information were identified in Chapter 2: (1) information supplied by the client, (2) design information from other professionals and (3) historical cost information generated by the estimator - either from internal or external sources. Information from the first two sources come in the form of design data and project drawings - statement of requirements, performance standards, sketches, calculations, etc. - which the estimator **must** consider in his predictions. The third source yields cost data which may be obtained from internal or external sources.

Three of the research findings being considered in these chapter relate directly to the use of information in cost estimating: (1) the use of information with which estimators are familiar (2) the frequent use of cost data from one historical project, (3) the use of the most recent cost analysis irrespective of the error it might contain and (4) the fact that adjustments are not made to cost data. There is thus *prima facie* evidence suggesting that the cost data used in estimating is inherently inaccurate to some degree. This significantly affects the ability of design estimators in making accurate cost predictions. In this section, attention is focussed on the factors that determine the choice and use of cost data for estimating.

5.1.2.1 The Preference for Self-generated Data

Hoch and Deighton (1989) remarked that people grant special status to conclusions drawn from experience. They do so for two reasons:

1. motivation and involvement tend to be higher and exposure is self selected. Because individuals have greater control of the situation and context, learning is more germane.
2. individual pride is taken in such learning and internal attributions about personal efficacy develops.

We may theorise that design estimators have greater confidence in self-generated information since adjustments made during cost estimating can only be fully appreciated by the estimator involved. Self generated information will be preferred if estimators have high opinions of their ability. If otherwise, they should prefer a more credible source of information. Since it is known that estimators prefer self-generated data, it may be assumed that it is treated as being more credible than other sources (eg. BCIS on-line and published price books).

5.1.2.2. The Preference for Individuating Information.

Social psychologists distinguish between the use of base rate and individuating information in quasi-rational task settings in developing the theory of "base rate fallacy" (Kahneman and Tversky, 1974 see also Feldman, 1983) . Base rate information is defined as the relative frequencies or percentages associated with the occurence of certain events or entities in a particular population (e.g. the percentage of construction students in a university). **Individuating information** is information specific to a particular event or entity. The base rate fallacy refers to "a consistent tendency when solving certain inference problems to ignore or underemphasise distributional or base rate information while overemphasising diagnostic or individuating information." It is reported that individuals presented with both types of information tend to rely more on individuating information when making judgements, thereby deviating from normative optimal judgements (Kahneman and Tversky, 1973). In the estimating setting, it concerns the use of a single and most recent cost analysis of a historical project for price predictions. The explanations proposed for the phenomena are as follows: (Hinsz et al., 1988)

1. Representative heuristics (Khaneman and Tversky, 1973) - The prediction of outcome is estimated based on the degree that the individuating information is similar to the salient features of the outcome being predicted. If this explanation were accepted, estimators should use data from a past project which has most of the features of the new project.

2. Causality Principles (Ajzen, 1977) - Choosing information to the degree it fits one's intuitive notions about the causes of the event in question.

3. Vividness (Nisbett et al. 1976) - The vividness of individuating information relative to the typically abstract base rate information accounts for its greater influence on judgement. Information that easily catches the attention of estimators is more likely to be used for estimating.

4. Relative relevance (Bar Hillel 1980) - Available information is ordered according to its relative relevance to judgement being made. More relevant information is prferred to less relevant information. Bar Hillel further argues that information judged to be more specific to the event in question will tend to be perceived as being more relevant.

5. Source credibility (Hovland et al., 1953 and Birnbaum and Steger, 1979) - Sources perceived to be inaccurate are often ignored. The consistency between the evidence the source provides and the accuracy of the source determine its use.

6. Diagnosticity (Ginosar and Trope, 1980) - The extent to which the information can be perceived as useful for making predictions determines its use. As individual information becomes less consistent, it becomes less diagnostic for making judgement

and will be discarded.

7. Availability (Bar Hillel, 1980) - Information that is more readily available will be used. Vividness of information may also aid its availability to potential users. Media advertisements tend to work on this principle.

8. Completeness (Bar Hillel, 1980) - Information that seems more complete will be seen as having better predictive ability than less complete information.

The information currently being used for estimating satisfies some of the conditions stated above. It may be that the absence of centralised information storage in design offices (Morrison and Stevens, 1981) makes information on other projects less available and/or less vivid while the cost analyses from other practices (e.g. those published in journals) may suffer lack of representativeness or source credibility (since the estimator is unfamiliar with the treatments made to the data). It is known however, that price books are used only to make up for rates that are not available in the estimating office (completeness).

It is axiomatic that cost data with which the estimator is familiar, especially the latest cost analysis, satisfies availability via vividness. The source may also seem more credible since the estimator is aware of any imbalance that may exist in the rates. Also, since the information is most likely from a similar project in the locality, it may be seen to have more causal effects and be representative or relevant to other predictions in the locality.

5.2 ESTIMATING EXPERIMENT

The effects of the choice of information on estimating could not be tested on professionals in the industry for lack of willing subjects. It was therefore decided to conduct an estimating experiment on available subjects to gain insight into how individuals faced with the task of selecting information for cost estimating would proceed and the factors that will be considered for choosing 'similar projects' from which cost data could be abstracted.

5.2.1 Design

The experiment was designed around a problem of predicting cost for a particular project by a young professional who has newly arrived in the area and who lacks historical cost data for making prediction. The alternative was to 'puchase rates' form others established sources in the area. The projects used are however not live data as used by the professional because other parameters were built into the information to test the effects of the psychological explanations listed above.

5.2.2 The Subjects

The subjects were Post Graduate (Course and Research) construction and construction management students in the Department of Civil Engineering, Loughborough University of Technology. All but one respondents were male.

5.2.3 Materials

The problem concerns choosing historical projects from which rates could be abstracted for estimating cost for a proposed project. The subjects were given information on 11 projects. Ten of the projects were historical projects with information on:

- Project type
- Date
- Design
- Size
- Location
- Number of tenders
- Estimator
- Duration
- Details of site restrictions

All the projects contained information on element breakdown and, except for the eleventh project, cost data on the estimate and the winning bid. A sample of the information and questionnaire is contained in Appendix D.

5.2.4 Methodology

The task was explained to the subjects in two ways:

1. Post Graduate Construction and Construction Managenent Course Students

The subjects in groups of 8 were familiarised with the practice in estimating offices as many of them had experience in the contracting side of the industry. The explanation to each of the two groups took approximately 10 minutes. The subjects were then advised to spend about 25 minutes on the task of choosing the projects to use.

2. Research Students

It was impossible to get research students together for the explanation of the task. The subjects in this group were therefore approached individually and then taken through the requirements of the task. Individual explanations lasted approximately 7 minutes. These subjects were also advised to spend about 25 minutes on the task.

Subjects from the two groups (Course and Research) reported spending more than 25 minutes on the task. On average, the research students showed better understanding of the task than course students. Also, research students were generally more interested in the experiment and willing to discuss with the experimenter after the task. 25 responses were received from the 55 students who received the information on the experiment.

5.2.5 Results

The results of the experiment are displayed in Tables 5.1 - Table 5.10. Tables 5.1-5.4 show the results according to projects preferred while Tables 5.5-10 show the results according to reasons proferred for choosing projects.

The results were divided into two classes : (1) Novices (N=11) comprising respondents who, though are familiar with design phase cost estimating, are not normally engaged in the task of estimating construction costs in their working life. (2) Average estimators (N=14) are respondents who have estimated costs for five or more projects in their professional career. The distribution of average respondents between course and research students is even (7 from each group).

5.2.6 Discussion

The information from this experiment, although limited because of sample size, provide useful insights into the psychological reasons behind the choice of information for estimating. They concern : (1) the choice of historical project for estimating; and (2) the underlying reasons for the choice of projects. These issues are discussed in details below.

5.2.6.1 Choice of Projects

The experiment provided for respondents choosing three projects. There is a marked preference by both novices (Table 5.1) and average estimators (Table 5.2) for projects 1 and 9 as first choice project. Although the division amongst projects is not very clear for the two groups, the overall picture, presented in Table 5.3, show clearly that the two projects are preferred by 64% of the respondents.

There is less agreement among novices in the choice of second projects. Average respondents however show preference for projects 8(N=6) and 9(N=4). This preference is also reflected in the overall preference for second choice projects (Table 5.3).

Table 5.1: Novice Respondents' Choice of Projects

Project No	No of respondents		
	1st	2nd	3rd
1	4	1	-
2	2	1	1
3	-	-	1
4	-	-	1
5	-	-	-
6	-	2	-
7	1	1	-
8	1	3	5
9	3	1	3
10	-	2	-

Table 5.2: **Average Respondents' Choice of Projects**

Project No	No of respondents choosing project 1st	2nd	3rd
1	5	-	2
2	1	1	1
3	-	1	2
4	1	-	2
5	-	-	-
6	-	1	1
7	1	-	-
8	-	6	2
9	4	4	1
10	2	1	4

Table 5.3: **Overall Ranking of Respondents Choice of Projects**

Project No	No of respondents choosing project 1st	2nd	3rd
1	9	1	2
2	3	2	2
3	0	1	3
4	1	0	3
5	0	0	0
6	0	3	1
7	2	1	0
8	1	9	7
9	7	5	4
10	2	3	4

Table 5.4: **Rank Indices of Projects**

Project No	Points Scored	Index Rank
1	32	2nd
2	14	5th
3	5	9th
4	6	8th
5	0	10th
6	7	6th
7	7	6th
8	28	3rd
9	34	1st
10	16	4th

Point = $\sum iN$ {i=index score, N=frequency} Index score: 3 for first choice, 2 for 2nd choice and 1 for 3rd choice.

The distribution of third choice projects is less revealing. However novices tend to prefer project 8 while average respondents show a preference for project 10.

The rank ordered result (Table 5.4), using relative index scores (3 for 1st choice project, 2 for 2nd choice project and 1 for 3rd choice project), show that the respondents from both groups concentrated on five projects (Projects 1, 2, 8, 9 and10).

The results are quite interesting in that, when faced with the task of choosing one historical project from which cost could be abstracted for estimating, the difference between average estimators and novices is not as much as would have been expected. However, when 3 projects are desired, differences emerge separating both classes of people.

5.2.6.2 Reasons for Choosing Projects

The analysis by reasons profered for project choice again distinguishes between novices and average estimators.

1st Choice Projects

Average estimators seem to consider project type, comparability (the extent to which the features of the historical project matches the features of the proposed project), year, estimator, duration and project size (Table 5.5). Novices (Table 5.6) on the other hand concentrated on size, comparability, estimator's expertise, and duration while also giving consideration for project type, year and first estimate of the cost of proposed project.

2nd and 3rd choice projects

In the choice of second and third choice projects, average estimators also consider the exstimator's expertise, project type, comparability, year and size of project. Novices, however, seem to give different reasons without focussing on specifics for choice of second project (Table 5.6). This lack of focus is reflected in the divergence of choice (Table 5.1). The expertise of the estimator dominated novices' choice of second project; it is responsible for the concentration on project 8 (a medium sized project handled by Olu - expert).

Table 5.5: **Variables Considered by Average Estimators in Choosing Projects.**

Variables	1st Project Point	1st Project Rank	2nd Project Point	2nd Project Rank	3rd Project Point	3rd Project Rank	Total Point	Total Rank
Project type	9	1st	6	2nd	6	2nd	21	2nd
Year	6	3rd	5	4th	5	4th	16	4th
Design	1	10th	1	9th	1	9th	3	10th
Size	5	6th	5	4th	4	6th	14	6th
Location	4	7th	2	8th	1	9th	7	8th
No of tenders	2	9th	1	9th	2	8th	5	9th
Estimator	6	3rd	8	1st	8	1st	22	1st
Duration	6	3rd	5	4th	5	4th	16	4th
Other details	3	8th	4	7th	3	7th	10	7th
Comparability	7	2nd	6	2nd	6	2nd	19	3rd
Estimated value	0	11th	0	11th	0	11th	0	11th

Table 5.6: **Rank Order of variables Considered by Novices in Choosing Projects.**

Variables	1st project Point	1st project Rank	2nd project Point	2nd project Rank	3rd Project Point	3rd Project Rank	Total Point	Total Rank
Project type	4	5th	4	2nd	2	5th	10	4th
Year	4	5th	4	2nd	2	5th	10	4th
Design	0	11th	0	10th	0	10th	0	11th
Size	7	1st	4	2nd	3	2nd	14	2nd
Location	3	8th	4	2nd	2	5th	9	6th
No of tenders	1	10th	0	10th	0	10th	1	10th
Estimator	6	2nd	5	1st	8	1st	19	1st
Duration	5	4th	3	7th	1	9th	9	6th
Other details	2	9th	3	7th	3	2nd	8	8th
Comparability	6	2nd	4	2nd	3	2nd	13	3rd
Estimated Value	4	5th	0	10th	2	5th	6	9th

Overall, both groups seem to prefer a project by considering estimator's expertise, comparability, project type, year and size of project (Table 5.10). As choice moves though 2nd to 3rd choice projects, estimator's expertise gains prominence while other factors diminish in importance.

Table 5.7: **Variables considered by both groups in choosing projects.**

Variables	1st Project Point	1st Project Rank	2nd Project Point	2nd Project Rank	3rd Project Point	3rd Project Rank	Total Point	Total Rank
Project type	12	3rd	10	2nd	8	2nd	30	3rd
Year	12	3rd	9	4th	7	3rd	28	4th
Design	1	11th	1	9th	1	11th	11	10th
Size	12	3rd	9	4th	7	3rd	28	4th
Location	7	7th	6	8th	3	8th	16	8th
No of tenders	4	9th	1	9th	2	9th	8	9th
Estimator	13	1st	13	1st	15	1st	41	1st
Duration	11	6th	8	6th	6	7th	25	6th
Other details	6	8th	7	7th	7	4th	20	7th
Comparability	13	1st	10	2nd	8	2nd	31	2nd
Estimated value	4	9th	0	11th	2	9th	6	11th

Table 5.8: **Variables Considered by both groups in Choosing 1st Projects.**

Variables	Average Estimators Point	Average Estimators Rank	Novices Point	Novices Rank
Project type	9	1st	4	5th
Year	6	3rd	4	5th
Design	1	10th	0	11th
Size	5	6th	7	1st
Location	4	7th	3	8th
No of tenders	2	9th	1	10th
Estimator	6	3rd	6	2nd
Duration	6	3rd	5	4th
Other details	3	8th	2	9th
Comparability	7	2nd	6	2nd
Estimated value	0	11th	4	5th

Table 5.9: Rank Order of Variables Considered by both Groups in Choosing 2nd Projects.

Variables	Average Estimators Point	Average Estimators Rank	Novices Point	Novices Rank
Project type	6	2nd	4	2nd
Year	5	4th	4	2nd
Design	1	9th	0	10th
Size	5	4th	4	2nd
Location	2	8th	4	2nd
No of tenders	1	9th	0	10th
Estimator	8	1st	5	1st
Duration	5	4th	3	7th
Other details	4	7th	3	7th
Comparability	6	2nd	4	2nd
Estimated value	0	11th	0	10th

Table 5.10: Variables Considered by both groups in Choosing 3rd Projects.

Variables	Average estimators Point	Average estimators Rank	Novices Point	Novices Rank
Project type	6	2nd	2	5th
Year	5	4th	2	5th
Design	1	9th	0	10th
Size	4	6th	3	2nd
Location	1	9th	2	5th
No of tenders	2	8th	0	10th
Estimator	8	1st	8	1st
Duration	5	4th	1	9th
Other details	3	7th	3	2nd
Comparability	6	2nd	3	2nd
Estimated value	0	11th	0	10th

The result of this limited experiment may be used to support the first assumption that source credibility plays a vital role in estimator's choice of information. Despite that the subjects were informed that the rates to be used are the rates submitted by the low bidder, and not the original estimator, there is still a marked preference for source credibility as the criteria for choice of projects. The projects favoured by the subjects have the characteristic of being handled by either good or evarage estimators.

The overall picture show a desire on the part of the respondents to make the features of the historical project as similar as possible to the proposed project. However, apart from the general preference for the estimator's expertise in the choice of most projects, there are differences between what average estimators and novices consider as making a project diagnostic. Both classes of respondents concentrated on medium sized projects executed by 'acceptable' estimators.

Whereas average estimators tend to be unwilling to change the criteria for choice of projects and are therefore more stable, novices tend to be more analytical. After choosing the first project, novices evince a desire to fulfil all the criteria used by the design office in choosing projects. They also responded that their choice of projects would change if the initial cost estimate changes. This suggests that novices are more likely to be affected by the effects of adjustment and anchoring than average estimators i.e. they respond more to changes than average estimators do. Average estimators seem to be overconfident in supposing that they know what to look for and rigidly sticking to those factors.

The subject of comparability was discussed further with the respondents. Most respondents stated that the projects to be used should contain as many elements in the proposed projects as possible. The shortfall, they remarked, could be catered for by choosing other 'good' projects. This, on the face value, will suggest an attachment to completeness of information. However, from further discussions, it became clear that other factors, such as size and type of project were also considered by the respondents for deciding whether a project is good or not. The respondents do not depend entirely on one factor or set of factors. Divisions along the lines suggested in psychological literature (see section 5.2 above) could not be rigidly adhered to. Whereas some of the respondents stated that they tried to minimise error made in estimating cost for historical projects, the same respondents also chose project 9 with the highest estimating error (+19.6%) because the estimator was described as good enough on other projects.

If the rates from the projects chosen are used without making further adjustments, the results would show more consistent estimates from the average estimator group than for the novices. It would seem therefore, that if the estimator is to maximise the use of cost data for estimating along the lines suggested by Jupp [1980] (i.e. use data from 3 past projects for estimating), understanding the factors considered by experienced estimators for choosing historical projects from a database would be beneficial.

5.3 SUMMARY

The results from this chapter are:

1. Design estimators are not learning sufficiently from experience. Historical cost data is not used to the optimum for improving performance in cost estimating

2. Failure to learn derives from the absence of a system for monitoring estimating performance in design offices.

3. Illusion of validity, of the generally held view that estimating performance is good enough, persists because estimators' attention is not drawn to evidences contradicting this assumption. This oversight derives from the absence of a system requiring regular monitoring of estimating performance.

4. A model for aiding learning from experience in design cost estimating has been presented.

5. The choice of historical estimating data is greatly influenced by the credibility attached to the source of information.

6. Experienced estimators are more stable in considering factors for choice of estimating information. This suggests that they are more capable of producing consistent estimates than novices. This is only true when the number of projects from which estimating data is abstracted is increased to three.

Chapter 6

THE NATURE OF ESTIMATING INACCURACY

Accurate reasoning is possible only in a world where information is complete and certain, and where cause and effect links are known.
- D. J. Isenberg, 1987

6.0 INTRODUCTION

It was tentatively accepted in Chapter 4 that estimating accuracy improves with the development of the project. This assumption is used in the establishing of association between eastimating accuracy and project development shown Figure 6.1. The figure suggests:

1) that estimating accuracy improves with the development of projects. The distribution of errors narrows from feasibility to settlement.
2) that underestimates are more likely than overestimates.
3) that the final cost of a project cannot be established until the settlement of project accounts.

Others have suggested a more complex relationship between estimating accuracy and project size, construction time and other parameters in the project environment. Although there have been various suggestions regarding the real nature of estimating accuracy (or inaccuracy), evidence in each case has not been conclusive. A useful starting point in the development of a strategy for improving estimating performance is to examine the evidence in each case and establish a relationship that might be useful to the estimator. This chapter contains a review of the literature on the subject and analysis of data collected for this purpose.

6.1 FACTORS AFFECTING ESTIMATING ACCURACY

Construction work is fraught with uncertainty. Like any other human activity it contains an element of risk. Whittacker (1973) differentiated risk and uncertainty in construction contracting. Risk, he explained, relates to the occurence of low probability events of major consequence. Such events result in substantial cost increases which the contractor must bear. A one in a hundred year flood could wipe out parts of or whole jobs in progress, lightening could strike a work site resulting in major losses and delays. Uncertainty, on the other hand, relates to the consequence of more probable situations. Such events can be reasonably anticipated (e.g. labour cost rise on a four year contract) but the exact magnitude cannot be determined.

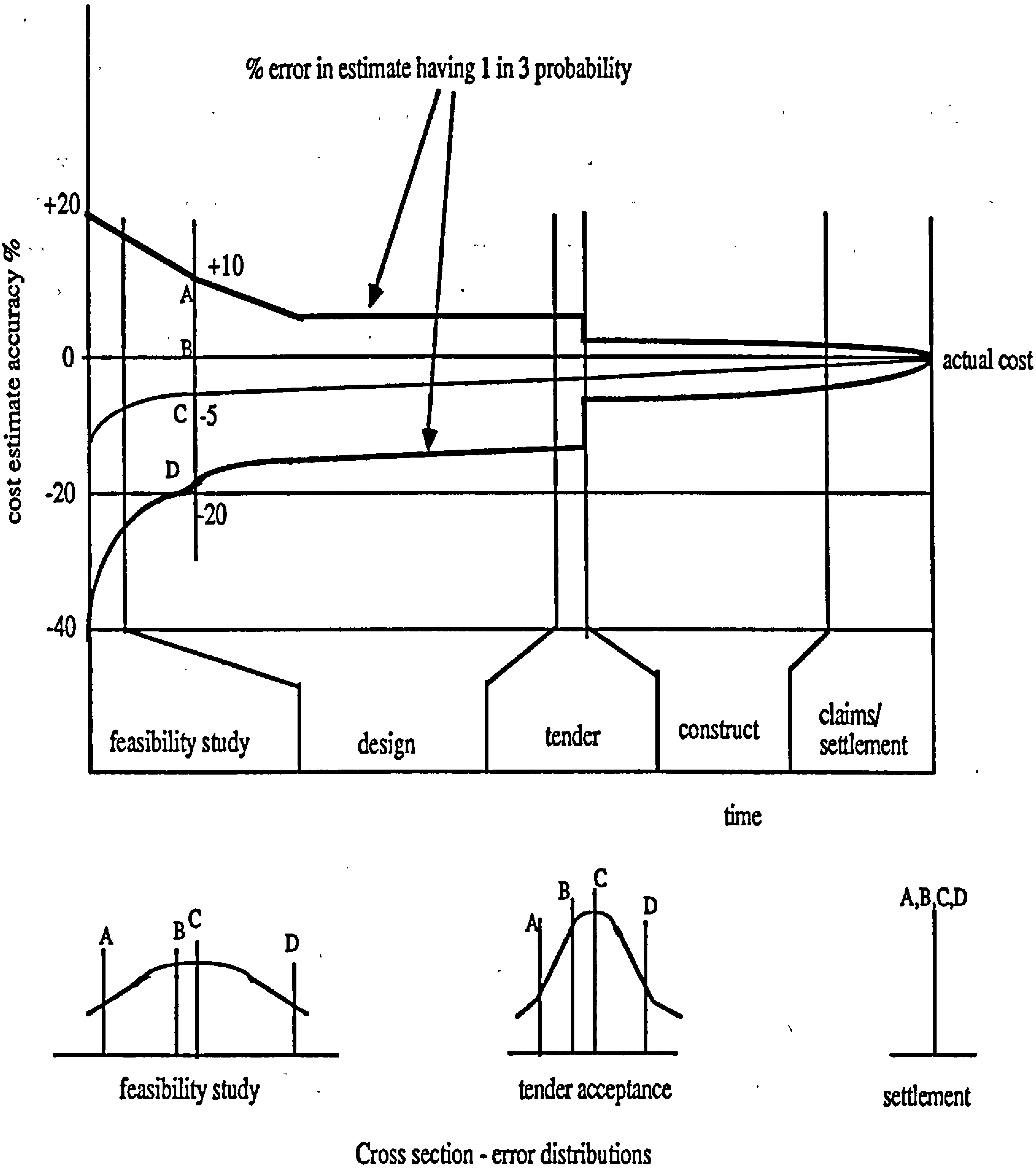


FIGURE 6.1: ERROR IN DESIGN COST ESTIMATE
Source: Barnes (ref. in Thompson et al., 1986)

Bennet and Ormerod (1984) further analysed uncertainty as comprising interference and variability. Interference are those external factors affecting the project which causes a stop to work on a particular task. These results from such things as inclement weather, delivery problems, sub-contract non-attendance, plant breakdowns and the many other influences of the project environment which cause delay. Variability refers to the rate of productivity with which work is executed. What distinguishes estimating from being mere technical calculation of cost is the element of uncertainty inherent in the project situation. It is the level of uncertainty in a judgement that determines its accuracy.

Outside the construction industry, uncertainty has been described in a variety of ways - the rate of change in the environment (Bourgeois, McAllister, & Mitchell, 1978; Lawrence and Lorsch, 1967), a lack of information about the environment (Duncan, 1973; Lawrence and Lorsch, 1967), and the variability and difficulty of a task (Delbecq, Koenig and Van de Ven, 1976). The themes of environment and incomplete information about the task or the environment underlies the definitions. In this thesis, uncertainty is defined as a lack of information about the task or the task environment.

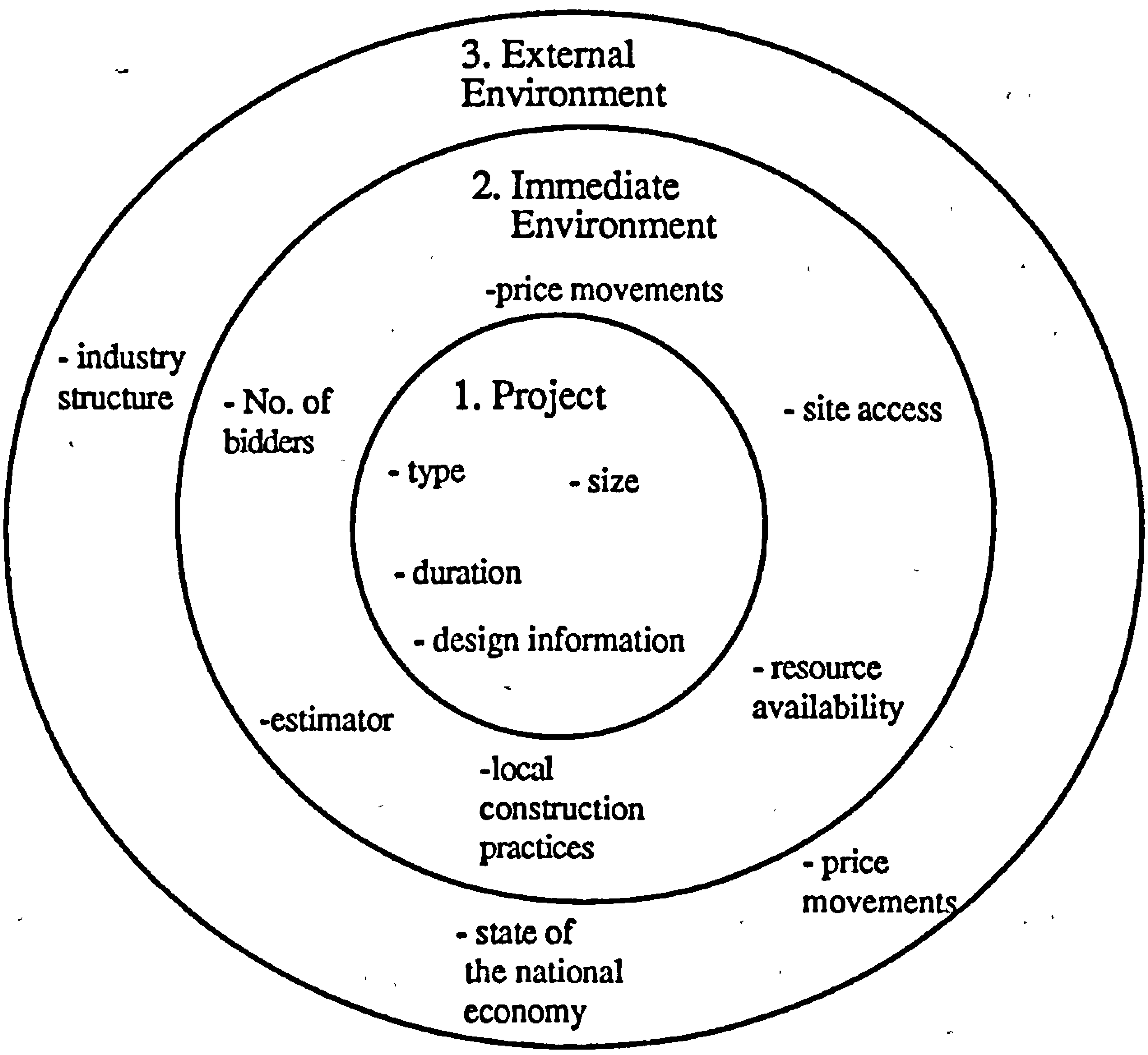


FIGURE 6.2: THE CONSTRUCTION PROJECT IN IT'S ENVIRONMENT

Uncertainty derives from variables in both task and the environment which cannot be modelled correctly. The variables are represented in Figure 6.2. The magnitude of uncertainty therefore will vary with:

- the type of project
- the size of the project
- the geographical location of the project
- the number of bidders
- the state of the market
- the level of information available
- the ability of the estimator
- the project duration

The effects of these factors on estimating performance are examined in detail below.

6.1.1 Type of Project

Uncertainty in a project relates to the type of construction and the method of assembly. Whereas in some projects, such as house building, it may be possible to measure individual elements to a reasonable degree of accuracy, such precision is rare in civil engineering works. In earth works and dewatering for example, the industry does not yet have access to technology for ascertaining the condition of grounds and the situation underneath the ground surface to a sufficiently high degree of accuracy. Where it is possible to measure quantities with precision, accuracy should improve.

Also, the design and assembly procedures for some types of buildings (e.g. systems building) is such that the time required for assembly becomes easier to estimate and hence cost estimating can be reduced to a fairly analytical task. In such instances, estimating cost demands very little more than attaching rates to large components. The productivity of labour and plant is also easier to assess.

McCaffer's (1976) analysis of estimating performance on some Belgian projects showed a distinction between the levels of accuracy achieved in building contracts and road contracts. Building contracts show an underestimation of 5.2% and a standard deviation of 13.8 while road contracts show 1.5% underestimation with standard deviation of 18.6. Harvey (1979) also analysed data on 2401 Canadian contracts which showed that estimates were higher for non-building contracts than for building works. Morrison and Stevens' (1981) study too showed a distinction between estimating performance on schools projects and other projects. Skitmore's (1987) experiment with 12 quantity surveyors was reported as showing significant differences in achieved accuracy for different project types: Health Centre (15.14% mean error), Offices (24.76% mean error), Schools (-11.11% mean error) Housing (-7.52% mean error), and Factories (19.89% mean error).

Merrow et al. (1981) also reported unusually high error levels in Nuclear Power plant suggesting that the level of accuracy achievable on new type of construction is very low. They accepted that this was tied to the magnitude of uncertainty on such contracts.

The evidence from these studies would seem to suggest that achieved estimating accuracy relates to project type and the varying uncertainties associated with that project type.

6.1.2 Project Size

It has earlier been stated that accuracy measurement relies on the assessment of errors. When error is expressed in relative terms, it results in better accuracy on large contracts (e.g. an error of 3 out of 10 constitutes 30% error while 3 out of 20 constitutes 15% error).

Also, if a project is made up of individually measured parts, and there is equal likelihood of positive and negative errors in each part, the law of averages (and the cental limit theorem) suggests that the probability of errors cancelling out on large projects is higher than for small projects.

There is also a managerial factor that favours keener cost estimating in high value contracts. Construction cost estimates are costly to prepare. Only large projects can justify devoting much time to cost estimating. It is axiomatic that when the value of expected utility of a contract to an organisation increases, more resources will be devoted to ensuring that the project runs smoothly.

A contrary position exists however. Large projects have higher levels of inherent uncertainty while smaller projects should *ceteris paribus* have lower levels of uncertainty. Runeson (1988) presented evidence suggesting that since large projects tend to attract more bids than small projects, they show higher variability.

McCaffer's (1976) analysis of low bid/ design estimate ratios on Belgian contracts showed very little relationship between estimate accuracy and project size. Also Wilson et al. (1987) analysis of Australian contracts showed the approximate median low bid/design estimate ratio for three classes of projects as: small (1.041), medium (0.921) and large (0.963). This does not show any statistically significant relationship between project size and accuracy. Morrison and Stevens' (1981) study however showed a tendency for accuracy to improve with project size. Harvey's (1979) analysis also showed some positive relationship between accuracy and project size.

Although there are indications from the studies suggesting a positive relationship between project size and accuracy, the true form of the relationship remains unclear.

6.1.3 Duration of project

It is easy to see a relationship between project duration and estimating accuracy. The relationship derives from two sources:

External changes in the project environment (e.g. movements in materials and labour prices and the changes in costs of services employed) are more likely to affect a longer duration project than a shorter duration project.

Design changes are more likely as the project duration increases. Taste may change requiring substitution of some materials or redesign of sections of the work. Also, there is greater likelihood for scope changes with time.

Flanagan (1980) proposed a construction time related model for cost forecasting. He argued that this is a surer method of improving accuracy in cost estimation. Merrow et al. (1981) observed that scope changes are more frequent on longer duration projects than on shorter duration projects. They remarked that this results in very significant underestimation of construction cost.

The need to make adjustments for variations ocassioned by changes in scope and design have tended to make analysis based on contract duration unreliable. The problem being that, adjustments made to data cannot be precise, thus introducing error into such analyses.

6.1.4 Geographical Location

The effect of geographical location on construction cost estimating is somewhat difficult to visualise. However, differences in local practices in terms of labour availability, union restrictions, services and subcontractors may affect tendering levels which also may affect the ability of the design cost estimator to model cost correctly. Wallace (1977) noticed that local labour regulations and building code requirements make it more difficult to build in some areas and thus affect tendering levels.

Harvey's (1979) analysis also showed significant differences in estimating errors across six Canadian Regions after allowing for the effects of other variables. However, Wilson et al. (1987) noticed no relationship between geographical location and estimate accuracy in Australia.

6.1.5 Number of Bidders

The relationship between number of bidders on a contract and estimate accuracy derives from the degree of competition amongst bidders. Projects with more bidders are expected to provide wider scope for variability between tenders. Consequently, estimates may be less accurate. However, projects with few bidders make collusion and price fixing by bidders more likely. This may result in higher prices being submitted than could be anticipated by the estimator. This is likely to result in underestimation.

McCaffer's (1976) analysis of Belgian contracts showed negative correlation between low bid/design estimate ratios and the number of bidders both for road and building contracts. Also, de Neufille et al. (1977) noticed similar negative corelation between lowbid/design estimate ratios and number of bidders. Wilson et al. (1987) have also presented data showing such correlation.

Skitmore's (1985) analysis of seven projects showed that competition expressed in terms of number of bidders may result in price differences up to 25% between low intensity and high intensity.

6.1.6 The State of the Market

Competiton levels are known to vary with the state of the construction market. The view in construction literature (see Skitmore, 1987) is that contractors will be willing to undertake less attractive projects, sometimes at a loss, in periods of low market activity. Conversely, tender levels are expected to rise and competition become more lax in periods of boom. The changes in utility of the projects to contractors are difficult to model and therefore affect the accuracy of estimates adversely.

A psychological effect of personality may also serve to introduce bias into estimating. Human estimation biases, for example the effects that result in people losing money on stocks derive from inaccurate predictions of the market. Market instability enhances distinctions between pessimists and optimists. Pessimists are prone to believe that things will be worse when prices are going down while optimists will set a target for themselves and strongly hold the opinion that things cannot get worse. Hogarth (1981) distinguished between biases in ascending and descending series. He suggested that people systematically underestimate growth processes irrespective of the mode of data presentation. He observed that sensitivity to such processes is neither enhanced by mathematical training nor by experience with them. Such biases are less severe for descending as opposed to ascending series. Wagenaar and Sagaria (1975) also noted similar effects while investigating fitting of non-linear curves by eye. They observed that subjects tend to underestimate growth in particular when it was exponential.

De Neufille et al. (1977) demonstrated variations in estimating biases with the state of the market. Estimates made in good years are said to be higher than those made in bad years. Morrison and Stevens' (1981) study show differences in estimating error that correlate with the level of uncertainty in the building industry. Harvey's (1979) analysis also showed cyclical variations in different regions of Canada which tend to match the state of the construction market in those regions. Skitmore's (1985) analyses suggested that prices may show up to 25% difference between low intensity and high intensity competition depending on the state of the marcket.

6.1.7 Level of Information

Construction literature tend to support the notion that estimating accuracy improves with the amount of information available for making predictions. A picture similar to that presented in Figure 6.1 is usually drawn to explain this situation.

However, the issue of information resolves into two: (1) More information about the project for which predictions are being made derives from better scope definition and design development i.e. details of component sizes and materials to be used tend to reduce uncertainty especially on building contracts. (2) The use of more price information is statistically expected to reduce the effect of error in cost data (Beeston, 1983; McCaffery, 1978; and Jupp, 1980).

Skitmore's (1987) experiment tested the first proposition by providing more information on projects to subjects. The result show slight improvement in accuracy as more information become available to the estimators involved.

Jupp and McMillan (1979) conducted an experiment which tested the second proposition. Their experiment involved using cost data from different numbers of bills of quantities. Improvements in accuracy of forecasts were noticed when more than one bill were used. However, the results suggest no further improvement after three bills had been used.

6.1.8 Ability of Estimators

It seems reasonable to assume that there should be an improvement in task performance commensurate with the level of expertise possessed by the performer. The effect of expertise should normally derive from two sources: (1) experts should be better at sorting through information and deciding which is relevant for making predictions, and (2) experts should possess more knowledge of the substance and processs of estimating (Feldman, 1986). They should therefore be able to perceive true relationships between information and the task to be performed.

Morrison and Stevens' (1981) study showed a correlation between familiarity with a particular type of project and estimating accuracy. They suggest that where a professional office have a high proportion of their work coming from a particular project type (e.g. schools or housing), their performance is better on the dominating type of project. Skitmore's (1987) experiment with 'experts' and 'novices' showed significant differences between the performance in the two groups. He suggested that experts were 'more relaxed and confident', more 'concerned with the market situation' and 'able to recall prices of projects undertaken'. Novices on the other hand, were more concerned with careful analysis of the project information and considered this of more importance than market effects.

6.1.9 Other Factors

Other factors have been shown to have effects on the ability to estimate cost correctly. Cowie (1987) showed that incentive contracts were capable of yielding better cost estimates. Bodily and Hogarth (1981) presented anecdotal evidence suggesting that technological complexity reduces the ability to forecast costs acurately.

Also, estimating offices that set up a system for monitoring performance have been shown to improve their performance (Runeson, 1988). Others have stated that good management practices, using sampling techniques and requiring defense of rates and quantities used, will minimise poor effort by estimators (see ASPE, 1989 for example).

The limited studies so far conducted in these areas have tended to provide very little support for the opinions often expressed in literature about the nature of estimating inaccuracies.

6.2 FIELD TESTS

The effect of environmental conditions on accuracy was tested in two ways: (1) through opinion survey of design offices; and(2) empirical analysis of estimating performance data.

The aim was to establish the relationships between the factors discussed in section 6.1 above and the accuracy of estimates. It was also considered necessary to see if there are differences between the opinions of practising cost estimators and the true situation. The two approaches are now discussed.

6.2.1 Opinion Survey

Design offices, randomly chosen from a list obtained from the Institute of Civil Engineers, were required to rate, on a seven point scale, some factors thought to affect estimating accuracy. The question was put thus:

> Please rate each of the following factors as they affect the accuracy of estimates on a 7 point scale (e.g. 1- least effect on estimate accuracy, 7 - most effect on estimate accuracy.

Number of Bidders	Project location
Design information available	Project type
Historical cost data	Market condition
Project complexity	Project duration
Project size	Estimator's expertise

6.2.1.1 <u>Results</u>

The results of the ratings are contained in Tables 6.1-6.4

Table 6.1: Responses of Various Offices: Factors Affecting Estimanting Accuracy

Factors \ Office	A	B	C	D	E	F	G	H	Total
Number of Bidders	4	1	2	1	5	1	-	5	19
Design information	7	7	7	4	7	6	1	5	34
Historical cost data	6	7	5	4	6	6	7	5	46
Project complexity	4	4	3	5	3	5	1	4	29
Project size	5	1	2	2	3	3	-	5	21
Project location	2	1	3	3	1	1	1	5	17
Project type	6	4	3	6	3	2	1	6	31
Market condition	1	4	5	5	2	7	7	6	37
Project duration	5	1	4	2	2	1	1	2	18
Estimator's expertise	6	7	6	7	7	3	5	5	46
Total	46	37	50	39	39	35	22	48	308

Table 6.2: Strength of Feelings About Factors *

Factors \ Office	A	B	C	D	E	F	G	H	Total
Number of Bidders	0.09	0.03	0.05	0.03	0.13	0.03	-	0.10	0.46
Design information	0.15	0.19	0.18	0.10	0.18	0.17	0.04	0.10	1.11
Historical cost data	0.13	0.19	0.13	0.10	0.15	0.17	0.29	0.10	1.26
Project complexity	0.09	0.11	0.08	0.13	0.08	0.14	0.04	0.08	0.75
Project size	0.11	0.03	0.05	0.05	0.08	0.09	-	0.10	0.51
Project location	0.04	0.03	0.08	0.08	0.03	0.03	0.04	0.10	0.43
Project type	0.13	0.11	0.08	0.15	0.08	0.07	0.04	0.13	0.79
Market condition	0.02	0.11	0.13	0.13	0.05	0.20	0.29	0.13	1.06
Project duration	0.11	0.03	0.11	0.05	0.05	0.03	0.04	0.04	0.46
Estimator's exp.	0.13	0.19	0.16	0.18	0.18	0.09	0.21	0.10	1.24

* Strength of feeling is calculated using the equation:

$$\text{Feeling} = \frac{\text{Office score for factor}}{\text{Total office score for all factors}} \quad \text{------------} \quad (6.1)$$

Table 6.3: **Ranking of Factors**

Factors \ Ranking	1	2	3	4	5	6	7	Total
	Frequencies							
Number of Bidders	3	1	-	1	2	-	-	7
Design information	1	-	-	1	1	1	4	8
Historical cost data	-	-	-	1	2	3	2	8
Project complexity	1	-	2	3	2	-	-	8
Project size	1	2	2	-	2	-	-	7
Project location	4	1	2	-	1	-	-	8
Project type	1	1	2	1	-	3	-	8
Market condition	1	1	-	1	2	1	2	8
Project duration	3	3	-	1	1	-	-	8
Estimator's expert.	-	-	1	-	2	2	3	8
Total	15	9	9	9	15	10	11	78

Table 6.4: **Overall Importance Ranks and Strength of Feelings**

Factor	Total Score	Strength of Feelings
Historical cost data	46	1.46
Estimator's expertise	46	1.24
Design information	44	1.11
Market condition	37	1.06
Project type	31	0.79
Project complexity	29	0.75
Project size	21	0.51
Number of Bidders	19	0.46
Project duration	18	0.46
Project location	17	0.43

Mean: **30.8** (0.83) Standard Deviation: **11.86** (0.37) Range: **29**(1.03)

Median: **30** (0.77) CV: **38.5%** (0.45)

The offices were also asked to describe what they think helps them in improving accuracy of their estimates. Their answers centred on the following issues:

- a knowledge of the projects from which rates were extracted
- similarity between schemes from which rates are extracted

- design information and information on soil conditions
- independent check of estimates
- monitoring accuracy
- awareness of the market
- accurate inflation figures
- short time lapse between schemes from which data are extracted
- having sufficient time to prepare estimates

The result of this survey agrees with a similar survey of 29 companies on conceptual estimating practices conducted by Ashley et al. (1988). The survey result is shown in Table 6.5. Prominence is given to estimator's expertise and completeness of information about the project and project environment. The emphasis on expertise is justified considering that the survey relates to early stage estimate.

Table 6.5: **Most important issues in conceptual estimating**

Most important issues	% of companies
Estimator experience and expertise	59.0
Availability of a complete scope definition	52.0
Information about the project and its location	28.0
Information about market environment	17.0
Appropriate estimating procedure	14.0

Source: Ashley et al., 1988

6.2.2 Empirical Survey

The same design offices and others were approached for data on recent projects to test the effects of the factors discussed on estimating accuracy. Each office was supplied with data forms to fill in design estimate together with the bid prices for their projects. A sample of the data form is shown in Appendix E.

Seven offices supplied data on 51 construction projects, the remaining offices declined for various reasons.

6.2.2.1 The Projects.

All projects in this survey were from County Council Road and Transportation Departments. It was difficult to obtain data from other sources. They were mainly for facility improvement in township roads or for road reconstruction. The projects range in value from £36,000- £2.4m.

6.2.2.2 The Analyses

Three tests for accuracy and consistency were conducted on the data for each project.

1. Error in forecasting low bid measured by the quantity

$$e = \frac{\text{Estimate - Low bid}}{\text{Low bid}} \qquad \text{------------- --------} \quad (6.2)$$

2. Coefficient of variation of tenders.

3. Coefficient of variation in design estimates using the ratio of estimate/lowbid.

The results were then grouped to allow for testing the effects of the factors theoretically considered to be capable of influencing the accuracy of design estimates.

6.2.2.3 Project Information and Other Factors

The data supplied by the design offices relate to the prediction of tender price and the bids submitted by contractors. The nature of the information supplied made it impossible to analyse the data according to project information, project duration, type of project and other relevant factors. The data could only be analysed according to: project size, geographical location, number of bidders, year of construction and office of origin.

6.2.2.4 Project Size

The analysis according to project value divides the 51 projects as follows: (1) projects less than £100,000 in value; (2) projects greater than £100,000 but less than £500,000; (3) projects greater than £500,000 but less than £1.0m in value; and (4) projects greater than £1.0m in value.

Table 6.6 shows the result of the analysis according to project size. Part of the data is also plotted in Figure 6.3. Improvement in accuracy is noticed as the value of the contract improves [increases]. Also, coefficient of variation amongst bids reduce, suggesting keener competition. However, the analysis of variance tests yielded an F value of 1.38 revealing that there is no significant difference in design accuracy at the 95 per cent level of significance ($F_{3,47,0.05}$ being 2.81).

FIGURE 6.3: Project Value - Error

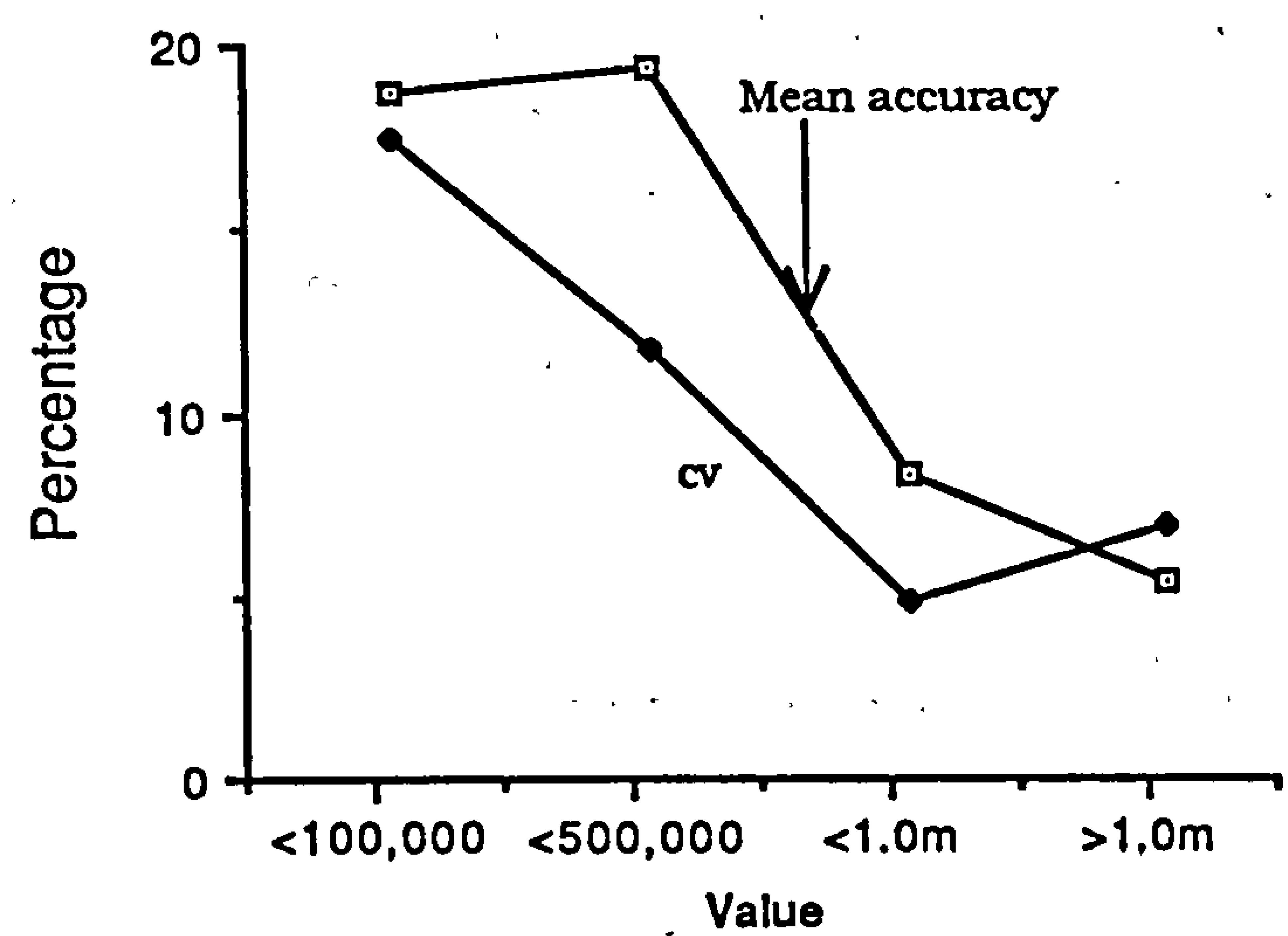


Table 6.6: Analysis According to Project Value

Project value (£)	No of Projects	*Mean Accuracy (%)	*Mean Absolute Accuracy	SD	CV (%)
< 100,000	24	18.18	19.98	20.61	16.99
< 500,000	9	18.84	22.89	20.14	11.19
< 1.0m	5	7.72	9.53	8.43	4.31
> 1.0m	13	4.80	10.64	13.90	6.39

* Mean accuracy is obtained by averaging the e values calculated using equation 6.2 while mean absolute accuracy is obtained by averaging the absolute values of e calculated from the same equation.

6.2.2.5 Geographical Location

Analysis of the data according to geographical location is presented in Table 6.7. The table shows results for three geographical locations in England and Scotland: North, Midlands and the South. It was expected that the results should show variations according to the level of prosperity (construction activity) in the three regions; the North being least prosperous while the South is the most prosperous. An analysis of variance yielded an F value of 5.98 ($F_{2,48,0.05}$ being 3.19) suggesting significant differences in the achieved accuracy in design estimates from the three regions.

A visual inspection suggests that the accuracy results contradict expectations. In theory, estimating accuracy should be better in the North than the South because of closeness of bids which should result from keener competition for projects. The results however show better results coming fom the South and the Midlands with the Midlands having the lowest value for error in estimating low bid. The relationship between the state of the economy and estimating accuracy is perhaps more complex than suggested in earlier theories of estimating accuracy.

Table 6.7: Analysis According to Geographical Location

Location	No.	Mean Accuracy (%)	Mean Absol Acc.	SD	CV (%)
North	20	23.61	25.44	20.53	15.71
Midland	18	3.63	9.23	11.68	9.07
South	13	7.65	12.59	14.07	3.66

6.2.2.6 Number of Bidders

The results from the analysis according to the number of bidders is shown in Table 6.8. The table shows no apparent trend in the mean accuracy. Analysis of variance test also yielded an F value of 0.93 suggesting no significant differences according to the number of bidders ($F_{5,45,0.05}$ being 2.43) at the 95 percent level of significance.

Table 6.8: **Analysis According to Number of Bidders**

Number of Bidders	N	Mean Accuracy (%)	Mean Absolute Accuracy	SD	CV (%)
3	4	6.84	10.99	18.64	4.26
4	3	34.64	34.64	18.06	10.02
5	12	11.59	13.22	12.47	14.08
6	24	13.23	17.47	20.03	11.14
7	4	10.40	10.40	3.98	11.11
8	4	5.49	17.21	26.91	9.53

6.2.2.7 Year of Tender

Table 6.9 shows the result according to the year of tender. It was expected that design accuracy will decrease in line with the prosperity in the construction industry in the years 1986 to 1988. The coefficient of variation figures suggests a wider spread of bids after 1986. Accuracy of design estimates also show deterioration. The plot in Figure 6.4 show detorioration of both mean accuaracy and mean absolute accuracy after 1986. However, analysis of variance tests produced an F value of 0.51 suggesting no significant variation in accuracy according to the year of tender ($F_{4,46,0.05}$ being 2.57).

FIGURE 6.4: Yearly Analysis

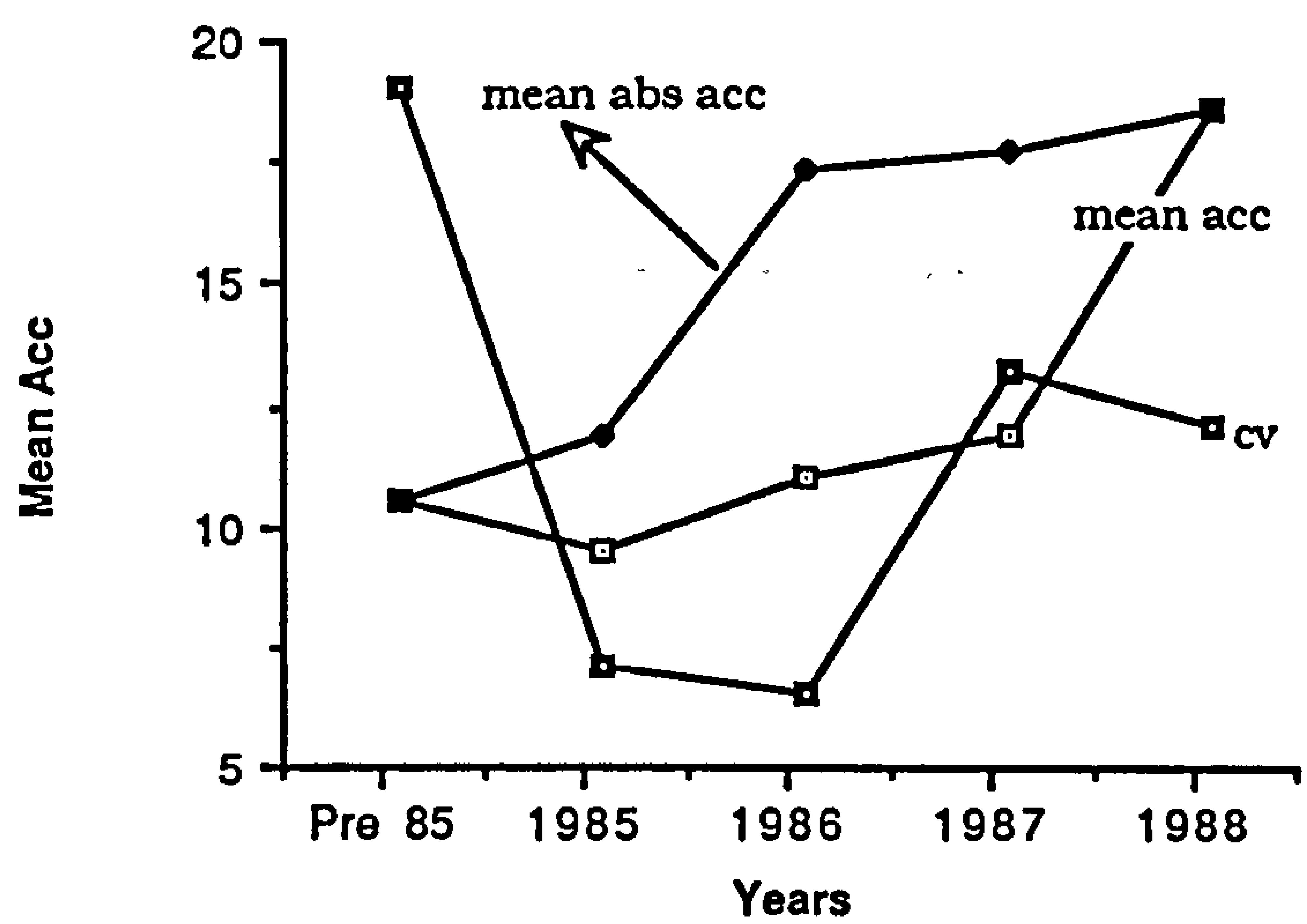


Table 6.9: **Analysis According to Year of Tender**

Year	N	Mean Accuracy (%)	Mean Absolute Accuracy	SD	CV (%)
Pre 1985	5	10.19	10.19	12.54	18.71
1985	3	9.15	11.53	11.75	6.72
1986	6	10.66	16.98	21.41	6.17
1987	24	11.47	17.28	20.98	12.85
1988	13	18.15	18.15	15.56	11.65

6.2.2.8 Analysis according to Design Office

A summary of the analysis according to design office is shown in Table 6.10. The table suggests a general trend to overestimate low bid irrespective of the office. However, achieved accuracy varied across offices. The best results are from Office D with a mean error of +0.94 per cent when the coefficient of variation amongst bids is 6.48%. The worst results seem to come from Office A with mean error of +29.17% when the coefficient of variation amongst bids is 17.18%. Office B results show remarkable accuracy of +2.08% with a coefficient of variation amongst bids of 10.57%.

Analysis of variance tests produced an F value of 3.88 suggesting significant differences in achieved accuracy between the different offices at the 5 per cent level of significance ($F_{6,44,0.05}$ being 2.31).

Table 6.10: **Analysis According to Design Office**

Office	N	Mean Accuracy (%)	Mean Absol Acc.	SD	CV (%)
A	15	29.17	29.17	19.20	17.18
B	12	2.08	6.04	7.32	10.57
C	6	6.72	15.62	18.14	6.08
D	5	0.94	5.09	5.86	6.48
E	5	6.96	14.25	15.79	11.30
F	3	15.28	15.28	4.94	4.27
G	5	13.11	18.42	20.31	7.56

6.2.3. Overall Result

The mean accuracy from this analysis was +12.77% (13.9 SD) with a mean absolute error of 16.44%. On average, design estimates were 12.77% higher than the low bid. The consistency of design estimates from this study compares well with other previous studies (ref. Chapter 4). The coefficient of variation between bids is 11%.

6.3 OPINION AND EMPIRICAL SURVEY RESULTS

The results of the opinion survey of offices and empirical data analyses are presented in Section 6.2. It was anticipated that the studies would show agreement between design cost estimator's opinion and evidence presented by empirical data. The results are discussed under 3 headings below.

6.3.1 Highly Rated Factors

The factors historical cost data, estimator's expertise and design information were rated highly by the offices (Table 6.4).

6.3.1.1 Historical Cost Data

It has been suggested in previous studies that the quality (McCaffer, 1976; Morrison and Stevens, 1981) and quantity (McCaffrey, 1978; Jupp, 1980) of historical data used affects the accuracy of estimates. Also, some of the offices surveyed have started using data from more than one project for estimating costs (for example three projects). From the opinion survey, the total factor score for historical cost data is 46. This score suggests equal rating for historical cost data and estimating expertise. The strength of feelings rating (1.46) provide justification that historical cost data is the most highly rated factor in design cost estimating. Unfortunately, the nature of data acquired from design offices preclude analysis according to the quality or quantity of historical cost data. The result of the opinion survey is however consistent with previous studies, particularly Jupp (1980) and Morrison and Stevens (1981). It would thus seem that the accuracy of design cost estimates could benefit from improved quality and quantity of historical cost data.

6.3.1.2 Estimator's Expertise

The results of the opinion survey show that estimator's expertise is consistently rated highly by design cost estimators (average rating 5.75). According to the offices surveyed, the contribution of expertise to cost estimating is in three major areas, viz: (1) ability to select relevant cost data better than other; (2) ability to establish cost relationships and design parameters; and (3) intuitive abilities necessary for adjusting rates acquired through familiarity with projects.

The analysis of empirical data could not be conducted strictly along the lines of individual estimator's expertise but rather on the basis of office of origin (Table 6.10) However, four of the offices from which cost data were acquired reported that the projects (for which cost was analysed) were handled by the same estimator. Two of the remaining three offices indicated that their projects were handled by more than one estimator. If despite this constraint, the data from each office are attributed to one 'expert' it would seem that accuracy of design cost estimates are significantly influenced by individual expertise.

6.3.1.3 Design Information

The completeness or validity of design cost information is thought to have significant effects on the estimator's ability to model costs accurately (See Section 6.1 and Figure 6.1). Discussion with two of the offices suggest that the notion of accuracy improving as design evolves is justified. However the magnitude of the improvement that could be achieved by improving project information is accepted to be unquantifiable. The data acquired from design offices could not be tested along the lines of improving design data since they relate to tender estimates only.

6.3.2 Moderately Rated Factors

The factors market conditions, project type and project complexity were rated moderately by design offices (Table 6.4).

6.3.2.1 Market Conditions

The moderate ratings and fairly strong feelings of design offices for this factor may seem to justify opinion in literature that market effects influence accuracy. The analysis of data according to year of tender (Figure 6.4) show a decrease in accuracy starting from the year 1985. The construction industry in the UK is generally accepted to have been in a recession prior to 1985, while a boom in construction activities has been recorded between 1985 and 1988. The deterioration in accuracy may be attributed to the boom in the construction market resulting in wider distribution of tenders. However, the analysis of variance test suggest that the increase in accuracy is not statistically significant.

6.3.2.2 Project Type

The data acquired for this research could not be analysed according to project type because the offices were mainly involved in road construction and improvement. The offices however accorded the factor a moderate rating of 31 (Table 6.4).

6.3.2.3 Project Complexity

Project complexity should normally correlate with project size. Complexity is rated moderately in the opinion survey (Table 6.4) while project size received a relatively low rating. This is probably due to the differences in project composition. Most projects are standard road construction/improvement projects while others included railway bridges, subways, etc. that are judged to be more difficult to estimate than others. The evidence from opinion survey suggest that unfamiliar items in projects are more difficult to estimate than standard items. The data from this survey could not be analysed according to complexity and as such, association between accuracy and project complexity can only be inferred from the opinion survey.

6.3.3 Lowly Rated Factors

The factors project size, number of bidders, project duration and location of project were given low ratings by the design offices (Table 6.4).

6.3.3.1 Project Size

The size of projects originating from each office, measured by the contract price, did not vary much. This is probably responsible for the low ratings given to this factor. Empirical data analysis show that improvement in accuracy correlate with project size (Figure 6.3). Analysis of variance tests suggest that the association between project size and accuracy is not statistically significant.

6.3.3.2 Project Location

The low rating for project location is fairly predictable. The offices, being County Council Transport and Highway Departments, operate in fairly compact areas. Except for restrictions in site accessibility ocassioned by differences between rural and urban roads, location plays little role in the project situation. The design offices are therefore, unlikely to attach much importance to geographical location.

Data analysis according to project location show significant differences between achieved accuracy in different regions of the UK (Table 6.7). The implication is that whereas in compact locations (County Council areas) the effects of location on pricing may not be significant, differences exist between regions.

6.3.3.3 Number of Bidders

The effect of the number of bidders may not have been very salient to the estimating offices unless there is a system that monitors the performance of estimator on different projects. The current practice does not consider this factor in cost predictions. Except in three offices, two of which incidentally monitor costs regularly, the ratings for the factor is generally low.

Analysis of data according to number of bidders did not show significant effects on accuracy. This suggests that the low ratings accorded this factor by design offices is justified.

6.3.3.4 Project Duration

The offices did not attach much importance to project duration. It was expected that the effects of design changes on estimate accuracy should be considered by design offices as significant. However, since the offices do not compare estimates with final accounts, the effects of design changes on accuracy is unlikely to be considered important.

6.4 SUMMARY

From the analysis presented in this chapter, it has been possible to establish relationships between some factors that constitute uncertainty in the task and task environment and the ability to model costs accurately.

The opinion survey established cost estimating data, ability of the estimator, design information and market condition as prominent factors affecting estimating performance. Design estimators also attach moderate importance to project type and complexity.

From empirical studies, only geographical location and office of origin has been shown to relate statistically to estimating performance. Although not statistically significant, project size also shows a positive relationship with estimating accuracy.

If the data originating from each design office is assumed to come from one estimator, it would seem that performance in estimating is affected by the ability of the estimator. This seems a plausible assumption since 4 of the seven offices reported that their projects had been handled by one estimator. However, two of the other offices suggested that more than one estimator was involved in estimating cost for the projects for which cost data were supplied. The seventh office being unable to remember how many estimators were involved in their projects.

CHAPTER 7

TARGETING THE DESIGN ESTIMATE

Forecasting is not easy, but if we have an idea of where we want to go, we're more likely to get there.
- ASCE prospectus for the Bicentennial Convention.

7.0 INTRODUCTION

As part of the process of fulfilling his responsibilities to the client, the cost consultant prepares cost estimates at various stages in the design phase. The general expectation is that the cost consultant should predict the probable cost of the project to the client, but in reality this is not so. The parameter which the cost consultant predicts is determined by several factors which include: the purpose for which the estimate is required; the information available for making the prediction; and the ability of his methods and cost data to predict the required parameter.

Sometimes a historical estimate is judged as being inaccurate without reference being made to the parameter the estimator tried to predict. For reasons of convenience, the low bid is often used to assess the accuracy of estimates resulting in undue dissatisfaction being expressed about the quality of the design estimate (See Chapter 4 for example). However, the estimator may not have predicted the low bid.

It has been stated earlier that an acceptable definition of 'the right price' for a construction project remains elusive. It is impossible under such ambiguities to measure accuracy of estimates correctly. As Flanagan (1980) and others have stated, we can only measure the precision of the design estimate. Whereas accuracy presupposes the existence of a right price for a project, precision only measures the closeness of the estimate to any chosen bid parameter. To assist in measuring estimate precision, the cost consultant needs to set a target. Assessments can then be made regarding his ability to hit the target correctly. This chapter addresses the setting of appropriate targets for design estimates by examining the parameters which the client's cost consultant may estimate at the design stage.

7.1 THEORETICAL EXPECTATIONS

7.1.1 Client

As a service to the client at the inception and early stages in design, there is an obvious case to suggest that estimating should aim at predicting the probable total cost to the client in getting the facility built. It is also being advocated nowadays that the cost consultant should advise his client on the probable running and maintenance costs (costs in use) when the facility is eventually built as a means of assessing the desirability of the project. Advocates of cost in use predictions argue that the client should know the full extent of future financial commitments before a design is accepted. Although a discussion of the quantity surveyor's ability to render this service to the client is beyond the scope of this chapter, it is worth noting that prediction of future costs in a rapidly changing world will increasingly become difficult.

Cost predictions at the design phase take various forms: ranging from simple factor estimating to more involved estimating based on bills of quantities. The cost consultant inevitably relies on historical data to make his forecasts. However, because of the scant information usually available, the cost consultant would not expect high accuracy from such predictions. The data available seems to suggest that estimators rarely get within ±20% of the project cost or about ±15% of the lowest tender (ref. Chapter 4).

7.1.2 Other Designers

Apart from the client, designers are the next group likely to be directly affected by the design estimate. Newton (1987) argued that cost modelling has no effective purpose unless it contributes in some way to the design process. Cost estimating enables designers to assess whether the proposed design falls within the client's cost limits. The source of high costs is also of interest to designers. It should also be of interest to designers to know how costs are distributed among the various elements of the building. Beeston (1987) doubted the possibility of improving the design estimator's present methods to produce estimates capable of adequately meeting this requirement. He argued that, since the cost consultant does not calculate costs in the way in which they arise, their ability to advise the design team on cost reduction possibilities is greatly limited. Because of the nature of their assignment, designers are interested in knowing how much different elements of the facility 'are likely to cost when constructed' and the probable maintenance costs.

It was speculated that complete computerisation of the estimating process with the possibility of linking to CAD systems may eventually eliminate the need for the cost consultant at the design phase. This is not yet the case in the industry. However, it is becoming clear that unless the cost consultant can convince other members of the design team that he is better able to forecast construction costs, the design-phase estimating function may no longer be his exclusive domain.

7.2 LATER STAGE PREDICTIONS

Theoretically, there is no limit to the number of estimates a project cost consultant may be required to prepare at the design phase. Practical limitations are however imposed by cost considerations - as estimates are costly to prepare. The greater the level of detail required, the higher the cost of producing the estimate. Ideally, the number of estimates should not be less than two. The earlier estimate is used to set a cost limit for the project budget while the later estimate would be used to assess the cost efficiency of the design as well as predict the probable tender prices. As the design evolves the cost consultant is able to predict cost more accurately and set a realistic target for his estimate.

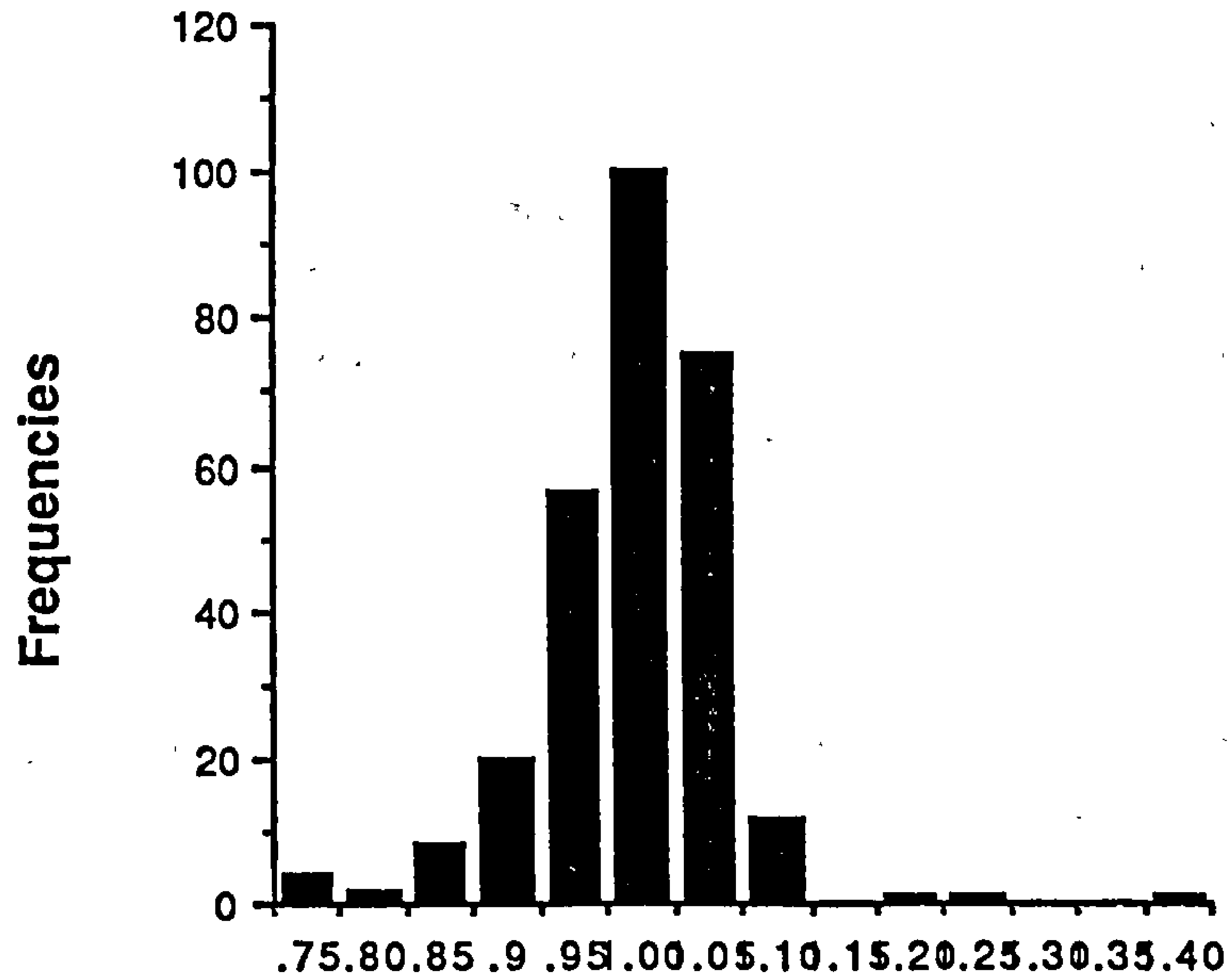
Thus, later stage estimates will usually be predictions of tender prices. At this stage there is still a general lack of agreement regarding which tender parameter the cost consultant estimates. Flanagan (1980) demonstrated that estimating is like firing shots at a moving target. The gunman, if not totally confused, should have a target in mind, irrespective of how fast (and not withstanding how unstable) the target may be moving. Design cost estimators have yet to agree on a target on which tender price efforts should focus. But the cost consultant must aim at a particular target to enable him to assess the success of his estimating efforts. He could try to predict any of the following parameters: (i) the lowest tender, (ii) the second, third or any other tender, (iii) the mean of tenders, (iv) the median of tenders, or (v) a high figure above which reasonable tenders are not expected to be located. The suitability of using each of the parameters as a target for the design estimating effort is discussed below.

7.2.1 Low Bid

Unless the client's advisers have reasonable doubt about the ability of a contractor to undertake the work, the practice in the UK is to award contracts to the lowest bidder.

Because of this and other considerations, studies into estimating accuracy have tended to compare the quantity surveyor's forecast with the low bid (ref. Chapter 4).

Figure 7.1: Estimate/Lowbid relationship on 290 projects



Low bid/cost estimate ratios

Source: Skitmore (1987)

Data in Figure 7.1 show the relationship between low bid and estimates on 290 construction projects. The figure indicates a negatively skewed bid distribution with low bid/estimate ratio between 0.75 and 1.1. The mean is calculated as 0.995; thus indicating that (1) on average design cost estimates are more than the low bid, and (2) estimates are very accurate. However, this condition cannot always be reproduced in real life situations.

Although the case for predicting the lowest tender price looks obvious, it is indeed a difficult task for the client's estimator to perform. This may be illustrated by two practical experiences:

1. "A low bidder submitted a price which was substantially lower than others that had been received. The contractor's quantities differed from others because a designated fill area in the building plan had been filled by the waste material excavated from an adjacent site. Only the low bidder knew this. His rates were found to be in order. This contractor won the contract thereby profiting from the anticipation of the changed condition prior to tender." - Douglas (1963)

2. Two quantity surveyors interviewed for this research maintained that in estimating, they aim to be just above the second or third lowest tender. On a particular contract, the estimator succeeded in getting his estimate just above the third lowest tender for which he commended himself as being accurate. He was dissapointed by the results from another contact. The lowest tender for the second contract was just above £35,000. The second lowest tender was well over £72,000. The estimator's price for the contract was about £50,000. Conventional methods for excluding outliers suggested that the low bid was not a reasonable price. However, the low bidder won the contract and reported making a profit of about £10,000 on the project. Unknown to both the design estimator and the other bidders, the low bidder had recently completed a contract in the vincinity and had surplus materials which were diverted to the new project.

Chance occurences such as those illustrated in the examples above abound in the construction environment and it is known that contractors often tender low for elements such as preliminaries and earthworks to win contracts. The result is that predicting the low bid is a difficult task. However, on projects where the low bidder will normally be awarded the contract, there is a case to suggest that predictions of the low bid are appropriate.

7.2.2 The Second, Third or any Other Tender

Flanagan and Norman (1982) suggested that when estimating the cost of a project, surveyors should take into account bidding range, the relationship between the lowest, second and third lowest bids, and use more detailed information on historical jobs as a database. Their suggetion is based on the observation that the distribution of tenders show that the lowest tender is a poor indicator of the true price for projects. Although their study suggests that the second or third lowest tender may be a better representation of the true cost, they did not indicate how the cost consultant is to use this information in estimating.

From the second example presented above, the second lowest tender could not have been a true cost for the project. However, the estimator, having succeeded in staying above the low bid would seem to be in a comfortable position. For reasons known only to the low bidder, he was able to reduce the tender price to a level well below the expectations of the cost consultant and the other contractors. Although it could be argued that the low bid on the contract is an outlier and as such, it may not be a fair representation of the actual situation in the industry, no doubt, the cost consultant should seek to know the 'hidden' reasons likely to increase the disparity between tender prices and his estimates.

7.2.3 Mean, Mode and Median of Bids

In statistics, the mean, mode and median are used as descriptive measures of location for populations and samples. The mean is the sum of all values in a collection divided by the number of values. The median for a collection of values is the value at the middle when all the members of the collection are arranged in increasing order. The mode is the most popular value or the value with the highest frequency.

In a unimodal and symmetrical distribution the values of the mean median and mode are all the same value as in Figure 7.2a. For a negatively skewed distribution, the mean has a lower value than either the mode or median as indicated in Figure 7.2b. For a positively skewed distribution, the mean has the highest value of the three collection parameters as shown in Figure 7.2c.

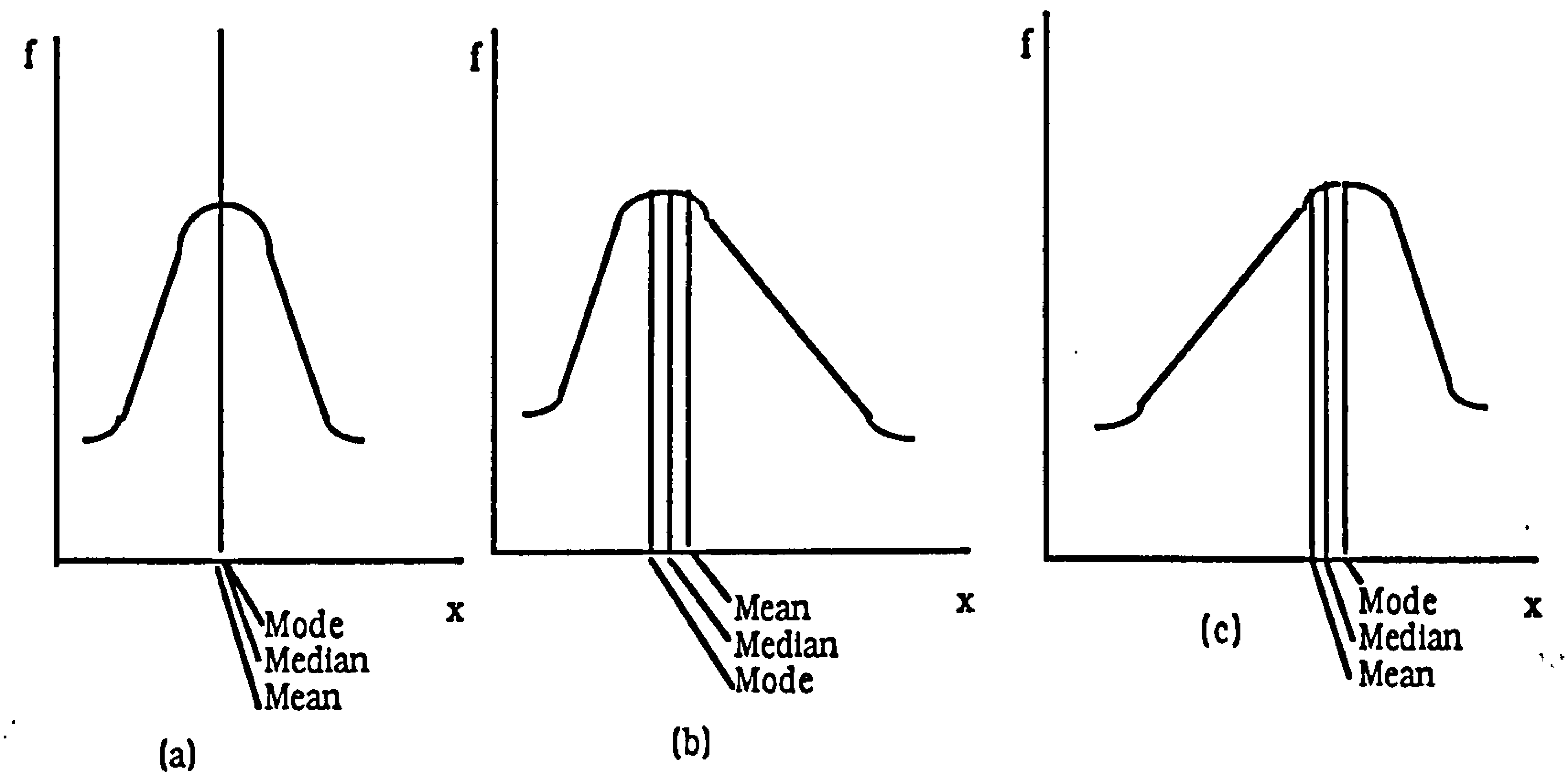


FIGURE 7.2: RELATIONHIP BETWEEN MEAN, MEDIAN AND MODE OF DISTRIBUTIONS

For a small collection, (ie less than 30) the mode is the least reliable value of average. Since tenders submitted for most construction contracts will generally be less than 10, the mode is not a reliable measure of average. Also, no two bids submitted for the same construction contract are likely to be exactly the same. Therefore, the mode of tenders will be an impossible target for the design estimator.

The mean is always more affected by extremely low or high values in the collection, therefore, for non-symmetrical distributions the median is considered a more stable measure of average for statistical description. A non-serious tenderer or a low bidder may easily offset the value of the mean. Also, the median satisfies the criterion that the sum of the absolute value of errors be minimised. However, the mean satisfies the mathematical criterion that the sum of the squared errors be minimised. The objective of minimising the sum of the squared errors is the criterion underlying the development of the techniques of analysis in inferential statistics. This implies that the mean is mathematically consistent with the principal techniques of statistical inference. Beeston (1983) observed that apart from a negligible skewness to the right, the distribution of bids can be assumed to be normal. This implies that the mean is a good representation of the collection. For these reasons, the mean would appear to be a more advisable target for the estimator to aim at.

There is however a practical problem associated with the mean and median of tenders. The mean or median of tender, being averages, do not facilitate direct comparison on an element by element basis with the design estimate. The only obvious solution to the problem is to compare the mean or median price for each element with the quantity surveyor's estimate. If there is an odd number of bids, there is no problem with using the median of tenders as the tender with the median bid can be used.

7.2.4 A High Value

On some contracts, quantity surveyors/engineers are now being required to forecast a high contract value which bids and sometimes actual costs should not exceed, as is the case on fixed price contracts. Such predictions, which require a thorough understanding of market conditions, help in guarding against the high incidence of cost growths and require the design estimator's professional expertise to be utilised to the utmost. Determining the accuracy of estimates will be much easier where cost ceilings are predicted: the tender prices and final account figures can easily be compared with the quantity surveyor's forecast. However, the cost consultant is being asked to foresee all changes likely to occur when the facility is being built; a task which he is ill-equiped to perform and which even a contractor is unable to undertake.

Also in some instances, design estimators may aim high because clients are happier when told they could make savings on projects than when asked to pay more than budgeted. Evidence also show that on some government contracts, estimators may deliberately produce high or low estimates depending on their disposition towards investment in such undertakings (Merrow et al., 1979). Morita (1987) has reported that Japanese clients are unwilling to approve project cost increases under any circumstace once a budget is set. It can be speculated that, as Japanese companies move into Europe and European companies gain access into the Japanese industry in the nineties, more requests for prediction of cost ceilings may be made by clients.

7.2.5 A Fair Tender or Reasonable Figure

Admitting that it is difficult if not impossible to estimate a true figure for project cost, it is now being suggested that perharps the cost consultant should be able to estimate a fair price for the project (see McCaffer, 1976 and Beeston, 1983). The fair price is expected to cover construction costs and include a reasonable profit for the contractor considering the market situation. This seems to be a reasonable proposition, but in trying to achieve this goal, the cost consultant will have to estimate construction cost and a fair profit separately. Current methods can not do this, and as such, the cost consultant may have to adopt the contractor's method of estimating. If this is done, the cost consultant may only succeed in adding the contractor's tendering problems to his own thereby increasing his workload without a guarantee of a better estimate. Whether or not he will be able to use contractor's methods well is another consideration which is beyond the scope of this chapter (see Chapter 4 for a full discussion).

7.2.6 Movement in Tender Price Level

Design cost estimators have to forecast construction costs in a dynamic situation in which three basic options are possible:

1. movement in tender price level;
2. greater or less competition for projects; and
3. combinations of (1) and (2).

These basic options are represented in Figure 7.3 [a-i]. They have varying effects on the ability to predict tender prices by affecting edge values (represented by the low bid) and middle values (represented by the mean of bids) differently.

Competition

A standard normal distribution is assumed in Figure 7.3(a). Greater or less competition will have the effect of compressing or widening the distribution of bids as shown in Figures (b) and (c). In both instances, there is no change in the mean whereas the position of the low bid has changed by dl.

Competition plus upward movement in price level

The combined effect of competion and upward movement in the general price level is demonstrated in figures (d) to (f). In (d), an upward movement in price level without a change in the level of competion have the effect of producing equal changes in the mean and the low bid i.e. m'-m = dl.

If however an upward movement in the general price level combines with greater competition for projects (e), the resultant change in the position of the low bid will be greater than the change in the mean i.e. dl>m'-m. An upward movement in the general price level coupled with less competition (periods of general economic prosperity) results in changes in the low bid which is less than the corresponding change in the mean (f) i.e. dl<m'-m.

Competition plus downward movement in price level

The effects of competition and downward movement in the general price level are shown in figures (g) to (i). Equal changes in the mean and the low bid result from a downward movement in prices which is not accompanied by greater or less competition (g). Greater competition results in greater change in the mean than the low bid (h). Less competition produces more change in the low bid than the mean (i).

All the instances represented in Figure 7.3 show that edge values have greater scope for change than values in the middle of tender distribution. Thus, if these conditions are reproduced in real life situations, there is a good case for suggesting that a value in the middle of the distribution is more appropriate for the design cost estimator to target. However, the situation in the industry is more complex than can be represented in a simple model as this example has demonstrated.

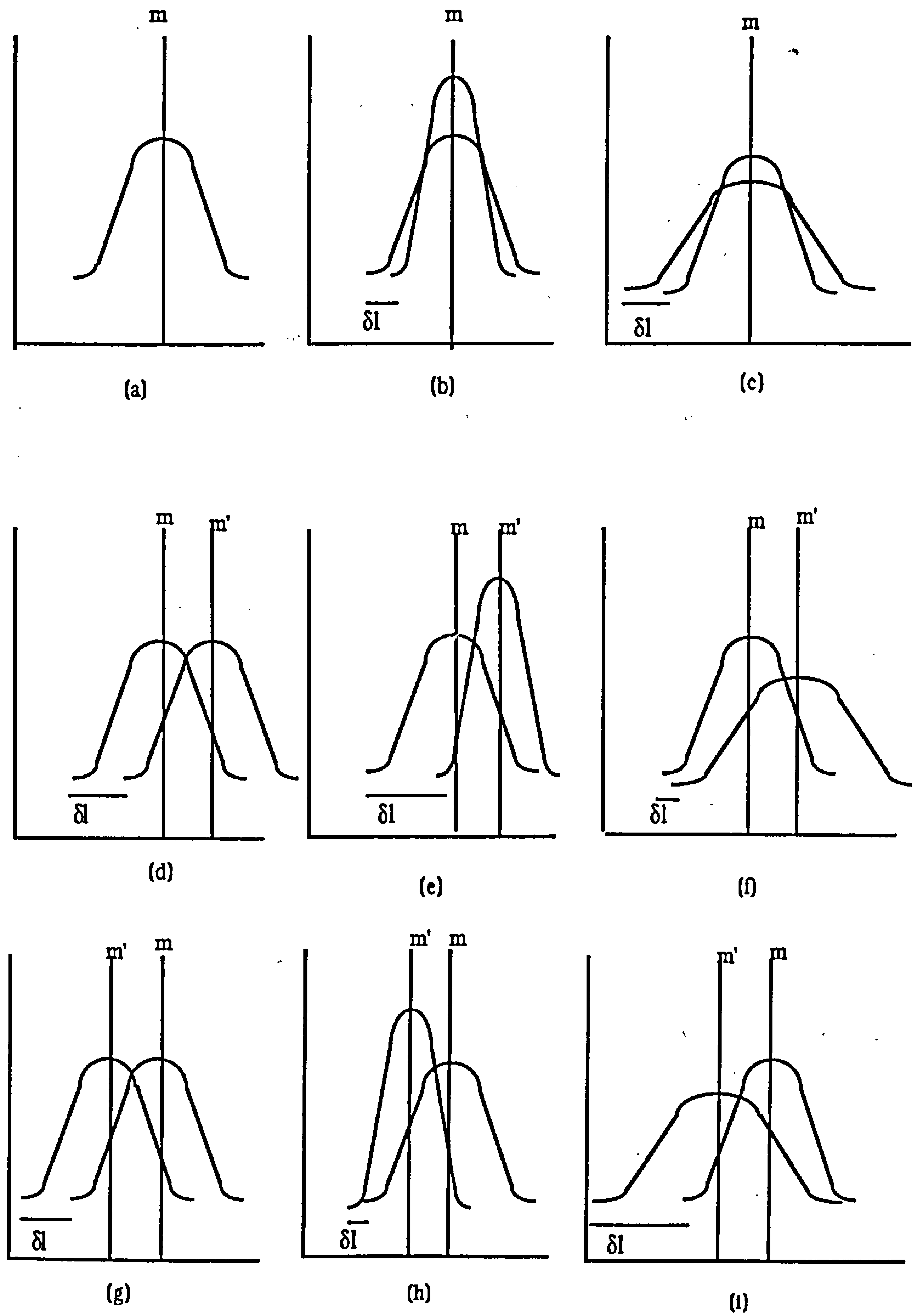


FIGURE 7.3: MOVEMENT IN TENDER PRICE LEVEL

7.3 FURTHER ANALYSES

The foregoing discussion did not attempt to suggest the best target for design cost estimating. Whereas it seems obvious that a parameter in the middle of the collection is more appropriate than end values, it remains to be tested in the real world. The design estimator should be at liberty to determine a suitable parameter for cost targetting. However, his accuracy should be tested by measuring the deviation from his target. From studies of outcome feedbacks he may adjust to focus more on his target or choose another target depending on which is the better proposition.

Data were collected for the purpose of determining which of the parameters of low bid and mean bid is more stable as a target for estimating. The resulting analyses are presented below.

7.3.1 Data Collection

Two approaches were adopted in verifying the need for or the usefulness of estimate tergetting in the industry. First, design offices were approached via a questionnaire survey and telephone interviews to understand the practice in industry and to seek the opinion of the office regarding estimate targetting. Secondly, empirical data from the offices was used to assess the estimator's ability in producing estimates close to targets.

7.3.1.1 Questionnaire Survey

Responses to the questionnaire survey were received from 8 offices spread throughout the UK (see Appendix F for details). The responses are presented in Tables 7.1-7.6.

Estimate Comparison

Of the 8 offices, 5 regularly compare estimates with the tender. However, comparions are made, not to aid future cost predictions but, to detect any 'obvious errors' in the winning bid.

All offices compare estimates with the tender when there is a significant difference between the two. Such comparisons are made to detect the sources of error in the design estimates.

The result justify the opinion in chapter 5 that causal relationships between estimating error and predictive ability are sought only when design estimators' expectancies are disconfirmed through outcome feedbacks. It also shows that practice in the industry have not deviated significantly from those reported by Morrison and Stevens (1981).

Table 7.1: **Comparison of Estimate with Tender**

	Time of comparison	No	Identifier
a.	When prediction is close	5	C,G,D,E,P
b.	When prediction is not close	8	All Offices

Parameter used for comparison

Six of the 8 offices compare estimates with the low bid (Table 7.2). One of the 6 offices also compare estimates with the 2nd lowest bid. All the 5 offices who regularly compare estimates, use the low bid as the basis for cost comparison. Three offices compare estimates with the mean or the median of bids. Only one of the 3 offices compare estimates regularly with the winning tender.

This result show differences between the practice in the industry and the measurements made by researchers (see chapter 4). Whereas professionals in industry do not depend solely on making cost comparisons with the low bid, researchers for reasons earlier stated are often constrained to use the low bid as the basis for assessing accuracy.

Table 7.2 **Parameter Used for Comparison**

	Parameter	No	Identifier
a.	Low bid	6	C,G,D,S,E,P
b.	2nd lowest bid	1	D
c.	mean/median of bids	3	H,L,P
d.	Final Account	-	-
e.	Any other	-	-

Useful parameters for cost comparison

Because it was recognised that there could be differences between industry practice and the opinion of design offices regarding practices that may benefit estimating, the offices were asked to suggest parameters that are useful for comparing estimates with tender. The results are shown in Table 7.3. Six offices reported that comparing estimates with the low bid will benefit cost management effort. Three of the six offices do not compare costs on a regular basis. One of the offices interviewed reported that since it was not required standard practice, resources could not be expended on it.

Two of the offices who compare costs with the low bid regularly also thought comparisons with the second lowest bid will benefit the cost management. Only one office thought comparison of estimates with the final account can be beneficial.

One office reported that making comparison with the average of the three lowest bids will benefit future predictions. This office uses the average of the three lowest tenders on a project to make predictions of construction costs.

The results show that what professionals do in industry is often constrained by available facilities. Comparisons of estimates with tenders, which are deemed beneficial, are not done because the offices may not have the time or the facility to make them; or worse still, because they are not accepted practices in the offices.

Table 7.3 Good Target for Design Cost Comparison

Target		No	Identifier
a.	Low Bid	6	C,G,D,S,H,L
b.	2nd lowest bid	2	C,D
c.	Mean/median of bids	3	D,L,P
d.	Final account	1	S
e.	Average of 3 lowest bids	1	E

Opinion on Estimate targeting

The design offices were asked if in their opinion, and from experience in the industry, setting targets e.g. low bid, median of bids etc. will help in improving the accuracy of design cost estimates. Four offices thought it definitely would. Two offices thought it would not; the remaining two offices could not tell whether or not there are benefits to be derived from estimate targetting.

Table 7.4 **Opinion on Target Setting**

Opinion		No	Identifier
a.	Useful	4	G,H,L,P
b.	Can't say	2	D,S
c.	Not useful	2	C,E

Desirable Level of Accuracy

Each office was also asked to give the desirable level of accuracy in the most detailed design cost estimate. Four offices responded that ±10% was good enough. Two offices settled for ±15%. One office thought a figure between -10% and +15% of the tender is appropriate. the remaining office thought estimates should be higher than the tender but not exceeding +15% of the tender.

The responses demonstrated that offices are in favour of estimates being acceptable within ±15% of the tender. However, responses from the last two offices show that overestimates are more likely to be deemed more acceptable than underestimates. This is probably due to the fact that, being County Council offices, it is easier to execute projects when tenders received are below cost predictions than when there are significant underestimations. This fact corroborates the assertions that some offices may be predicting cost ceilings for projects.

Three of the 4 offices suggesting a figure of ±10% regularly compare costs with the low bid.

Table 7.5 Acceptable level of Accuracy

Target		No	Identifier
a.	±5%	-	-
b.	±10%	4	G,D,S,E
c.	±15%	2	C,H
d.	-10% to +15%	1	L
e.	+15%	1	P
f.	±20%	-	-

Datum for Assessing Estimating Accuracy

In view of the fact that design estimators may not always be predicting the low bid for projects, the offices were asked to suggest an appropriate datum for assessing estimating accuracy. Three offices suggested the low bid. Two of these offices regularly compare estimates with the low bid. Two offices suggested the third lowest bid, 2 offices suggested the mean or median of bids. The remaining office suggested the the mean of bids 'after excluding the low bid and any obvious outlier'. This office regularly compares estimates with the low bid but also compares estimates with the second lowest bid occasionally.

The results demonstrate a lack of agreement between practitioners regarding the appropriate datum for assessing accuarcy in design cost estimates. A good approach to assessing accuracy therefore will be to allow comparisons of costs with as many parameters as are possible.

Table 7.6 Appropriate datum for measuring estimating accuracy

Target		No	Identifier
a.	Low bid	3	C,G,S
b.	2nd lowest bid	-	
c.	3rd lowest bid	2	E,L
d.	Mean/median of bids	2	H,P
e.	Mean of tenders excluding outliers	1	D

7.3.12 The Empirical Data

Data for statistical tests were acquired from 7 design offices. The data from the offices related to the design estimate and bid prices for (51) recent construction projects. Six of the seven offices submitted element prices (usually contained in the general summary section of the bill of quantities) while the seventh office only submitted overall estimate and bid prices.

7.3.2.1 The Analysis

The data was tested using three procedures:

1. Normality tests conducted on the MINITAB and OPEN ACCESS softwares.
2. R-values (Ratio of bid to design estimate) were determined using the ACCEST programme (IBM PC based programme purpose written for this research).
3. The results from the R-value calculations were transferred to Cricket Graph on the Apple Macintosh for plotting.

7.3.2.2 Normality Tests

Tender prices submitted for each project were tested to know whether the data conforms to any known distribution. Tests using the MINITAB and OPEN ACCESS packages show that except for 3 projects showing slight positive skewness, all the data can be assumed to be normally distributed.

7.3.2.3 R-Values

The R-value is a measure of the ratio of a bid to the estimate. The formula employed in the calculation being:

$$R = \frac{\text{Bid}}{\text{Estimate}} \qquad \text{--------------------------} (7.1)$$

The asumption inherent in the use of R-values for analysing tenders is that the design estimate is the true cost for the project. Tender values are assumed to represent contractor's predictions of the true value. Hence, it is assumed that the estimate is a true price which could be used to measure movements in tender prices across projects. It is the reciprocal of having the design estimator set a target for monitoring the accuracy of his estimate.

7.3.3 The Overall Results

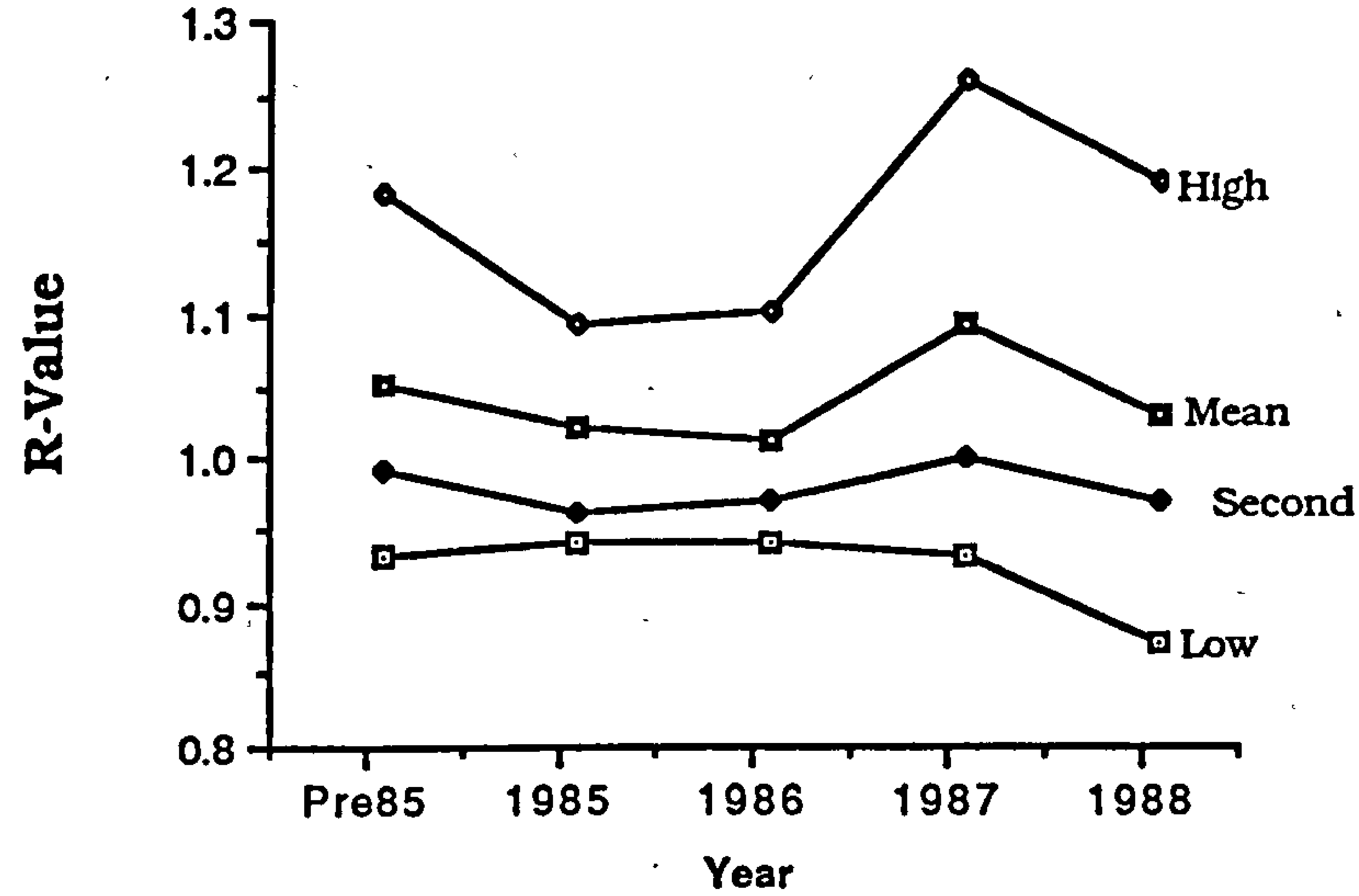
The results presented in Table 7.7 show the R values for both the low bid and the mean of bids for the years 1983 to 1988. The data is also plotted in Figures 7.4 - 7.6.

Table 7.7: **R-values for Different Years**

Year	R-Values for bids				
	Low	Second	Mean	High	STD
Pre 1985	0.92	0.98	1.04	1.17	0.11
1985	0.93	0.95	1.01	1.08	0.14
1986	0.93	0.96	1.00	1.09	0.16
1987	0.92	0.99	1.08	1.25	0.17
1988	0.86	0.96	1.02	1.18	0.16

Low refers to the low bid, while
Second refers to the second lowest bid;
Mean refers to the mean of bids; and
High refers to the highest bid.

FIGURE 7.4: Movement of Parameters



The analyses revealed that up to 1987 the low bid is more stable than any other parameter. If the figures for 1988 are included, the choice between the mean and the low bid becomes difficult. The second lowest bid show similar pattern to the mean of bids over the period 1983 -1988. The R-values for the low bid varied between a low value of 0.86 in 1988 and a high value of 0.93 in 1985 and 1986; the maximum yearly variation being 0.07. The mean values, on the other hand, varied between a low value of 1.00 in 1986 and a high value of 1.08 in 1987 representing a range of 0.08.

Figure 7.4 shows also that the pattern of variation is more steady for the low bid than the mean. The maximum variation between two consecutive years is 0.06 for the low bid and 0.08 for the mean; thus indicating poorer results for the mean compared to the low bid.

The results should be viewed in the light of the parameters predicted by the design offices. It has earlier been shown that more offices predict the low bid than the mean. this may be responsible for the slight improvement in the figures achieved for the low bid. The values for the high bid is predictably much worse than the low bid or the mean bid.

7.3.3.1 Tender Prediction Using the Mean

One of the benefits in calculating R-values is the ability to predict the distribution of reasonable tenders in a bidding exercise. The result shown in Table 7.8 indicate that a fairly good prediction of the low bid may be achieved by subtracting the standard deviation from the mean while adding the standard deviation to the mean gives a less accurate value of the high bid. The plots are shown in Figures 7.4 and 7.5.

Table 7.8: Relationship of Parameters for Different Years

Year	R-Values for bids			
	Low	Mean-SD	Mean+SD	High
Pre 1985	0.92	0.86	1.15	1.17
1985	0.93	0.86	1.15	1.08
1986	0.93	0.84	1.16	1.09
1987	0.92	0.91	1.25	1.25
1988	0.86	0.86	1.18	1.18

FIGURE 7.5: Relating the low bid to the mean

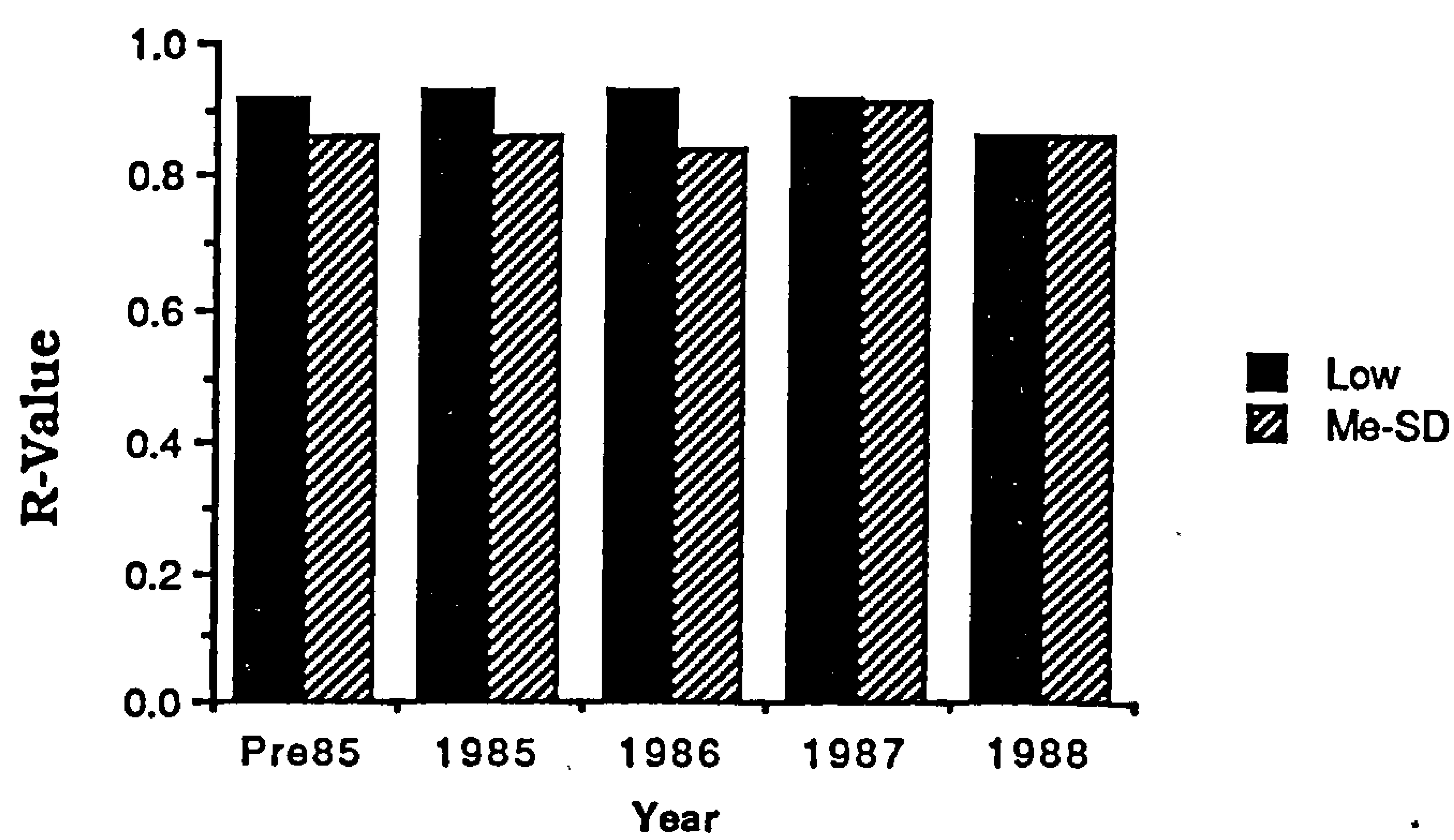
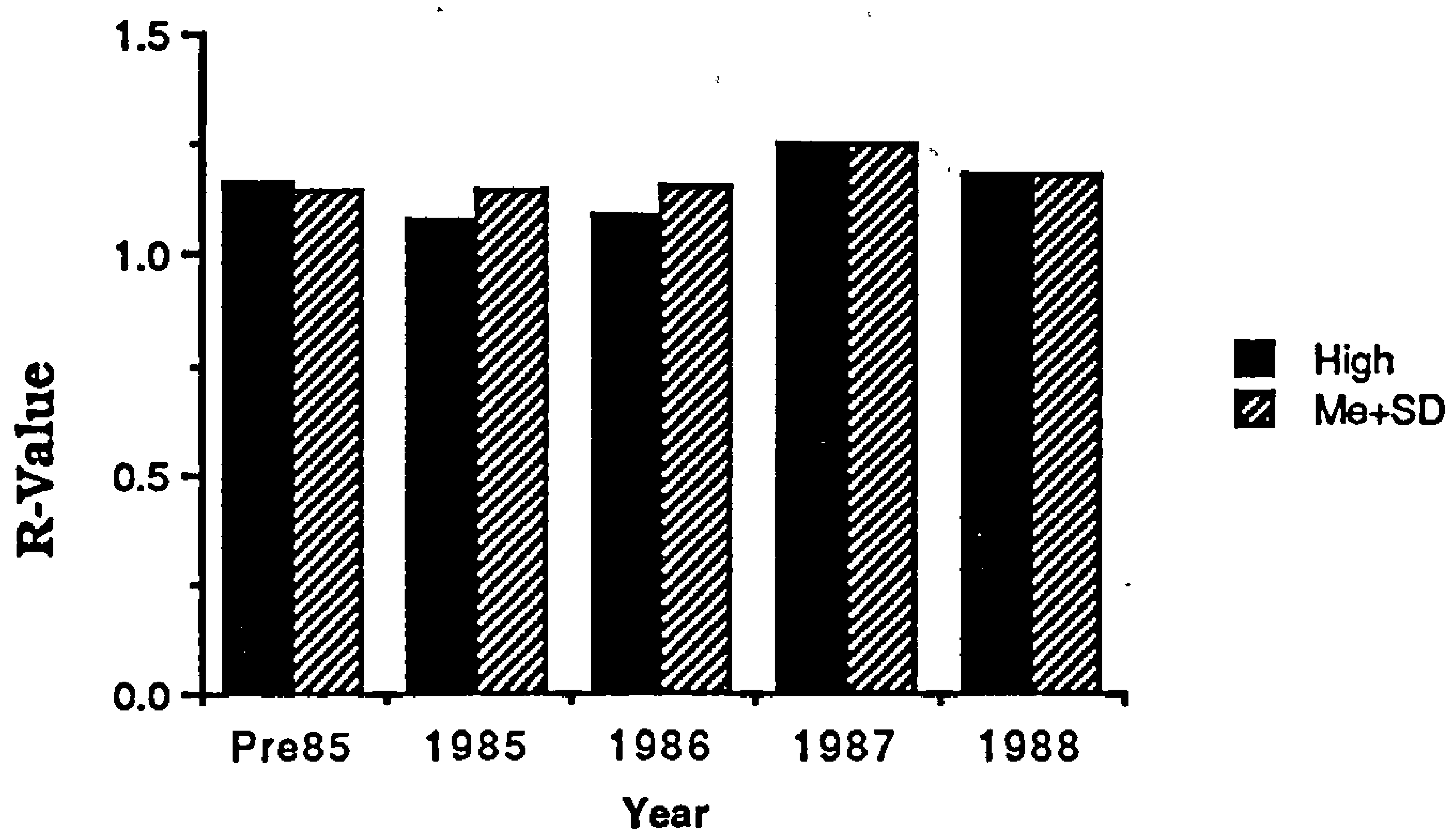


FIGURE 7.6: Relating the high bid to the mean



7.3.4 Analyses According to Offices

The data were analysed according to the office of origin in order to test if there are associations between parameters with which offices compare estimating results and the accuracy achieved in estimating. An additional test was done by measuring the deviation of esitmates from desired parameters. The quantity measured is calculated from the equation:

$$D = \frac{\text{Estimate - Parameter}}{\text{Parameter}} \times 100 \quad \text{-----------------} \quad (7.2)$$

Equation 7.2 is was used with the low bid, mean of bids and the highest bid as the desired parameter.

Results from Office L

The design estimators from Office L reported that their estimates are compared with the mean of bids only when tenders received differ significantly from predictions. They have also set a limit of ±15% of the mean of tenders as being acceptable. It would seem appropriate therefore to expect that their performance relative to the mean of bids should be better than the lowest or any other bid.

The result in Table 7.9 show the performance of the office. Accuracy in predicting the mean of bids is +4.25% (15.38 SD). mean absolute accuracy is 13.59% (7.63 SD). The analysis using R-values however show marginal improvement in consistency (measured by the coefficient of variation) if the low bid has been predicted. It would seem therefore that, for Office L, the task of predicting the mean of bids is relatively well accomplished if we accept the limit of ±15% error as being adequate.

Table 7.9: **Results for Office L**

	No.	Range			Mean	STD	CV
AcLow	15	0.49	-	56.55	29.16	19.20	65.84
AcSec	15	-4.78	-	55.45	17.93	19.35	107.91
Acmean	15	-21.23	-	23.90	4.25	15.38	361.63
AcMax	15	-42.23	-	8.73	-14.40	16.64	115.56
R.Low	15	0.64	-	1.00	0.79	0.12	14.93
R.Sec	15	0.64	-	1.05	.87	0.13	15.46
R.Mean	15	0.81	-	1.27	0.98	0.15	15.38
R.Max	15	0.92	-	1.73	1.21	0.25	20.65
Absolute AcLow	15	0.49	-	56.55	29.17	19.20	65.84
Absolute AcSec	15	0.85	-	55.45	19.11	18.10	94.71
Absolute AcMean	15	2.88	-	23.90	13.59	7.63	56.11
Absolute AcMax	15	0.61	-	42.23	17.10	13.63	79.75

Aclow is D value for the low bid, R.Low is the R value for the low bid. Similar values are also calculated for the second lowest, mean, and the highest bids.

Office LT

The opinion survey result for Office LT was not available. However, the office reported that they aim to be 'somewhere between the second lowest bid and the third lowest if possible but always in the middle of the distribution of bids'. Results from the office (Table 7.10) show that accuracy in predicting the second lowest bid is -3.76% (6.81 SD) while the absolute accuracy value is 8.54 (8.87 SD). The results for the mean (which should be above the second lowest tender since all contracts from the office had more than 3 bidders) is however worse. The mean accuarcy is -10.50% (17.04 SD) while the mean absolute accuracy is 11.58% (4.85 SD). More estimates from the office are below the second lowest bid than are above it.

Table 7.10: Results From Office LT

	No.	Range	Mean	STD	CV
AcLow	12	-8.48 - 14.96	2.08	7.32	352.52
AcSec	12	-15.46 - 11.05	-3.76	6.81	180.33
Acmean	12	-17.87 - 6.47	-10.50	17.04	67.03
AcMax	12	-33.15 - -5.94	-23.12	8.56	37.02
R.Low	12	0.87 - 1.09	0.98	0.07	7.05
R.Sec	12	0.90 - 1.18	1.04	0.07	6.92
R.Mean	12	0.94 - 1.22	1.12	0.08	7.37
R.Max	12	1.06 - 1.50	1.31	0.14	10.57
Absolute AcLow	12	1.16 - 33.30	8.54	8.87	103.84
Absolute AcSec	12	1.95 - 15.46	6.40	4.16	65.00
Absolute AcMean	12	4.15 - 17.87	11.58	4.85	41.92
Absolute AcMax	12	5.94 - 33.15	23.12	8.56	37.02

Office C

The office reported that estimates are compared regularly with the low bid. The results from the office shown in Table 7.11, show mean error in predicting the low bid is +6.48% (3.54 SD) with the mean absolute accuracy being 5.09% (1.75 SD). The result is within the acceptable limit of ±15% used by the office and it is remarkably better than for other parameters such as the mean, or second lowest bid. The R-values also show that the consistency in predicting the low bid is very good (5.91 CV).

Table 7.11: Results From Office C

	No.	Range	Mean	STD	CV
AcLow	5	1.33 - 11.04	6.48	3.54	54.67
AcSec	5	-17.13 - 0.77	-4.83	7.28	150.76
Acmean	5	-19.59 - -2.12	-9.13	6.75	73.91
AcMax	5	-25.49 - -6.23	-14.90	7.82	52.46
R.Low	5	0.93 - 1.07	0.99	0.06	5.91
R.Sec	5	0.99 - 1.21	1.06	0.09	8.31
R.Mean	5	1.02 - 1.24	1.11	0.09	7.81
R.Max	5	1.07 - 1.34	1.18	0.11	9.41
Absolute AcLow	5	3.09 - 7.14	5.09	1.75	34.43
Absolute AcSec	5	0.42 - 17.13	5.30	6.85	129.17
Absolute AcMean	5	2.12 - 19.59	9.13	6.75	73.92
Absolute AcMax	5	6.23 - 25.49	14.90	7.82	52.47

Office S

Office S compares result with the low bid only when tenders received differ significantly from predictions. The limit acceptable to the office is ±10% of the low bid.

The results for the office, shown in Table 7.12 show mean accuracy in predicting the low bid as +6.96% (15.79 SD) and a mean absolute accuarcy of 14.25% (7.47 SD). The results are worse than comparison with the second lowest bid which gives values of -5.79% (15.85 SD) mean accuracy and 12.88% (9.25 SD) for the mean absolute accuracy. The consistency in predicting the low bid (16.75 cv) is also slightly worse than that for the second lowest bid (16.07 cv). However, if the aim is to produce more overestimates than underestimates, the results for the low bid would seem more acceptable. The mean absolute accuracy is much higher than the limit of 10% set by the office.

Table 7.12: Results From Office S

	No.	Range	Mean	STD	CV
AcLow	5	-18.23 - 24.91	6.96	15.79	226.78
AcSec	5	-21.33 - 17.73	-5.79	15.85	273.72
Acmean	5	-29.38 - 15.11	-10.47	19.86	189.64
AcMax	5	-47.32 - 8.63	-20.06	24.76	123.44
R.Low	5	0.80 - 1.22	0.95	0.16	16.75
R.Sec	5	0.85 - 1.27	1.08	0.17	16.07
R.Mean	5	0.87 - 1.47	1.16	0.26	22.61
R.Max	5	0.92 - 1.90	1.36	0.45	33.25
Absolute AcLow	5	6.45 - 24.91	14.25	7.47	52.41
Absolute AcSec	5	1.40 - 21.33	12.88	9.25	71.83
Absolute AcMean	5	1.53 - 31.77	16.52	13.80	83.56
Absolute AcMax	5	4.90 - 47.32	23.51	20.62	87.69

<u>Office H</u>

Office H compares design estimates with the mean of tenders when tenders received deviate significantly from predictions. A figure of ±15% accuracy in design estimate is acceptable to the office.

Results from the office, shown in Table 7.13, show mean error in predicting the mean of bids as +9.69% (6.89 SD) and also a mean absolute error of 9.69% (6.89 SD). The result is much better than for the second lowest bid or the mean. The consistency in predicting the mean (6.48 cv) is however worse than those for the low bid (4.35 cv) and the second lowest bid (4.43 cv). The result for the office is within the acceptable limit set.

Table 7.13: **Results From Office H**

	No.	Range	Mean	STD	CV
AcLow	3	9.89 - 16.35	15.25	4.94	32.34
AcSec	3	6.97 - 16.73	12.19	4.92	40.33
Acmean	3	1.88 - 14.93	9.69	6.89	71.15
AcMax	3	-7.68 - 9.47	3.35	9.57	285.81
R.Low	3	0.84 - 0.91	0.87	0.04	4.35
R.Sec	3	0.86 - 0.93	0.89	0.04	4.43
R.Mean	3	0.87 - 0.98	0.91	0.06	6.48
R.Max	3	0.91 - 1.08	0.97	0.10	9.78
Absolute AcLow	3	9.89 - 19.60	15.28	4.94	32.35
Absolute AcSec	3	6.97 - 16.73	12.19	4.92	40.32
Absolute AcMean	3	1.88 - 14.93	9.69	6.89	71.15
Absolute AcMax	3	7.68 - 9.47	8.47	0.91	10.80

Office D

Office D regularly compares results with the low bid. A limit of ±10% is also set by the office as being acceptable.

The results from the office, Table 7.14, show that results for the low bid +16.00% (20.31 SD) mean error and 18.42% (14.26 SD) mean absolute error is much worse than the result for the second lowest bid - +15.48% (18.31 SD) mean error and 15.22% (9.12 SD). The result for the mean is also better, having a mean error of +2.9% (17.49 SD) and a mean absolute error of +12.31% (11.26 SD). The consistency in predicting the second lowest bid (17.45 cv) or the mean of bids (17.06 cv) is also better than for the low bid (18.75). The results deviate significantly from the limit of ±10% acceptable to the office.

Table 7.14: Results From Office D

	No.	Range	Mean	STD	CV
AcLow	5	-13.28 - 34.55	16.00	20.31	126.98
AcSec	5	-15.47 - 27.00	5.48	18.31	334.20
Acmean	5	-19.38 - 27.76	2.90	17.49	602.96
AcMax	5	-28.86 - 22.31	-6.11	17.49	299.08
R.Low	5	0.74 - 1.15	0.91	0.17	18.75
R.Sec	5	0.79 - 1.18	0.97	0.17	17.45
R.Mean	5	0.78 - 1.24	0.99	0.17	17.06
R.Max	5	0.82 - 1.41	1.10	0.21	19.00
Absolute AcLow	5	1.10 - 34.55	18.42	14.26	77.41
Absolute AcSec	5	4.08 - 27.00	15.22	9.12	59.93
Absolute AcMean	5	0.18 - 27.76	12.31	11.26	91.46
Absolute AcMax	5	8.13 - 28.86	15.04	9.92	66.00

Office DR

Data from the seventh office (Table 7.15) show good accuracy using the mean error values. However, the figure for the second lowest bid is much better showing a mean error of +0.79% (17.42 SD) and a mean absolute error of 13.63% (9.02 SD) The consistency in predicting the second lowest bid is 20.48 (cv).

Table 7.15: Results From Office DR

	No.	Range			Mean	STD	CV
AcLow	6	-22.17	-	27.58	6.72	18.14	270.04
AcSec	6	-28.98	-	19.07	0.79	17.42	2201.31
Acmean	6	-33.06	-	17.26	-1.76	17.54	997.67
AcMax	6	-37.67	-	12.62	-7.71	16.75	217.12
R.Low	6	0.83	-	1.28	0.96	0.18	19.04
R.Sec	6	0.84	-	1.41	1.02	0.21	20.48
R.Mean	6	0.85	-	1.49	1.05	0.23	21.94
R.Max	6	0.89	-	1.60	1.12	0.25	22.30
Absolute AcLow	6	4.53	-	27.58	15.62	9.51	60.89
Absolute AcSec	6	3.49	-	28.98	13.63	9.02	66.20
Absolute AcMean	6	0.09	-	33.06	12.07	11.70	96.94
Absolute AcMax	6	0.66	-	37.67	11.92	13.47	112.97

7.3.5 Predictions of Maximum Value

The figures in Tables 7.9 - 7.15 show accuracies that would have been achieved if the maximum bids have been predicted by the offices. From all the offices, values for the maximum bid is predictably worse than values for the low bid or the mean of bids. This is attributable to the effects of slight positive skewness in bid distribution and the fact that the offices were not trying to predict the maximum bid.

7.3.6 Further Discussion

Offices comparing design estimates with parameters in the middle of the sample fared slightly better than those making comparisons with the low bid. However there is no evidence suggesting that those who compare costs regularly are better than those who only compare costs ocassionally. A possible explanation for this may be that, since regular costs comparisons are made to detect errors in winning tender, rather than to assist in improving the quality of predictions, the offices are unlikely to benefit from such compariosns. In other words, because causal associations between estimating accuracy and outcome feedbacks were not sought, the offices did not benefit from the comparisons.

A further analysis of accuracy using the targets employed by each design office show that, for the 51 projects, overall the mean accuracy is +3.60% (12.48 SD) and the mean absolute accuracy is 11.20% (7.31 SD). This shows that estimates are usually 3.60% higher than the target being predicted. This result is much better than the comparisons made in chapter 6 suggesting that design estimates are on average 12.77% higher than the low bid and that mean accuracy is 16.44%. Since the coefficient of variation amongst bids is 11%, the design offices could not have fared badly. This result justifies the assertion earlier made that, comparison of estimates with the low bid without deference to the parameter predicted by the estimator is inappropriate and produces misleading results.

7.3.5 Tender Price Prediction

One advantage in targeting design estimates is that the cost consultant can use the result of his performance to assist the prediction of tender in future. If it is assumed that the distribution of tenders is normal, a combination of the accuracy figures achieved relative to one parameter on past projects and the monitoring of R-values can be used to forecast other parameters. For example, the low bid is known to be within one standard deviation from the mean of bids. If the error in modelling the mean of bids averages ±10% over a series of projects, the values of the low bid and the high bid can be predicted using the equations:

Predicted mean of bids (M) = R x Estimate -------------------- (7.3)
Predicted low bid (L) = (R - SD) x Estimate ------------------ (7.4)
Predicted high bid (H) = (R + SD) x Estimate ----------------- (7.5)

A correction for error can be made by subtracting 10% from the estimate to get the lower bound and adding 10% to the estimate to get the upper bound. Thus, 0.90R and 1.10R will be substituted for R in equations 7.4 and 7.5 respectively. Continuous monitoring of performance over a long period should result in substantial increases in accuracy.

An alternative tender price prediction equation allows the design estimator to predict individual tender prices using normal scores. The assumption in using the equation is that the distribution of tenders is normal.

$$X_{(i)} = \mu(1 - \frac{cv}{100}S_i) \quad \text{------------------------------------} \quad (7.6)$$

where: $X_{(i)}$ is the estimated ith lowest tender
S_i is the ith normal score
μ is the estimated mean
cv is the coefficient of variation

Ideally, for prediction purposes, the cv should be taken as the measured cv for the number of tenders expected. This cv is calculated from historical cost data. Since the number of tenders have not been shown to statistically relate to estimating accuracy in this study, (see chapter 6 and section 7.4) the value of 11% cv has been used in testing the equation. Normal scores are available in standard statistical tables and on some computer based statistical packages such as the MINITAB.

Example: There are 7 tenders. The estimated mean is £125,000. Assuming a cv in the tenders of 11%, estimate the lowest tender.

$n = 7$
$S_i = 1.3522$
$cv = 15$
$\mu = 125,000$
$\therefore X_{(i)} = £125000(1 - (15/100) \times 1.3522)$
$= \underline{£99600}$

Tests, on 40 projects, using the data aquired for this research, have shown that the equation can consistently predict tender prices to within ±10% accuarcy desired by most design offices.

These simple methods overcome many of the disadvantages of complex methods discussed in Chapter 4.

7.4 FACTORS AFFECTING ESTIMATING ACCURACY

The results of the analyses of factors affecting estimating accuracy was presented in Chapter 6. The analyses were based on the predictions of the low bid. Geographical location and office of origin were shown to be statistically related to accuracy. Project size was also shown to have effect on achieved accuracy though it failed the F-test. A re-analysis using the parameter predicted by each design office does not show similar relationships. The results, shown in Table 7.16, show that none of the five factors tested have significant effects on estimating performance. A major conclusion from this re-analysis is that estimating performance does not differ (statistically) across offices if the correct parameter is used for measuring error. This seems to contradict the conclusion in Chapter 6 where the low bid was used to assess error. It is however an indication that the true relationship between estimating factors and accuracy cannot be established using the low bid as datum for measuring error in design estimates. The offices surveyed identified prominent factors affecting estimating accuracy as: historical cost data, estimator's expertise, and project information. The effects of these factors could not be tested because the nature of data acquired from offices preclude such tests. A necessary area of future research is to seek ways for recording data in a format that will allow the three factors to be tested. ACCEST, the estimating accuracy testing package developed for this research allows data recording in this format. It is hoped that future analysis of data from the package will allow definite relationships between estimating factors and accuracy to be established.

Table 7.16: Analysis of Factors Affecting Estimating Accuracy

Factor	n	Degrees of freedom numerator	Degrees of freedom denominator	Calcul. F-value	Significant F-value
Project value	51	3	47	1.13	2.80
Geog. location	51	2	48	2.47	3.19
No. of bidders	51	5	45	1.02	2.42
Year of tender	51	4	46	0.75	2.57
Office of origin	51	6	44	0.98	2.31

7.4 SUMMARY

The results from the various offices have served to reinforce the arguments presented earlier. Specifically it shows that:

1. the parameter being predicted differs across offices. Whereas researchers routinely compare estimates with the low bid, design offices do not always predict the low bid.

2. opinions regarding 'what is accurate enough' also varies across offices. However, most offices accept that figures outside ±15% of the predicted parameter are unacceptable.

3. the ability in achieving the limits set by offices differ also. Some offices find it quite easy to predict costs to within the acceptable limit while others do not.

4. since the distribution of bids can be assumed to be normal, prediction of bids can be effected by targetting of estimates and continuous calibration around the target.

5. comparing results from cost prediction exercises with the low bid without deference to the parameter predicted by the design cost estimator is inappropriate.

6. two equations for predicting tender prices are possible using data from historical projects.

7. none of the five factors: geographical location, office of origin, project value, year of contract and number of bidders have significant effects on estimating accuracy. This result confirms that establishing relationships between estimating factors and accuaracy is inappropriate.

CHAPTER 8

MODEL FOR ASSESSING ESTIMATING ACCURACY

It is a truth very certain that, when it is not in our power to determine what is true, we ought to follow what is most probable.
-Descartes-

8.0 INTRODUCTION

The preceeding chapters of this thesis have established the need to develop a system for monitoring accuracy in design estimates. The major requirements of such a system have also been established. The work presented in this chapter describes a computer program (ACCEST) written to monitor accuracy in design cost predictions. Reliance is made on the major conclusions from the previous chapters for developing the model.

8.1 NEED FOR A PURPOSE WRITTEN PROGRAM

The necessity to write a program for monitoring accuracy in design estimates derive from the fact that no such software is known to the author to be in existence in the industry. The obvious reason for this being that monitoring of accuracy in cost estimating is (as described in chapter 3 and confirmed in Chapter 7) not a regular requirement in the cost management process. The result has been that cost estimating software such as RIPAC, do not provide the facilities necessary for consistent monitoring of cost accuracy. Theobald and Gardiner, a firm of chartered quantity surveyors, have just advertised an estimating package which is claimed to be capable of improving estimating performance (Construction Weekly, 1989). Unfortunately, the package too does not provide for cost comparison on the elemental level with tender results.

The analyses described could be done on a proprietary spreadsheet but each office will need to purchase a spreadsheet for that purpose and, an experienced spreadsheet user will require an additional 80 to 100 manhours to analyse each project. This time requirement is greatly reduced with a purpose written program.

8.2 OBJECTIVES

The object in writing a program for monitoring accuracy is to allow design cost estimators to monitor the accuracy of the last cost forecast prior to tender. This being the last forecast made by design estimators, is most likely to be the nearest design estimate comparable to the contractor's bid. It is needed to provide as much relevant feedback information about the process of design cost estimating and the outcome of predictions as possible.

8.3 REQUIREMENTS

The major requirements of the program are:

- Element by element comparison of costs for individual tenderers.
- monitoring of predicted/actual ratios from project to project.
- relevant information about the process and data used for estimating including the estimator's opinion about market conditions and other related variables that are likely to affect the accuracy of cost predictions.
- serve as a database for making cost predictions.

8.4 ABOUT ACCEST

8.4.1 The Program

The ACCEST program is written in the Fortran 77 language, compiled and linked on Microsoft Corporation Fortran 77 Compiler Version 4.1 and Linker version 5.10. The program runs on IBM PC AT/XT and IBM PS/2 and on all fully compatible machines.

ACCEST can be installed on machines with a Hard Disk Drive or Double Disk Drives, monochrome or colour monitor. The memory requirement is 180k bytes. The program runs on the MS-DOS operating system version 2.0 and above. Other requirements for installation and using the ACCEST program are stated in Appendix G.

8.4.2 Data Requirement

The ACCEST program accepts data both from the keyboard and through files.

8.4.2.1 Keyboard Data Entry

Interactive data entry through the keyboard is required for entering project information into the program. The data required relate to the project and concerns the estimator's perception of the construction environment. Details of such data are discussed in section 8.6.

8.4.2.2 Data Entry Through Files

File data entry has been chosen for entering cost data and project element data because of the need to minimise the amount of time spent in interactive data entry and to enhance user friendliness. Data required through files include:

1. Project Element Description - A short desciption of the individual cost headings for which design estimate of project cost will be compared with contractor's bids. The usual descriptions in the summary section of bill of quantities have been chosen for this purpose. Such descriptions include:

- Preliminaries
- Earthworks
- drainage and service ducts
- concrete works
- Flexible surfacing
- Kerbs and footways, etc.

The limitation to the rough elemental level was necessary for two reasons:

A. The analysis should show causal relationships between error and project cost.

B. The level should not be as detailed as to require too much data entry by the user. It was decided that once a user has identified an element/elements where major inaccuracies exist, he/she may proceed to study the element in detail rather than be provided with a mass of information of limited use.

2. Project Element Cost - Design estimates for each element and individual contractor's tender for the elements are entered into a file called the Project Cost Data file. The cost information is at a coarse level specified in the summary section of the bill of quantities.

3. Project Final Account - A file containing the final cost for each element after the project has been completed is also required. This is an optional file which could be entered anytime after the project has been completed.

The files can be written by the program user using any proprietary software available for word processing on IBM and compatible PCs. The only requirement is that the text versions of the file be stored by the software. This approach allows flexibility in entering project costs and descriptions as uncompleted files can be stored and edited before they are entered into ACCEST.

8.4.2.3 Data Processing

Data entered through the keyboard and through files are converted to and re-structured for use by ACCEST program into special files available for later uses of the program - especially for browsing and report printing. These files are also accessible to standard word processing packages such as WORDSTAR and WORD. They can therefore be modified without having to go through the data entry routine in the ACCEST program.

8.5 PROJECT ORGANISATION IN ACCEST

Due to the results of the preceeding studies(chapters 3-7) projects input to ACCEST are organised according to type and size.

8.5.1 Project Type

Projects in ACCEST are organised according to type under the following headings:

1. Housing

2. Schools
3. Offices
4. Commercial Facilities
5. Roads
6. Factories
7. Health Buildings
8. Sports Facilities
9. Others

The need for such organisation arises from studies by Morrison and Stevens (1981) which showed that accuracy in forecasting project costs relate to the type of project. Their study suggested that accuracy is better on schools projects than for other type of construction. Organising ACCEST data according to type of project facilitates analysis which may be useful to design estimators in determining real associations between project size and estimating accuracy.

In ACCEST, the user is not constrained to storing data under any particular type specification. For instance, in offices where only health buildings are executed, projects may be stored under roads or any other heading. Other descriptions of the project allow users to know what type of project is involved.

8.5.2 Project Size

The study in chapter 6 show a possible relationship between project size and estimating accuracy. Since this relationship has not been established statistically, it is considered necessary to allow users of ACCEST to store data according to project sizes. Estimating practitioners in industry as well as novices and average estimators involved in the experiment described in chapter 5 believe that such relationships exists. It is thus possible to use cost data at the descretion of the estimator as to its suitability in predicting costs in certain ranges.

Three sizes of projects have been specified for ACCEST viz.: small medium and large. Users of the program are at liberty to specify the contract sizes to include in each of the three categories.

As for project type specification, the user is not constrained to store project data under any size. Data organisation is completely at the discretion of the program user.

8.6 PROJECT INFORMATION

When a project is entered into ACCEST for the first time, the user is required to provide information on the project. The purpose is to allow users of the databank created to decide which projects are suitable for making predictions. It is also useful for judging under what conditions cost predictions were made. Thus, in measuring accuracy, information about the process of estimating is available for aiding better judgement on performance.

8.6.1 Number of Bidders

The analyses in chapter 7 did not provide sufficient evidence to suggest that the number of bidders involved in a bidding competition affects the accuracy of design cost predictions. However, other studies suggest that a relationship between both could be assumed (see Runneson, 1988 for instance). The provision for number of bidders not only allows the users of information generated from ACCEST to judge if such relationships exist, but is also necessary for reading the cost data file. ACCEST currently provides for 10 bidders in a bidding exercise. This limitation is imposed for two reasons:

1. To maintain economy in memory usage.

2. The maximum number of bidders encountered in the studies in Chapters 7 is 8. This is corroborated by the fact that in the UK a mode of selective tendering through prequalification of contractors is now preferred. This approach tends to limit the number of contractors in any bidding exercise to about six - the modal group encountered in chapter 7. It seems justified therefore, to limit the number of contractors to 10 (2 extra provisions being made above the number encountered in live situations).

8.6.2 Prediction and Expiry dates

The prediction date is required for updating purposes by the users of ACCEST and to decide to what extent time lag between prediction and tendering may have affected the accuracy of forecasts.

The expiry date specification is considered necessary because there is a limit to how far into the future costs estimates can be accepted as being valid.

8.6.3 Project Duration

An agreed or assumed project duration is required by ACCEST to enable fair comparisons to be made with the final account figures and to eliminate any discrepancies in forecasts that may be attributable to differences in opinion between the design estimator and tenderers.

ACCEST allows durations up to 99 months to be entered. This is considered much higher than the normal range of projects that are encountered in industry.

8.6.5 Estimator Code

The studies in Chapters 5 and 6 established estimator's expertise as a very important factor perceived by novices and practising estimators alike as affecting accuracy of cost predictions. By putting in a unique code for the estimator, the performance of individual estimators can be monitored by the design office. However, it is necessary to ensure that attention is not focussed on individual failures but on the possibilities for improving accuracy of forecasts. Therefore, ACCEST does not sort projects according to the estimator involved in the prediction.

8.6.5 Estimating Method

Because estimating inaccuracy is perceived by some as being method related (see Chapters 3 & 4), a provision is made for users to indicate the method of estimating used. This facility will enable users of the databank created by ACCEST to judge if there are real associations between estimating methods and accuracy of forecasts. This facility is useful if designers in the same office use different cost estimating methods and for testing the accuracy achievable using different estimating methods across offices.

8.6.6 Time Spent on Estimating

It was suggested in Chapter 4 that the time available for making cost predictions affect both the selection of method and the amount of information that can be used for estimating project cost. Consequently, a cost prediction required by the client or designers within a short period is likely to be more error-prone than a detailed estimate made with sufficient time being available to the estimator.

8.6.7 Client Description and Location

ACCEST uses the information provided for browsing and report printing purposes. It thus provide a unique for the project after the type and size has been specified.

8.6.8 Documents Used for Estimating

The studies of Jupp and McMillan (1981) and Skitmore (1987) provide positive reinforcement for the notion that estimating accuracy improves with the adequacy of project information. Consequently, it was considered necessary to make provision for a fair assessment of estimating performance by recognising the limitations imposed by inadequate design information. ACCEST allows entry of all major documents used for making the last cost prediction at the design phase.

8.6.9 Information Rating

To enable anyone judging the accuracy of cost predictions made by a particular estimator to understand his/her feelings regarding the adequacy of information used for estimating, provision is made for the estimator to rate the information available. This facility can also be used to assess which estimators are able to make fairly accurate cost predictions from very little information.

ACCEST allows three ratings for information: good, sufficient and poor. It is expected that accuarcy should improve with the adequacy of cost and project information.

8.6.10 Unusual Conditions

Accuracy in design cost estimating was postulated as being dependent on the magnitude of uncertainty surrounding the task and task environment in chapter 6. This implies that there are peculiar problems in a project which contribute to error by making it difficult to predict costs. For example, cost of earthworks in a water-logged site with unstable ground conditions will be more difficult to predict than for dry firm ground.

The fact that a condition is unusual in a project may preclude the use of a good cost database by the estimator - because the office is unlikely to have a database for unusual cost items. ACCEST allows the estimator to input such items to faciltate better understanding when performance is being assessed.

8.6.11 Price Level

The prevailing price level in the market is also expected to affect the accuracy of cost predictions. In periods of rapid inflation, cost prediction is a less precise art than when prices are fairly stable. The user of ACCEST is able to rate the level of resource prices in the market thereby providing a useful basis for assessing cost predictions.

8.6.12 Sources of Price Data

In Chapter 6, an explanation was advanced for the heavy weighting given to the ability of estimators by practitioners. The control over cost adjustments which experts are more able to exercise than novices was suggested as being responsible for the rating. In Chapter 5 also, average estimators and novices alike rated the source of price data as being very important for deciding predictive ability. In addition to these, an established cost data base was accepted by practising estimators as aiding better judgement. The source of price data is required in ACCEST to test if indeed there exist true relationships between source credibility and estimating performance. The opinion being that data on which the estimator has better understanding (in house data) should be better for predictions.

8.6.13 Bid Parameter Predicted

Chapter 7 of this thesis discussed the need for the design estimator to focus cost predictions on a bid parameter such as the low bid, mean of bids etc. as a means for enhancing calibration in cost predictions. Design estimators in industry, also stated that their cost predictions focus on either the low bid or the mean of bids. However, accuracy measurements in previous research (especially those reported in Chapter 4) has focussed on the low bid as being the parameter predicted by design estimators. This difference in datum contributes to error in assessing the accuracy of estimates. By entering the predicted parameter, the estimator receives a fairer assessment than would have otherwise, this being the case if the parameter has not been entered. Also, by judging his own performance, learning from experience is enhanced through continuous calibration.

8.6.14 Need for the Estimate

Although this assumption has not been tested in any research work, it is generally assumed that the effort input into cost estimating will depend on the need for the estimate. If an estimate is required for budgetary purposes more effort and time will be devoted to it than if it is required merely to brief potential clients.

8.6.15 Assumptions

In estimating costs for construction work, uncertainty surrounding the task and the environment lead estimators to make reasonable assumptions about some items of work on which information is incomplete. For instance, if prices are rising slowly (say about 2% annually) it is reasonable to assume that cost escalations during a project period of one year is unlikely to be too far from the figure of 2% predicted for inflation. This assumes that there will be no sudden occurences, such as outbreak of hostilities leading to trade embargoes, increase in interest rates, natural disasters, etc. which may result in abnormally high prices of construction resources through shortages. These assumptions are built into ACCEST and do provide a useful basis for judging inaccuracies especially after the final account figures have been received.

Information supplied to the program regarding condition of the project are written into a file called Project Description File or C**.DES in ACCEST format. This file can be viewed through the OLD option in the opening menu of ACCEST (described in Section 8.7).

8.7 PROJECT VIEWING AND REPORT PRINTING

Viewing outputs from ACCEST is achieved through the OLD option in the opening menu. The user then selects appropriate type and size, after which a listing of projects under a unique type and size code is provided.

By selecting a project from a list of 9 projects, the user gains access to the Project File Selection menu. The menu allows the selection of any of the following files:

1. General Information - a listing of the information stored in ACCEST as described in Section 8.6 is provided to the user. This information may be output on the screen or printed on paper.

2. Element Description File - a file containing the description of elements or cost headings under which project cost data can be analysed in ACCEST is provided. This is the information described under Project description file (Section 8.4.2.2).

3. Cost Data File - The cost data for each element/cost heading as stored by the computer i.e. design cost forecasts and contractors' prices for each element.

4. Final Account File - Outputs the file containing the final account figures if this has already been stored in the program.

5. Final Cost Input - Allows the user to input final account file if it has not been stored by the computer previously.

6. All Project Files - Allows the output of all the files described in 1-4 sequentially.

7. Exit Option - Allows Progress to the analyses sections of the program.

8.8 DATA ANALYSES IN ACCEST

ACCEST provides 4 types of data analysis:

1. Cost distribution to elements as percentages of total projects cost.
2. Monitoring of estimating accuracy.
3. Comparisons with final account figures.
4. Monitoring of price movements.

8.8.1 Cost Distribution to Elements

In 1988 the Royal Institution of Chartered Surveyors introduced distribution of costs to each element as percentages of the total project cost as part of the standard cost analysis provided through the BCIS on-line service. This was intended to give quantity surveyors a fair idea of cost distribution to elements to aid cost predictions. However, the provision on the BCIS on-line service is limited to the winning bid. ACCEST provides percentage distribution of costs, on the elemental level, not only for the winning bid but for all bidders as well as the design cost estimate.

Cost distribution to elements as a percentage of the total cost serves two purposes:

1. It can be used to assess if a bidder has deliberately loaded a particular element for his own gains. Thus, the relationship between individual bidder loadings and the opinion of the design estimator as to how costs should be distributed could be used to determine the suitability of a bid for tender award.

2. The percentage distribution can also be used to determine which elements deserve closer attention in estimating. Fine and Bennet (1978) and Beeston (1983) have suggested that 80% of the total cost of building contracts is accounted for by 20% of the elements. If the validity of this assertion is assumed, there is a *prima facie* evidence suggesting that attention should be focussed on the 20% most cost significant items rather than on the 80% less cost significant items. Such relationships may not be true for all projects or for different construction types. ACCEST thus allows the estimator to establish a relationship for the usual projects executed in each office.

8.8.2 Accuracy Monitoring

Monitoring accuracy in ACCEST is done both at the total project level and at the elemental level. At both levels, accuracy is assessed by : (1) calculation of D-values for tenders, (2) calculation of D-values for the design estimate, and (3) calculation of other statistical parameters.

8.8.2.1 <u>Calculation of D-values for bidders</u>

D-values measures the deviation of prices from a desired parameter such as the low price, mean price, etc. for elements. Provision is made in ACCEST for the following:

1. Contractor price relative to the low price

This facility relates, on the elemental level, the prices submitted by the individual bidders to the lowest price for the element. The quantity calculated is determined by the formula:

$$D_L = \frac{\text{Bidder Price - Low Price}}{\text{Low Price}} \times 100 \qquad \text{--------} \quad (8.1)$$

It is assumed that the low price is the value aimed for by all bidders and any deviation from the low price represents inaccuracy.

2. Contractor price relative to the mean price

This facility relates, on the elemental level, the prices submitted by the individual bidders to the mean of prices for the element. The quantity calculated is determined by the formula:

$$D_M = \frac{\text{Bidder Price - Mean element price}}{\text{Mean element price}} \times 100 \quad \text{---} \ (8.2)$$

It is assumed that the mean price is the value predicted by all bidders and any deviation from the mean price represents inaccuracy.

3. Contractor price relative to the median price

This facility relates, on the elemental level, the prices submitted by the individual bidders to the median of price for the element. The quantity calculated is determined by the formula:

$$D_{MD} = \frac{\text{Bidder price - Median of prices}}{\text{Median of prices}} \times 100 \quad \text{---} \quad (8.3)$$

It is assumed that the mean price is the value predicted by all bidders and any deviation from from the median price represents inaccuracy.

The D-values allow the user to monitor the movement of contractors' prices around a desired parameter.

8.8.2.2 D-values for the Estimate

1. A facility is provided for the design estimator to compare his prices to the low, mean, or median price submitted by contractors for each element. Ability to predict this value represent the accuracy of price predictions assuming the parameter used is the true cost being predicted. The quantity calculated is given by the formulae:

$$\text{ACLOW} = \frac{\text{Estimate - low price}}{\text{Low price}} \times 100 \quad \text{----------} \quad (8.4)$$

denoting the accuracy in forecasting the low price.

$$\text{ACMEAN} = \frac{\text{Estimate - Mean of prices}}{\text{Mean of prices}} \times 100 \quad \text{----} \quad (8.5)$$

denoting the accuracy in forecating the mean price.

$$\text{ACMEDN} = \frac{\text{Estimate - Median of prices}}{\text{Median of prices}} \times 100 \quad \text{---} \quad (8.6)$$

denoting the accuracy in measuring the median price.

2. It is recognised that some design estimators may not have predicted any of the parameters used in equations 8.4 - 8.6. Rather, some office declare that they try to be between the second or the third lowest bidder. Therefore, provision is made for

calculating the deviation of estimate from any desired bidders' price for any element. The quantity termed ACBID is therefore calculated using the formula:

$$\text{ACBID} = \frac{\text{Estimate - Bidder's price}}{\text{Bidder's price}} \times 100 \quad \text{--- (8.7)}$$

8.8.2.3 Other Satistical Parameters

Other parameters describing the price distribution for the individual elements and the overall project prices are also calculated. These parameters allow outcome feedbacks from each project to be used in predicting prices for other projects. They include: mean, coefficient of variations between bidders, standard deviation, skewness, etc..

8.8.3 Final Account Comparison

As a service to the client, design cost estimating should aim to predict the total cost of projects to clients. This need is often overshadowed by the prediction of tender prices. The final account option allows the user to assess the accuracy of the estimate and any bid assuming that the final account values are the true costs for the elements. The quantity calculated is given by the equation:

$$D_F = \frac{\text{X - Final value}}{\text{Final value}} \times 100 \quad \text{--------------------} \quad (8.8)$$

X may be the design estimate, low bid, mean bid, etc.

Values generated from the final account figure comparison are useful for advising clients on the possible sources of cost escalations on future projects.

8.8.4 Monitoring Price Movement

The accuracy monitoring procedure described in Section 8.2 assumes that the design estimate deviates from a notional "true cost" for each element and further assumes that the true cost may be any value (e.g. low price, mean, etc.) other than the design estimate. However, it is known that neither the design estimator nor the contractor know precisely what the true cost for a project is. A facility is therefore provided for the design estimator to monitor the movement of prices around his figures i.e. the assumption is made that the design estimate is the true cost for the project and all other figures represent deviations form the true cost.

The parameter used to measure the movement of prices around the estimate is called the (after Clough and Sears, 1979) R-value. It is measured by the formula:

$$R = \frac{X}{\text{Estimate}} \qquad \text{-------------------------} \qquad (8.9)$$

Where X may be low bid, final cost, mean, median or any particular bid.

By studying the movement of bids over time, informed target setting can be done by the design estimator. For example, the estimator may notice which of the parameters used is easier to predict than the others and thereby use the parameter as his target.

8.9 SUMMARY

This chapter contains the description of ACCEST - a purpose written program for monitoring the accuracy of design estimates. The program allows:

1 An assessment of price distribution amongst individual project elements.
2. An assessment of estimating accuracy irrespective of the target used for estimating.
3. Monitoring of price movements around different parameters.
4. Comparison of bid prices with the final account figures.
5. Information storage on different historical projects to enable design cost estimators select appropriate cost data for predictions.

ACCEST also provides a useful facility for aiding learning from experience in design cost estimating through the continual analysis of outcome feedbacks.

CHAPTER 9

RESULT OF TESTS USING ACCEST PROGRAM

Test all things; hold fast what is good.
(Holy Bible, I Thes. 5:21)

9.0 INTRODUCTION

In chapter 8, the features of the ACCEST - a purpose written computer program designed to test the accuracy of design estimates at the elemental level - were described. The major purpose for writing the program was to establish if by studying the results of contractors pricing in a bidding exercise an approach for improving accuracy in design estimates could be determined. The work in this chapter describes the results of tests on contracts for which data was acquired.

9.1 OBJECTIVES

The principal objective of this chapter is to test if the underlying hypothesis for this research can be justified through empirical data. That is, to see if by studying the prices submitted for each element/cost heading in construction projects by the design cost estimator and the contractors who tendered for a project, it is possible to to establish an approach for improving accuracy of design estimates.

Also, it is hoped that by analysing data at the elemental level the design cost consultant can advise the client better on the pricing policy of contractors.

A third objective concerns the possibility of using outcome feedbacks from bidding and estimating exercises to aid learning from experience by design cost estimators.

9.2 RESEARCH DATA

Data for the tests described in this chapter was obtained from the Department of Planning and Transportation of 7 County Councils in the United Kingdom. A sample of 50 offices randomly chosen from a list of 120 obtained from the Institute of Civil Engineers and the Royal Institution of Chartered Surveyors' Handbook for 1987 were contacted for data.

Overall, 36 projects were analysed at the elemental level. The breakdown of the projects from each office is as follows:

Office A	15 projects, -not part of the 36 analysed
Office B	12 projects,
Office C	6 projects,
Office D	5 projects
Office E	5 projects
Office F	3 projects
Office G	5 projects

Data for each project concerns the cost breakdown at the rough elemental level (general summary section of bill of quantities e.g. preliminaries, earthworks etc.) by the design estimator and the contractors. Other project information such as year of tender, design type (whether traditional or innovative), project title, etc. A typical form for data collection is shown in Appendix E. Data from Office A did not contain details of cost breakdown at the elemental level.

9.2.1 The Projects

All responses to the questionnaire sent out were from Departments of Planning and Transportation of County Councils. The projects supplied were therefore for road construction, reconstruction or facility improvement around village or township roads.

9.2.2 Data Treatment

Design estimates for some elements were not available on 3 contracts. Rogue values were entered into ACCEST for such elements and the results for the contract adjusted to allow for these inclusions.

4.2.3 Test Methodology

Due to the limitations imposed by the size and nature of cost data available, the progamme was tested in two stages:

1. Data for 28 projects (Offices B-E) were input into ACCEST and the results of the analysis interpreted for making inferences in line with the objective of the test.

2. Data for the remaining projects were then used to confirm/disconfirm the inferences made in the first test.

9.5 RESULTS

9.5.1 Percentage Cost Distribution

The percentage cost distributions of the various elements resolved into two areas: the pattern of the cost distribution amongst bidders and the design cost estimator; and the percentage for each element in projects.

9.5.1.1 Differences in Cost Distribution to Each Element

The purpose for determing building cost distribution amongst elements as a percentage of the total cost of the project is to reveal any lopsided cost distribution that is intended for financial gains by a contractor or that respresent a lack of understanding of how costs should be distributed by either a contractor or the design estimator. Results from ACCEST show three different situations:

1. A uniform distribution of costs to each element by all contractors and the design cost estimator. Table 9.1 shows an example of this. There is a close agreement between contractors in the pattern of cost distribution and the design estimators costs are distributed in a similar pattern. In such instances, the design cost consultant can assume that all is well if the level of prices is as predicted. The contractors show keen interest in the project and they all demonstrate a good understanding of the problem(s) involved. The cost consultant can advise his client accordingly.

TABLE 9.1: **Fairly uniform distribution of cost by all parties**

Elements	Estimate (%)	T1 (%)	T2 (%)	T3 (%)	T4 (%)	T5 (%)	T6 (%)
Preliminaries	18.46	17.45	19.30	18.62	21.28	17.09	17.79
Site clearance	.37	.41	.26	.16	.16	.30	.40
Hedges & Fencing	6.61	5.48	3.95	3.35	3.33	5.55	3.53
Drainage	7.50	8.60	7.18	6.25	7.26	8.55	8.46
Earthworks	10.37	12.22	11.62	15.98	11.18	10.47	11.80
Sub & Road base	21.74	19.74	20.64	22.20	20.52	22.70	19.29
Flexible Surfacing	8.68	9.59	9.64	9.92	10.35	10.32	9.75
Kerbs & Footways	3.75	3.42	5.10	3.56	3.74	4.35	3.42
Signs & Markings	.63	.45	.44	.44	.43	.42	.43
Street lighting	1.46	2.48	2.18	1.95	2.17	2.25	2.38
Parapet	15.55	14.59	14.60	12.80	14.78	12.89	17.52
Water proofing	4.60	5.11	4.80	4.47	4.52	4.64	4.79
Others	.29	.43	.30	.32	.28	.47	.45
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

2. Uniform distribution of costs by contractors but design estimate does not show a similar pattern. Table 9.2 shows such a result. The result demonstrates a case in which the the design estimator's pricing does not conform to the contractors' pattern of cost distribution. Two hypotheses may be advanced to explain this occurence:

TABLE 9.2: **Inappropriate Distribution of Cost by Design Estimator**

Elements	Est. (%)	T1 (%)	T2 (%)	T3 (%)	T4 (%)	T5 (%)	T6 (%)
Preliminaries	8.79	44.61	38.29	35.34	41.77	43.86	56.69
Roadworks	8.71	4.21	4.96	19.42	7.39	8.37	3.94
Substructure	22.06	12.49	12.66	6.89	10.86	9.60	8.18
Superstructure	36.83	23.14	28.93	23.21	25.97	25.68	21.66
Finishings	21.32	13.26	13.33	13.51	12.03	10.69	8.07
PC Items	1.33	1.09	1.07	.95	.93	.84	.70
Dayworks	.57	.90	.46	.41	.77	.72	.55
Variations	.38	.31	.31	.27	.27	.24	.20
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

(a) All the contractors could be assumed to be wrong by the design cost estimator. In this case, either there is a general lack of understanding of the problem occasioned by inadequacy of information supplied to contractors or, it is a case of collusion between contractors. Neither of these explanations prove satisfactory if the process of tendering has been carefully undertaken in a competitive market situation.

(b) The design estimator's pricing is wrong. This situation calls for learning on the part of the design estimator. He should establish why his pricing deviates from the contractors' pricing and decide on what strategies are necessary to correct the error on future projects and improve the quality of forecasts. The the above example, (Table 9.2), the design cost estimator has grossly misjudged the level of preliminaries in the contract even when there is a fairly close agreement betweeen contractor.

3. A contractor's pricing deviates from the pattern of cost ditribution amongst other contractors and the design estimator. This presents very little problem unless the deviating contractor is the lowest bidder.

Table 9.3 shows a case in which the lowest bidder's pricing deviates from the pattern of cost distribution amongst other contractors and the estimator. The contractor has deliberately submitted a low price for preliminaries (a high cost item on the contract). Three options are available to the cost consultant:

TABLE 9.3: Inappropriate Distribution of Cost by the Low Bidder

Elements	Est. (%)	T1 (%)	T2 (%)	T3 (%)	T4 (%)	T5 (%)
Preliminaries	12.15	.11	10.08	12.48	11.12	11.26
Site clearance	.46	.25	.21	.39	.18	.27
Drainage	7.52	8.97	8.47	6.50	8.28	7.84
Earthwoks	29.87	32.74	31.69	31.37	28.70	32.27
Sub & Road base	9.96	16.13	13.86	13.27	15.55	13.06
Surfacing	12.25	12.36	10.91	10.57	10.91	10.09
Kerbs & Footways	9.86	12.21	8.78	10.20	10.93	10.04
Signs and Markg	5.47	6.65	6.28	6.04	5.99	5.34
Public utilities	2.11	4.03	2.66	2.69	3.93	3.69
Provisional work	8.79	4.75	5.50	5.02	4.90	4.83
Dayworks	1.57	1.78	1.56	1.46	1.50	1.33
Total	100.00	100.00	100.00	100.00	100.00	100.00

i). The low bidder may be recommended for the award of the contract without correction being made to prices. If this approach is taken, the client would not have received good service from the cost consultant.

ii). Negotiation between the design team and the low bidder may be necessary to ensure fair pricing of the element(s). In that case the low bid may be accepted or rejected depending on the disposition of the client and his advisers to the bid.

iii). The low bid may be rejected outright on the basis that the contractor has not demonstrated a good understanding of the problem(s) involved in the project in question.

9.5.1.2 Percentage of Each Element in Projects.

It was hoped that results from ACCEST could be used to determine the average percentage content of each element in projects. The results shown in Table 9.4 show that the average distribution of costs for some common elements. It is noticed that the total does not add up to 100 because of the range of elements that were encountered on the projects. In many instances some elements are not present in a particular project e.g. a round about improvement scheme may not involve the felling of trees. The result therefore, is by no means definitive as the percentage content for each element varies widely from project to project.

TABLE 9.4: Contribution of Elements to Project Cost

Element	Min (%)	Max (%)	Mean (%)	Number of projects
Preliminary	.17	44.61	12.22	33
Site Clearance	.31	21.97	2.36	24
Earthworks	1.48	31.37	11.64	24
Drains & Ducts	3.10	28.30	11.74	24
Sub & Road base	2.21	38.86	16.36	23
Surfacing	2.13	37.51	20.30	22
Kerbs & Footways	0.31	33.47	12.01	25
Signs & Markings	.07	15.37	2.79	26
Road lighting	.36	4.68	2.04	12
Statutory utilities	.13	8.24	2.09	14
Carriageway	29.16	56.84	36.06	6
Water drainage	24.41	24.87	24.64	2
Accommodation	.56	9.09	2.89	11
Hedges	.03	1.73	.46	5
Fencing	.19	15.27	3.66	15
Concrete	.01	2.24	.81	4
Masonry	.16	.45	.31	2
Dayworks	1.45	7.89	4.67	2
Culverts	5.62	15.00	10.24	3
Bridges	10.29	27.13	16.70	6
Subway	7.32	26.25	16.79	2
Structures	1.51	36.82	16.79	4
Joints	.11	.60	.36	2
Roadworks	3.46	79.53	37.66	8
Substructure	7.00	12.49	9.75	2
Finishings	2.62	13.26	7.94	2
Provisional	1.09	5.02	3.06	2

9.5.2 Accuracy of Cost Predictions

The D-values calculated for the major elements encountered are displayed in Table 9.5. The frequencies show that some elements are not always present in the projects studied. Variations in the percentages of each element in a project is bound to affect the accuracy of cost predictions.

TABLE 9.5: Accuracy Achieved on Different Elements

Element	Min (%)	Max (%)	Mean (%)	Number of projects
Preliminary	-99.60	900.00	151.86	27
Site Clearance	-71.81	726.76	123.15	24
Earthworks	-37.34	123.65	30.19	23
Drains & Ducts	-99.72	136.87	15.65	27
Sub & Road base	-29.78	22.56	5.65	21
Flexible Surfacing	-14.11	26.35	9.10	21
Kerbs & Footways	-17.57	21.92	5.67	24
Signs & Markings	-68.01	500.00	43.98	25
Road lighting	-22.58	336.11	67.07	12
Statutory utilities	-98.82	136.56	30.96	12
Carriageway	-1.72	18.74	8.88	6
Water drainage	11.60	19.90	15.75	2
Accommodation	-31.52	192.43	35.69	11
Hedges	-45.31	104.79	52.56	4
Fencing	-26.59	160.78	50.16	13
Steel Reinforcement	-99.62	8.96	-45.33	2
Concrete	-13.98	11.00	-2.15	3
Masonry	5.74	5.74	5.74	1
Formwork	62.13	62.13	62.13	1
Dayworks	-29.96	115.85	22.30	5
Retaining wall	-96.72	35.33	-30.70	2
Water Proofing	-1.56	25.77	12.11	2
Culverts	14.33	59.00	41.24	7
Bridges	-49.09	55.78	0.39	7
Subway	33.72	102.38	68.05	2
Landscaping	34.35	34.35	34.35	1
Structures	-69.21	101.17	18.58	5
Pelican	301.70	301.70	301.70	1
Joints	102.49	102.49	102.49	1
Roadworks	0.86	859.02	202.43	8
Testing	-99.50	-99.50	-99.50	1
Utilities	-24.84	23.63	-0.61	2
Substructure	127.88	127.88	127.88	1
Finishings	39.47	39.47	39.47	1
Provisional	109.13	109.13	109.13	1
Trees	35.44	67.25	51.35	2
Maintenance	-99.89	-99.89	-99.89	1
Ancillary	24.52	24.52	24.52	1

The dispersion of bids is also displayed in Table 9.6. The measure of dispersion used is the coefficient of variation between bidders averaged over the number of instances in which the element was encountered.

TABLE 9.6: Variation of Prices for Different Elements (CV)

Element	Min (%)	Max (%)	Mean (%)	Number of projects
Preliminary	6.01	151.29	49.21	29
Site Clearance	6.83	166.99	42.63	24
Earthworks	2.02	38.01	19.29	23
Drains & Ducts	6.84	44.52	18.39	27
Sub & Road base	3.38	24.45	10.79	21
Flexible Surfacing	2.71	28.17	9.31	22
Kerbs & Footways	3.97	18.64	11.23	24
Signs & Markings	1.98	41.91	14.15	26
Road lighting	4.37	22.80	10.17	12
Statutory utilities	3.90	31.16	15.38	12
Carriageway	2.97	13.85	10.82	6
Water drainage	12.80	18.42	15.61	2
Accommodation	6.67	21.03	12.25	12
Hedges	21.88	78.15	48.12	4
Fencing	4.84	25.94	13.59	13
Steel reinforcement	10.88	45.86	28.37	2
Concrete	7.58	12.13	10.14	3
Masonry	32.83	32.83	32.83	1
Formwork	32.82	32.82	32.82	1
Dayworks	2.54	34.57	18.67	5
Retaining wall	6.11	37.64	21.88	2
Water Proofing	5.24	21.35	13.67	4
Culverts	6.20	23.94	19.38	5
Bridges	4.03	23.06	12.24	7
Subway	9.86	12.41	11.14	2
Landscaping	8.06	8.06	8.06	1
Structures	11.28	40.70	22.76	9
Pelican	29.35	29.35	29.35	1
Roadworks	5.73	70.59	23.23	9
Testing	22.04	22.04	22.04	1
Substructure	16.32	16.32	16.32	1
Finishings	7.34	7.34	7.34	1
Provisional	11.27	11.27	11.27	1
Trees	33.64	60.23	46.94	2
Maintenance	93.81	93.81	93.81	1
Ancilliary	8.37	8.37	8.37	1

It has been stated earlier that the coefficient of variation is not a measure of accuracy *per se*, but rather it measures the degree of agreement or consistency in pricing. With this understanding, a relationship was established between consistency amongst bidders and the accuracy of design cost forecasts. High agreement between bidders (i.e. low coefficient of variation) on a project should be associated with low forecast error in design estimate.

Tables 9.5 and 9.6 shows a pattern of accuracy in forecasting. Four classes of elements could be distiguished from the tables using the values of accuracy and coefficient of variation: (1) stable items; (2) development items; (3) asterisk, items, and (4) others.

□ STABLE ITEMS

These are elements for which variations between bids is very low (generally below 15% cv) and error in predicting low bid by design estimators is also very low (±15%).

Elements in this category are: Sub-base and Road base, Flexible surfacing, Kerbs and Footways, Concrete, Carriageway. Stable items constitute about 15% of overall project cost. Their contribution to error on most projects is less than 5% of total error.

It is noticed that elements in this category are, relatively, easy to measure and the process for arriving at their costs are simple and fairly straightforward. Good accuracy figures derive from the low uncertainty associated with these elements.

The present accuracy level is good enough and very little (if anything) can be done to improve accuracy in these elements. The in-place method of pricing bills of quantities for these items seems to be very apropriate.

○ DEVELOPMENT ITEMS

These are elements for which variation between bids is very low (generally below 10% cv) but error in predicting low bid -by design estimators- is very high (usually above ±20%).

Elements in this category are: Traffic signs, Road markings, Road lighting, Works for statutory undertakers. It is noticed that these elements are usually subcontracted or involve other people or organisations besides the main contractor. Between them, development items rarely exceed 10% of the overall project value. However, their contribution to error in design cost estimates is rarely less than 20%.

The error levels are sometimes greater than ±500%. It is considered that these elements are not condusive to the present cost forecasting strategy used by design estimators. On more than 8 contracts, at least 3 contractors submitted the same price (to the nearest penny) for these elements while design estimate error are in the region ±100%. Contractors receive quotations for these elements from subcontractors and generally submit the lowest or a close price for the element. This procedure can also be used by the design estimator to improve accuracy. The low bid figures or second lowest bid figures was substituted for the design estimate for these elements in 20 projects. This resulted in a reduction of about 15% in overall error for the projects. Thus, error in design estimates was reduced to within the expected ±10%. **This is probably the best hope for improving cost predictions at the moment.**

Related research in the Department of Civil Engineering, Loughborough University of Technology, has established that the use of subcontractors in construction work is on the increase. Abdel-Razek and McCaffer (1987) noticed that the value of work being undertaken by small firms employing less than eight workers rose from 14.1% of total private contractors' work in 1979 to 24.7% in 1984. They suggested that this change has forced tighter tendering by main contractor. This assertion seems plausible for development items, but evidence of tighter tendering at the overall project level has not been found in this resaerch. Since the shift towards subcontracting has been confirmed through other sources, it is axiomatic that accuracy in design cost estimating will not improve unless design estimators change the strategy for estimating costs for sub-contract items.

* ASTERISK ITEMS

Asterisk items are of two types:

a) Elements for which variations between bids is very high (above 20% cv) and the design estimate error is also very high (above ±20%). Elements in this category are: Preliminaries, Earthworks, Drainage and Service Ducts, Site clearance. Asterisk items constitute a large percentage of the total project cost. Low accuarcy in these elements therefore contribute an average 70% of total error in design cost estimates.

These element are high uncertainty elements for which project information does not allow for precision in measurement. Error in these elements therefore arise from contractors being able to manipulate costs because of profits desired for other elements, anticipated variations, etc. Since design estimating cost data relies on historical costs submitted by contractors, inaccuracies in the original data obtained from successful tenders propagate these inaccuracies in the cost data.

b) Elements for which neither the contractors nor the design estimator has a good cost data bank, e.g. felling of trees, clearing shrubs, etc. These items sometimes have very similar characteristics to (A) above.

There is little the design estimator can do to improve forecasting accuracy for asterisk items since the agreement between contractors regarding costs is poor. Neither the contractor's nor the design estimator's approach can offer any form of improvement to cost estimating for these elements. Error in these elements derive from uncertainty; a phenomenon which cannot be totally removed from construction work.

△ OTHER ITEMS

There are other elements for which a definite pattern could not be established. The percentage of these elements in the projects studied are low. However, the exact value fluctuates widely across projects and accuracy in forecasting costs for these elements also fluctuate widely. Because elements in this category account for a very small percentage of total project cost, they do not contribute significantly to error in design cost estimating.

1. Overall Accuracy

There are significant differences between the level of accuracy achieved across offices. The accuracy in predicting the low bid varied from ±29.7% to ±5%. The mean accuracy from the analysis was +12.77% (13.9 SD) with a mean absolute accuracy error of 16.44%. This suggests that, on average, design estimates are 12.77% higher than the low bid. This result is in agreement with those from other studies [see Ogunlana and Thorpe, 1987]. However, some offices reported that their predictions were not for the low bid but rather for the mean bid or second lowest bid. The results using the appropriate parameter predicted differ from that using the low bid in that, it shows accuracy levels much better than portrayed in previous researchwork on the measurement of accuracy of design estimates (ref. Chapter 4). This is reported in detail in Chapter 7.

9.5.3 Bidding Performance

A major objective in analysing bidding performance is to aid learning from experience by design estimators. The quality of advice offered to the client can be improved if the design cost consultant can see, from bidding results, how contractor's pricing for different elements relate to their ability to win contracts. Results from ACCEST allow distinctions to be made between the winning bid and others.

9.5.3.1 Characteristics of the Winning Bid.

Opinion in literature suggest that "the man who makes the lowest error wins the contract" (McCaffer, 1976) Results from ACCEST show that, in many instances, this assertion is true. The D-values calculated suggest that the wining bidder does any of the following:

1. Submits a very low price for a high cost (elements whose price constitute a high percentage of the total project cost) item. In such instances, asterisk items are targeted for this purpose. Because of the magnitude of uncertainty associated with asterisks, the low bidder often deliberately submits a low price on some items such as preliminaries and earthwork.

2. Consistently submits low prices for most elements. In such instances, the low bidder's price is hardly higher than 10% of the lowest price for most elements. Even when he makes a high error on some elements (usually not a high cost item), the error is compensated for by the gains on other items.

9.5.3.2 Characteristics of Losing Bids.

Losing bids have characteristics nearly opposite to those of wining bids.

1. Contractors who submit an abnormally high price for a high cost element loses the contract. This sometimes happen irrespective of low prices that might have been submitted for other elements. On average high tenders are associated with high prices for asterisk elements.

2. Contactors whose prices consistently deviate more than 10% from the lowest price for elements.

This pattern is sometimes disrupted if a contractor misjudges the percentage contribution of an item to the overall project cost.

9.5.4 Cost Comparison with the Final Account

The purpose of comparing costs with final account figures is to establish if the design estimator's cost predictions will show any correlations with final account values that may be useful for providing cost advice for the client and designers. The analysis is done at two levels: overall figures and at the elemental level.

9.5.4.1 Overall Price

The results shown in Tables 9.7 - 9.9 show cost comparisons with the final account at both the overall and element levels. The overall figures show that mean values submitted for projects and the design estimate show variations of +17.57% and +13.85% from the total final project cost. It shows the tendency for both the design estimate and the mean price submitted by contractors to be higher than the final cost of projects.

TABLE 9. 7: **Deviation from Final Account (Estimate)**

Element	Min	Max	Mean	Number
Total	-28.56	101.05	13.85	12
Preliminary	-83.88	3990.00	371.50	12
Site Clearance	-91.12	573.12	65.96	11
Earthworks	-53.38	130.14	5.48	10
Drains & Ducts	-38.54	94.25	17.11	11
Sub & Road base	-41.07	38.49	4.97	10
Flexible Surfacing	-19.13	38.17	10.93	10
Kerbs & Footways	-24.13	75.43	10.26	11
Signs & Markings	-57.83	550.00	43.59	14
Road lighting	-19.60	555.66	99.57	6
Statutory utilities	-98.84	324.49	83.89	5
Accommodation	-42.93	282.54	71.49	5
Fencing	-57.66	105.18	-0.07	8
Concrete	-32.62	12.94	-9.84	2
Dayworks	-99.75	29.82	-53.67	6
Retaining wall	0.00	0.00	0.00	1
Culverts	-40.78	6.94	-5.51	5
Bridges	4.19	4.19	4.19	1
Landscaping	35.25	35.25	35.25	1
Structures	-8.00	919.70	203.98	5
Pelican	256.29	256.29	256.29	1
Joints	-82.84	8.77	-37.04	2
Roadworks	10.34	69.36	39.85	2
Substructure	28.46	32.64	30.55	2
Finishings	-15.35	22.88	3.77	2

The result for the low bid shows all the ingredients of self-fulfilled prophecy (Table 9.8). The range of values show that the deviation of the total cost from the low bid is between -13.31% and +13.95%. The cost management procedures ensure that final account figure is not allowed to deviate much from the original tender even in instances were they were ordered by the client. Cost increases on some elements are compensated for by corresponding cost reductions on other elements to give an overall final account figure only 0.28% higher than the low bid for projects.

TABLE 9.8: Deviation from Final Account (Low Bid)

Element	Min	Max	Mean	Number
Total	-13.31	13.95	-0.28	12
Preliminary	-90.00	230.00	12.79	12
Site Clearance	-63.63	27.94	-2.42	11
Earthworks	-61.91	20.37	-4.70	10
Drains & Ducts	-21.79	45.56	7.54	11
Sub & Road base	-34.25	32.87	1.97	10
Flexible Surfacing	-22.19	21.86	-1.91	10
Kerbs & Footways	-20.73	91.77	10.74	11
Signs & Markings	-26.40	1071.40	80.15	14
Road lighting	-11.78	69.46	10.49	6
Statutory utilities	-68.15	350.65	66.86	5
Accommodation	-3.14	47.91	15.69	5
Fencing	-39.19	24.16	-5.45	8
Concrete	4.14	9.53	6.84	2
Dayworks	-87.64	230.30	33.01	6
Retaining wall	3729.00	3729.00	3729.00	1
Culverts	-4.93	0.81	-2.69	6
Bridges	-1.78	-1.78	-1.78	1
Landscaping	15.39	15.39	15.39	1
Structures	-3.10	60.17	11.94	5
Pelican	38.84	38.84	38.84	1
Joints	-82.84	-1.17	-42.01	2
Roadworks	0.00	1.64	0.82	2
Substructure	46.63	46.63	46.63	1
Finishings	-6.59	-6.41	-6.50	2

The result is instructive in many respects. Once a good prediction of the low bid can be made at the design phase, it is possible for the cost consultant to inform the client that overall final project cost is unlikeley to deviate from ±15% of the low bid.

9.5.4.2 Elemental Level

Detailed study of the result achieved at the elemental level are as reasonably anticipated. The greatest deviation from final account figures are recorded in development items. Neither the low bidder's prices nor the design estimate compares very well with the final account figures for this class of elements. However, there seem a slight improvement of the low bid values over the design estimate. The wide variation between the low bid figures and the final costs on development items may be accounted for by the location of constuction site being distant from the main contractor's organisation. The cost of these elements are therefore difficult for the designers and the client to control.

TABLE 9.9: Deviation from Final Account (Mean of bids)

Element	Min	Max	Mean	Number
Total	0.02	53.96	17.57	13
Preliminary	-15.30	28986.70	2628.84	12
Site Clearance	-54.22	112.43	12.03	11
Earthworks	-35.17	43.34	3.61	10
Drains & Ducts	-9.85	92.88	23.50	11
Sub & Road base	-27.97	57.28	17.50	10
Flexible Surfacing	-22.26	29.34	4.05	10
Kerbs & Footways	-11.95	94.73	19.36	11
Signs & Markings	-26.15	2649.07	191.00	14
Road lighting	-12.90	64.78	12.06	6
Statutory utilities	-70.87	414.51	58.60	5
Accommodation	-6.08	1410.20	296.42	5
Fencing	-26.50	42.49	-2.17	8
Concrete	-6.99	11.84	2.43	2
Dayworks	-87.64	210.54	23.37	6
Retaining wall	4965.75	4965.75	4965.75	1
Culverts	-21.55	9.99	-0.46	5
Bridges	5.93	5.93	5.93	1
Landscaping	11.71	11.71	11.71	1
Structures	-6.60	30.15	12.42	5
Pelican	34.20	34.20	34.20	1
Joints	-82.84	-26.67	-54.76	2
Roadworks	6.45	126.59	66.52	2
Substructure	-15.59	42.39	13.40	2
Finishings	-2.75	24.82	11.04	2

In asterisk items, the deviation of final costs from low bidder's figures is remarkably low; ranging from -4.70% for earthworks to +12.79% for preliminaries. The obvious explanation for this is that these items are directly executed by the contractor and offer the greatest scope for cost management. Also because these items are high cost items, expresssing accuracy in relative terms resolves in their favour (see Chapter 3).

Stable items also show very little deviation of final account from the low bid. The deviation in cost is usually within ±8% of the low bid. The reason for this is obvious. Unless reductions/increases in project scope are effected, very little can be done to change the cost of stable items, since the amount of stable items in a project is fairly predictable.

9.5.5 Price Movement Around the Design Estimate

The facility for measuring R-values was built into ACCEST to monitor the movement of bidder prices around the design estimate. This can therefore be used to aid target setting. The overall result reported in Chapter 7 showed that this is a viable proposition at the total bid level. At the individual element level prices were related to the estimate in two forms: (1) elemental prices submitted by individual bidders; and (2) elemental prices sorted in increasing order. The results from both approaches failed to show any definite pattern that could assist in the setting of targets at the element level. This is in line with Beeston's (1973) analysis suggesting that prices show wider variations at the elemental level than at the total tender level. The results on the elemental level are therefore not included in this treatise.

9.6 APPLICABILITY OF THESE RESULTS FOR OTHER FORMS OF CONSTRUCTION

The review of literature dealt extensively with cost prediction for both civil engineering and building works. However, the data used for testing is limited to civil engineering construction. It is important ot state that building works contain more stable items than civil engineering works. This will tend to make accuracy better on building works than civil engineering construction (see Chapter 4). However, the trend towards subcontracting in the industry (Abdel-Razek and McCaffer, 1987) will result in development items being more possible in building works. This in turn will result in accuracy deteriorating over time unless the measures suggested in this chapter are taken.

9.6 SUMMARY

Tests conducted on tendered prices (both at the elemental and the overall tender levels) on 51 road projects have shown that:

1. differences in percentage distribution of costs to elements by individual bidders may be used to provide better cost advice to clients (and the design team generally).

2. percentage distribution of cost to each element varies widely across projects.

3. achieved accuracy in design cost estimating varies widely across elements. The magnitude of error in predicting costs for each element depends on the magnitude of uncertainty in measuring the quantity of the element in projects.

4. by distinguishing between different classes of elements, it is possible to improve accuracy in cost prediction.

5. the worst accuracy in design cost prediction (relative to the variation between bids) is achieved on subcontracted items.

6. a winning bid in a tender exercise have one of two characteristics: (a) consistently contain low prices on most elements; or (b) have a very low price for a high cost item.

7. once construction contracts on most road projects are awarded, the final cost deviates very little from the low bid.

8. contractors tender prices at the elemental level does not have any definite relationship with the design estimate.

CHAPTER 10

CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH

The man who does not know where he is going goes the farthest.
- Oliver Cromwell.

10.1 BACKGROUND

This thesis set out to examine possible avenues for improving accuracy in design cost estimating for construction works. To achieve the objective, the methods for construction cost estimating were first examined.

A review of existing literature and practice revealed that various methods for cost estimating are used at the design phase depending on the stage of development of design. The choice of method is dependent on the information available to the design cost estimator, the need for the estimate and the quality of advice required by the design team. No single method can be described as being the 'best' in an absolute sense. All design cost estimating methods rely heavily on historical cost data and price indices are used to adjust for market conditions.

Contractor's cost estimating methods combine the analytical tasks of calculating resource requirements for different sections of work with the intuitive task of predicting resource productivity. Contractor's estimating also benefits from relatively more complete information about the project (since contract estimates are made at the tendering stage) and better understanding of resource prices. The differences in approach to cost estimating mean that contractors can be judged to be better equipped to estimate construction costs than designers.

Earlier research efforts aimed at determining the problems with design cost estimating were reviewed. Four leading researches reviewed suggested that there is much scope for improving accuracy in design cost estimating. The major areas for improvement were identified as:

- increasing the data used for estimating.
- computer applications.
- development of expertise in cost estimating.
- construction cost simulation.
- resource based estimating at the design phase.

10.1.1 Increasing the Data Used for Cost Estimating.

Reliance on a single historical project as the source of cost data for estimating construction costs was cited as being responsible for error in estimates. Research (Jupp and Macmillan, 1981) has demonstrated that by increasing the number of projects from which cost data is abstracted to three, significant increases in accuracy could be achieved. Evidence of averaging costs from three historical projects have been found in industry. However, corresponding increase in accuracy, deriving from the use of more information for estimating has not been found.

10.1.2 Computer Applications

A major advantage expected from the use of computers in estimating is the improvement in information storage and retrieval. It was also expected that computers could facilitate the use of more information and the consideration of alternative estimates (McCaffrey, 1978). This aim is currently being realised in industry.

10.1.3 Development of Expertise in Estimating

It has been suggested that the development of expertise/expert systems will be beneficial to design cost estimating (Skitmore, 1987 and RICS/ALVEY, 1986). Results of two separate exercises aimed at testing this have confirmed that individual expertise has a role to play in estimating performance. The survey conducted in this research show that both practising estimators and novices attribute good performance in estimating to expertise. Twenty five subjects in an estimating experiment rated individual expertise as a major factor to be considered in choosing historical cost data for estimating. Despite the subjects being informed that cost data used for estimating is abstracted from the low tender rather than the design estimate, the subjects still believe that the expertise of the design estimator is very important in data selection.

A survey of nine design offices also suggested that the ability of design estimators is a major determinant of the level of accuracy achieved in estimating. These two separate studies have demonstrated that the development of expertise/expert systems in estimating has great potential for improving accuracy in design estimates.

10.1.4 Construction Cost Simulation

Previous research has shown that simulation of construction costs could be a major step forward in design cost prediction. This approach is still at the development stage. No evidence of its use in industry has been found in this research.

10.1.5 Resource Based Estimating at the Design Phase

Some researchers have suggested that the best hope for improving accuracy in design cost estimating is probably through the adoption of resource based (contractor type) estimating at the design phase. This assertion has been rigorously examined in this thesis.

Previous research efforts have concentrated exclusively on the use of outcome feedbacks for assessing estimating performance. Attention has therefore been focussed, rather unduly, on either estimating data or estimating method as being responsible for error in design estimates. Despite no evidence of direct association between estimating method and error being provided in literature, it has been cited as the major source of error. Error in design estimates could originate from any or all of four sources: estimating data, estimating method, estimator, and constraints imposed by the process of estimating. Inability in attributing error stochastically to these four sources renders the assertion that contractor's method of cost estimating will be beneficial to designers baseless.

A theoretical limit to the level of achievable accuracy in design cost estimating has also been shown to exist. This limitation is imposed by the reliance on cost data from tenders for design cost estimating rather the method.

10.1.6 Factors Affecting Estimating Accuracy

The factors that affect estimating accuracy were also examined. From empirical data in this study, only geographical location, office of origin and project size relate statistically to estimating performance if the low bid is used as datum for assessing error. If however data originating from each office can be attributed to one estimator, as is possible in this research, estimating ability also relates statistically to accuracy.

10.2 CONCLUSIONS

The major conclusions from this research can be summarised as follows.

10.2.1 Error Assessment

Calculation of accuracy in construction costs rely on the assessment of errors in the estimate of a 'true cost'. A true cost for construction work has not been defined either in current or previous literature. This has resulted in design estimates being compared with tenders for the purpose of determining accuracy. For reasons of lack of a datum to which tenders could be compared, the calculation of errors in tenders have remained elusive. Variations amongst bids have therefore been substituted for accuracy in design estimates through the use of coefficient of variations. Also, attempts to calculate coefficient of variation in design estimates have also not produced satisfactory results. Researchers have therefore tended to compare variations in bids with accuracy in estimates (calculated by using the low bid as a representation of the true cost). This approach is unacceptable since the two quantities are not similar. However, low variations between bids is sufficient a basis to expect more accurate estimates. Variations in bids serve as indications of, rather than a substitute for, a measurement of accuracy.

The inability to determine the true cost for construction projects has tended to invalidate previous attempts to measure accuracy in design cost estimating. Evidence from this research have shown that when predicting tender prices, design offices focus on different parameters. Any attempt aimed at measuring accuracy in design estimates should take appropriate cognisance of the parameter predicted by the estimator.

Rather than using the low bid as the parameter to which design estimates should be compared, the predicted parameter should be utilised. For instance, rather than use equation 10.1 for calculating D values, a more appropriate procedure is to use equation 10.2.

$$D = \frac{\text{Estimate - Low bid}}{\text{Low bid}} \times 100 \quad \text{---------------------} \quad (10.1)$$

$$D = \frac{\text{Estimate - Predicted parameter}}{\text{Predicted parameter}} \times 100 \quad \text{---- ----} \quad (10.2)$$

Alternatives such as the low bid, mean of bids, second lowest tender, etc. can be substituted for the predicted parameter in equation 10.2. This approach will ensure that the design estimator gets a fairer assessment than is currently possible.

10.2.2 The Low Bid as Datum for Assessing Accuracy in Design Cost Estimates

The use of the low bid as the true cost being predicted by design offices has also been investigated. A survey of design offices showed that other parameters such as the second lowest bid or mean of bids are being predicted. Some evidence of the requirements for the prediction of the highest possible cost for projects have also been found in industry. As the industry in the UK opens up to other clients and contractors from other countries, (Japan and the USA for example) requirements for predictions of highest price will become more common in the industry. It has been shown that design offices demonstrate remarkably better ability in 'getting predicted parameters right' than is portrayed in the use of low bid as the datum for cost comparison. Previous researches have calculated the error in design estimates as averaging ±12.41%. An empirical survey of 51 projects in this research produced a value of ±12.77%. This result was achieved using the low bid as datum. By comparing costs to the parameters which the design offices have focussed on, it has been shown that the value of error rarely exceeds ±10% while the coefficient of variation of bids average 11% - equalling figures calculated by other researchers.

10.2.3 Resource Based Estimating at the Design Phase

The history of construction cost modelling was traced in this research. Research has progressed from elemental cost analyses through regression models to construction cost simulations and resource based estimating. Only elemental cost analysis have been widely accepted in the industry because of its relative simplicity. The tendency to use very simple models has been noticed in other industries concerned with predictions generally. Industry practitioners use simple models because they can be validated using data generated in house. Simple models are also preferred because they are simple to understand and do not remove control from model users. These preferences has resulted in models suggested by researchers being condemned permanently to 'paper' rather than real live models. Resource based estimating is likely to suffer the same fate unless an approach for in house data generation by design cost estimators can be found.

The argument for introducing resource based estimating at the design phase rests on the premise that design cost forecasts contain more inherent error than contractor's estimates. Also, previous calculations of accuracy in cost forecasts have been said to show less error in contractor's forecasts than are contained in design estimates. It has been shown in this work that differences in methods for calculating accuracy in design and contractor's forecasts preclude any direct comparison of accuracy between the two.

Adoption of resource based estimating at the design phase will require much learning on the part of design estimators and a search for alternative sources of construction cost data. The approach will also require design estimators having to estimate construction costs and mark-up separately as contractors do. Design estimators are currently ill equipped for such tasks. From evidence provided in other research works (both from within and outside the construction industry), the adoption of resource based estimating at the design phase is not a viable proposition in the immediate future.

10.2.4 Testing Accuracy in Design Cost Estimates

An analysis package for assessing error in estimates which gives due consideration to the parameters predicted by the design cost estimator was developed. The computer based package (ACCEST) incorporates estimating cost data and sufficient information about the process and method of estimating to enable a fair assessment of accuracy to be made. By giving consideration to the estimator, estimating method, data and process, it is possible for feedback information to be used effectively in performance assessment. The package also allows cost comparison at the elemental level. Results from the package show that good advice can be offered to the client and the design team by relating costs submitted by individual bidders for each element to the total project cost. Also wide variations in the pattern of cost distribution to each element on different projects precludes the attachment of rigid percentages to elements in road construction.

10.2.5 Learning and Design Cost estimating

Psychological explanations for some behaviour of design estimators (noticed in previous research work) were made in this research. Design estimators are not learning sufficiently from their experiences on previous projects. This failure to learn is attributable to the absence of a system requiring regular monitoring of performance in design offices. Design estimators therefore have an illusion that the level of accuracy achieved in cost estimating is better than they really are. This 'illusion of validity' (of opinion) persists because the estimator's attention is not drawn to evidence that disconfirm previous assumptions. A survey of nine design offices show that offices which compare estimates with tenders (at the element level) on a regular basis do so only to detect if there are errors in tenders rather than design estimates. Comparisons aimed at detecting errors in design estimates are only made when estimates differ significantly from tenders received. This development has meant that estimators assume that little or no error exists in the estimate if the overall tender is deemed to be acceptable.

In the industry, it has been shown that the relative credibility of source is responsible for the preferences shown in the choice of information used for estimating. An interaction of source credibility and the nature of information storage in design offices has resulted in design estimators using cost information generated in their offices - and sometimes by the estimators- only.

10.2.6 Comparing Costs at the Elemental Level

In current practice, design cost estimators compare estimates with tenders only when significant differences between the two are noticed. Also such comparison are made at the overall project level. This research has demonstrated that this contributes to error in estimates by failing to focus attention of estimators on the sources of error in estimates. Comparing costs at the elemental level on a regular basis have potential benefits for improving estimating accuracy.

10.2.7 Strategy for Reducing Error in Predicting the Low Bid

The magnitude of error in predicting costs at the design phase relates to the uncertainty in measuring the quantity of individual elements. Costs for elements such as road base, flexible surfacing, etc. are easier to predict than elements whose quantities are either unspecified or are difficult to quantify with a good degree of accuracy. These differences in the uncertainty associated with each element affect the pattern of costs submitted by tenderers. It has been shown from tender results on 36 projects that contractors and design estimator's prices follow a very similar pattern. A distinction has been made between four classes of elements :

- Stable items
- Development items
- Asterisk items
- Other items.

On stable items, both contractors and design estimators submit very close prices and little differences, if any, can be noticed between contractor's pricing and design estimating. Coefficient of variation of bids for these elements rarely exceed 10% while the error in estimating the low price is also usually below ±15%. Stable items show high accuracy in estimates because of the relative ease in measurement of quantities compared to other items.

On development items, coefficient of variation of bids are low (rarely exceeding 10%) but design error is rather high (rarely below ±20%). Elements in this category are subcontract items such as road lighting, road marking, etc. The high error in estimating has been attributed to the differences in the approach used for determining costs between contractors and design estimators. Main contractors request bids for each subcontract item and submit the lowest bid (in most instances) as part of their tender while risk on the item is transferred to other items. Design estimators, on the other hand, use simple extrapolation from previous cost data to arrive at costs of subcontract items. This difference in approach introduces 'error' to design estimates. Although the value of subcontract items rarely exceed 10% of the total price on road projects, the magnitude of the error on subcontract items is such that development items contribute more than 20% to error in estimating. However, the error in design estimates for development items may not be as great as they have been calculated to be - since risk on these elements is transferred to other items.

Asterisk items were noticed to be elements with high uncertainty in quantity measurement. They show high variations in pricing between contractors and very high error in design estimates. Accuracy can only improve if precision in measuring the quantities of these items is improved - this is more than can be hoped for at the moment.

There are other elements which do not fall strictly into the three categories listed above. The variations amongst bids and design estimate error vary widely for the elements.

10.2.8 Cost Predictions

Design cost predictions could benefit from targeting a particular parameter. Since the distribution of tenders can be assumed to be normal, relating estimates to the low bid or the mean of bids with appropriate adjustments being made for observed error calculated from previous estimates will ensure better quality cost forecasts. For instance, it has been shown in this thesis that the low bid and the high bid can be assumed to be within one standard deviation away from the mean of bids. If an office has recorded errors averaging ±7% (taken from the results from one of the offices studied) on previous projects and now estimates that a proposed project will cost £(E), the expected values of the low bid and the high bid can be predicted using the formulae:

Predicted mean of bids (M) = R x E ------------------------ (10.3)
Predicted low bid (L) = (R-SD) x E ------------------- (10.4)
Predicted high bid (H) = (R+SD) x E ------------------- (10.5)

if the ratio of mean to the estimate has been determined to be R on previous projects.

The predicted low bid can be corrected for error by subtracting 7% from the estimate. A similar correction for the high bid will require an addition of 7% to the estimate. Thus, the value 0.93E and 1.07E will be substituted for E in equations 10.4 and 10.5 respectively.

An alternative equation for predicting individual tender prices is

$$X_{(i)} = \mu(1 - \frac{cv}{100} S_i) \quad \text{---------------------------------} \quad (10.6)$$

where $X_{(i)}$ is the ith lowest bid

S_i is the ith normal score

μ is the estimated mean

cv is the coefficient of variation

These two equations can be used to predict tender prices to within ±10% level of accuracy if used with a databank incorporating projects which the estimator assumes to be suitable for predictions.

10.3 RECOMMENDATIONS

The importance of cost estimating to construction project management underlies the need for this research. From the findings detailed above, different strategies for improving accuracy measurement in cost estimating and for improving performance in design cost estimating are now proposed.

10.3.1 Accuracy measurement

Most design cost estimating packages currently in use in the industry do not incorporate facilities for comparing estimates with tender prices. This is partly a product of design practice procedures not requiring comparisons of estimates with tenders unless there are wide variations between them. There is evidence showing that this practice is changing, albeit gradually. Design cost estimating packages will need to provide cost comparison facilities in the near future. Such facilities should, ideally, allow estimates to be compared directly with the desired parameter.

10.3.2 Elemental Cost Predictions

Traditionally, design cost estimating relies heavily on historical cost data for predicting tender prices. Adjustments are made for market conditions by using tender price indices and other adjustments for quantity and quality differences are also made. Utilising this strategy for forecasting costs for subcontract items have been shown to contribute significantly to error in estimate. A method for reducing error in predicting low prices for subcontract elements would be for design estimators to request tenders directly from prospective subcontractors. This approach could lead to one of two results:

1. appointing subcontractors directly by the client. This approach has been going out of favour with the emergence of project management and management contracting. Traditionally, a distinction is made between domestic subcontractors (subcontractors appointed by the main contractor) and nominated subcontractors (subcontractors appointed directly by the client). Management contractors and construction managers prefer all subcontractors to be appointed by the project manager.

2. requesting project managers/management contractors to appoint subcontractors from a list prepared by the design team. This is only necessary if the project managers have not been involved with the design decisions generating the estimate.

Whichever of the two approaches is adopted will result in design estimators having prices comparable to the main contractor's price for subcontract items. A proportion of the subcontractor's price may be added for main contractor's attendance as is normally required in most contract conditions.

10.3.3 Learning From Experience

Evidence from this and other researches have shown that design cost estimators are not learning adequately from their previous performances in estimating. Feedbacks received from tender exercises represent a potent force for improving accuracy in design cost estimating and for providing better quality advice to construction clients and the design team. Deriving maximum benefit from previous data is contingent on the following:

- regular monitoring of performance.

Comparing estimates with tenders regularly will create an awareness of errors in design estimators. Also, it will be easy to see which of the factors currently accepted, without proof, as affecting performance in estimating have any true relationship with estimating performance. Design estimators will also be able to adjust their positions to focus properly on useful parameters when predicting tender prices.

- focus on evidence that disconfirm assumptions

For maximum learning to occur, estimators attention need to be focussed on outcomes which tend to disconfirm their opinions regarding error in estimating. The current practice in industry have meant that design estimators do not compare estimates with tenders on the elemental level because, in many instances the deviation of tenders are seen to be within the levels of accuracy set by design offices. However real associations between estimating performance and the incidence of error in estimates tend to be more visible at the element rather than the total tender level.

Design estimators also report that, in most instances, cost comparisons at the elemental level are made only to detect error in tenders. By focussing attention on other people's error, design estimators overlook error in estimates. To improve learning, errors in estimates should be sought and removed.

- adjustments to cost data.

The current practice does not require design estimators to make any adjustments to the rates in the low bid before being used for cost predictions for other projects. However, it is known that contractors submit low prices on certain elements (usually the preliminaries or earthwork) to enable them to win contracts. Evidence abounds in the industry where the pattern of cost distribution considered appropriate by the design estimator and other contractors is not followed by the low bidder. In instances where such deviations are noticed in the low bid, corrections should be made by using the percentage cost distribution favoured by the design estimator and other contractors to redistribute the contract price before rates in the low bid can be used for other projects.

- following trends in elemental cost pricing

This research has demonstrated that although subcontracting work on some elements may have introduced error to the design estimate, design estimators are ignorant of this development. For instance, although the incidence of subcontracting is on the increase (see Abdel-Razek and McCaffer, 1987), design estimating practice has not changed in line with this development. Advantage has not been taken of the changes in the industry to improve accuracy in estimating. A major step forward would be for estimates to be compared regularly with tenders and any emerging trends in contractors pricing to be followed closely by the design cost estimator.

10.3.4 Estimating Information Selection

The cost data used for estimating has been shown to have effects on the level of accuracy achievable. However, a method of systematic selection of estimating information is still missing in design offices. In building works, the Building Cost Information Service of the RICS provide elemental cost analysis for aiding cost planning/estimating. However, Cartlidge and Mehrtens (1982) have observed that the information most needed for estimating is sadly, missing from the analyses provided in the BCIS data. It is necessary for individual design offices to improve in-house information storage facilities and also to devise a method for selecting cost information from their data banks. ACCEST, the model developed in this research, allows storage of useful information for cost estimating. However, it does not incorporate a facility for selection of information.

Information selection can probably be achieved by the use of expert systems, since experts have been shown in this thesis to be more stable in considering information used for estimating cost.

10.4 FURTHER RESEARCH

Some methods for improving accuracy in design cost estimating have been suggested in this research. However, other new avenues have opened up which need further investigation.

- measurement of errors

Ideally, an error measurement program should be linked to an estimating package. The most appropriate procedure for incorporating error measurement into estimating packages need investigating. Such programs should allow the estimator to define the parameter to be used for accuracy measurement.

- factors affecting estimating accuracy.

To allow a thorough understanding of the factors affecting accuracy in design cost estimating, consistent monitoring of estimating performance over a long period of time with due consideration to the effects of each factor is necessary. This will require using a program such as ACCEST in design offices over a fairly long period of time.

- expertise development

The development of individual expertise in cost estimating seem a viable option for improving estimating performance. Research into the qualities in the individual that tend to make them better estimators is necessary. It is also necessary to determine how such qualities can be recognised in people, how they can be developed and what method of training will best enhance these qualities in individuals.

- expert systems for information selection.

Seeing that experts are better at choosing information for design cost estimating than novices, it would be appropriate to examine possibilities for building expert system programs for information selection. Such information should be from a database that recognises the magnitude of error in estimates/bids and should provide possibilities for linking with estimating packages.

- tests on building projects.

This research has dealt entirely with data on road projects. This was necessary because of the inability to obtain data on building works. Further research aimed at establishing if the relationships noticed between design error and variation of bids are also true for building projects is necessary.

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APPENDIX A

Outline Plan of Work

Stage	Purpose of work and Decision to be reached	Task to be done	People directly involved	Usual Terminology
A. Inception	To prepare general outline of requirements and plan futute action	Set up client org. for briefing. Consider requirements appoint architect	All client interests, architect	Briefing
B. Feasibility	To provide the client with an appraisal and recommendation in order that he may determine the form in which the project is to proceed, ensuring that it is feasible, functionally, technically and financially.	Carry out studies of user requirements, site conditions, planning, design, and cost etc., as necessary to reach decisions.	Client's representatives, architects, engineers and QS according to nature of project.	
C. Outline Proposals	To determine general approach to layout, design and construction in order to obtain authoritative approval of the client on the outline proposals and accompanying report.	Develop the brief further. Carry out studies on user requirements, planning, design and costs, as necessary to reach decusions	All client interests Architects, engineers, QS and specialista as required.	Sketch Plan
D. Scheme Design	To complete the brief and decide on particular proposals, including planning arrangement appearance constructional method, outline specification, and cost, and to obtain all approvals.	Final development of the brief, full design of the project by architect, preliminary design by engineers, preparation of cost plan and full explanatory report. Submission of proposal for all approvals	All client interests Architects, engineers, QS and specialista and all statutory and other approving authorities.	
E. Detail Design	To obtain final decision on every matter relted to the design, specification, construction and cost.	Full design of every part and component of the building by collaboration of all concerned. Complete cost checking of designs.	Architects, QS and engineers and specialists, contractor (if appointed)	Working Drawings
F. Production Information	To prepare production information and make final detailed decisions to carry out work.	Preparation of final production information i.e. drawings, schedules and specifications	Architects, QS and engineers and specialists, contractor (if appointed)	
G. Bills of Quantities	To prepare and complete all information and arrangements for obtaining tender.	Preparation of Bills of Quantities and tender documents	Architects, QS, contractor (if appointed)	
H. Tender Action	Action as recommended in NJCC Code of Procedure for Single Stage Selective Tendering 1977.	Action as recommended in NJCC Code of Procedure for Single Stage Selective Tendering 1977.	Architects, QS, engineers, contractor, client.	
J. Project Planning	To enable the contractor to programme the work in accordance with contract conditions; brief site inspectorate; and, make arrangements to commence work on site.	Action in accordance with the Management of Building Contracts and Diagram 9.	Contractor Subcontractors.	Site Operations

Outline Plan of Work (Contd)

Stage	Purpose of work and Decision to be reached	Task to be done	People directly involved	Usual Terminology
K. Operations on Site	To follow plans through to practical completion of the building	Action in accordance with the Management of Building Contracts Diagram 10.	Architects, engineers, sub-contractors, QS, client.	Site Operations
L. Completion	To hand over the building to the client for occupation, remedy any defects, settle the final account, and complete all work in accordance with the contract.	Action in accordance with the Management of Building Contracts Diagram 11.	Architects, engineers, QS, client.	
M. Feedback	to analyse the management, construction and performance of the project.	Analysis of job records. Inspections of completed building. Studies of building in use.	Architects, engineers, QS, client.	

* The publications Code of Procedure for Single Stage Selective Tendering (NJCC 1977) and Management of Building Contracts (NJCC 1970) are published by RIBA publications Ltd for the NJCC

APPENDIX B

TENDER ANALYSIS FORM

Tender date   Form name

Base rate multipliers for three lowest tenders: 1st 1.111764, 2nd 1.238186, 3rd 1.303659

RCPI at TENDER DATE: 103

SD Multiplier for averaging adjusted prices: 0.9675590

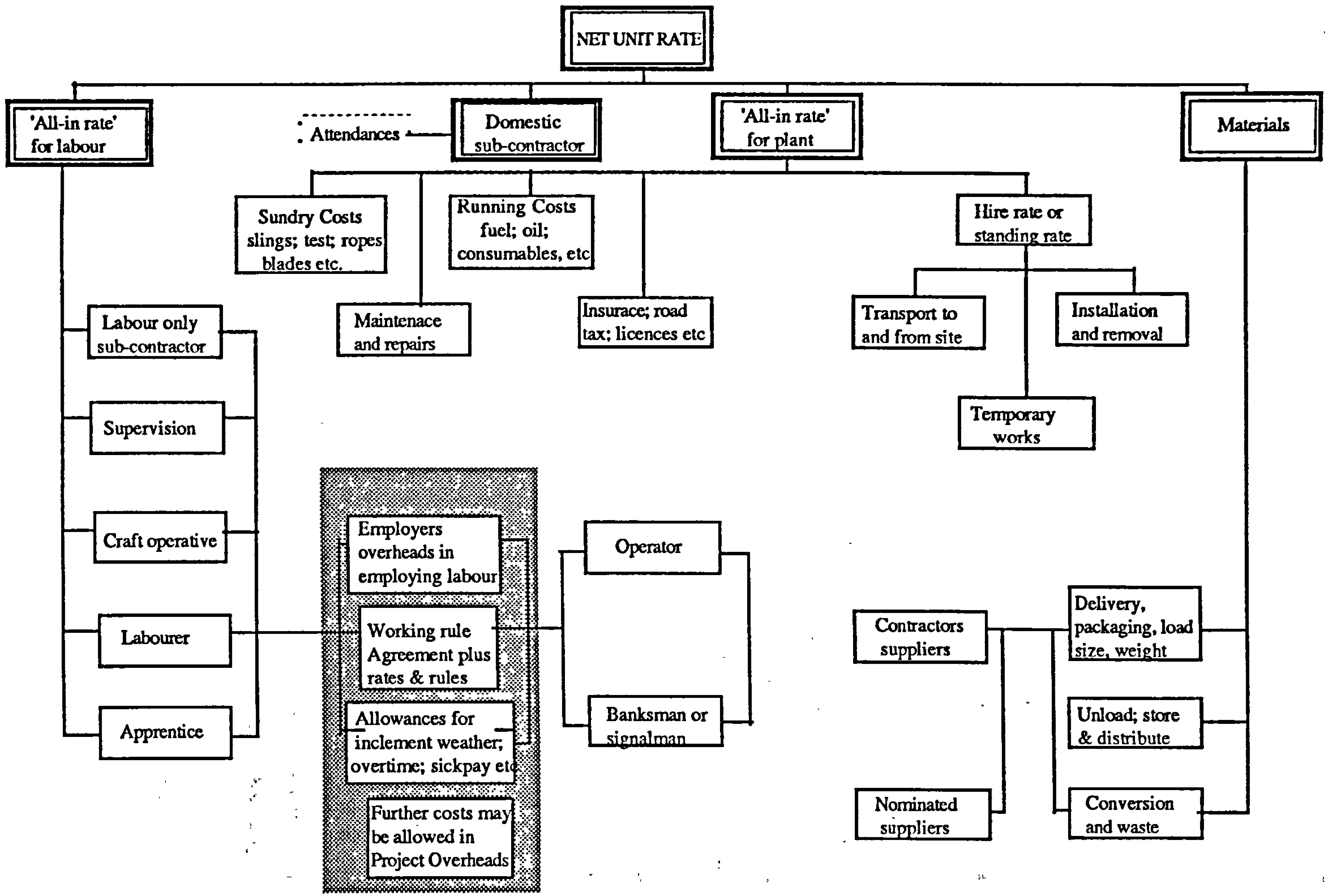
Job No.

Item Code No.	Quant Index	Tender rates: Ist Rate	2nd rate	3rd rate	Combined rates: 1st	2nd	3rd	Adjust. Avc.
1010214	101.0132205	1.21	1.06	1.2	1.3	1.31	1.56	1.36
1040801	1.3411840	42.75	7.5	40	47.53	9.29	52.15	35.14
1050101	23.1679792	25	10.35	10	27	12.82	13.04	17.30
1050102	4.2507999	25	27.5	14	27.79	34.05	18.25	25.83
1050201	1.3678488	50	10.5	37.5	55.59	13.00	48.89	37.89
1050400	125.6641383	29	30.56	27.07	138.97	37.84	35.29	68.41
1050402	8.4198844	33.5	44.18	32.33	37.24	54.70	42.15	43.25
1050912	10.7465024	75	102.5	21.56	83.38	126.91	28.11	76.89
1050911	22.525302	150	185	315	166.76	229.06	410.65	260.11
1051001	701.555640	154.63	135	121	171.91	167.16	157.74	160.23
1051401	10.2992642	50	16.5	15	55.59	20.43	19.55	30.82
1051501	85.1316446	8.8	15.24	10.27	9.78	18.87	13.39	13.56
1051520	10.0728229	5.43	9.58	4.11	6.04	11.86	5.36	7.50

To datafile with Job No.

APPENDIX C

COMPOSITION OF THE UNIT RATE



Source : CIOB, 1983

APPENDIX D

Estimating Experiment

<u>This experiment is not designed to test your ability/knowledge</u>

Information

The estimator on Project No 11 is faced with the task of selecting three (3) projects from which rates can be abstracted for predicting cost for the project. Information on ten (10) historical projects are available from three sources: **Olu** - expert estimator, **John** - Average and **Steve** - a novice. The information from each source must be paid for.

<u>All available information</u> on the 11 projects are attached (see attached sheets).

Typically, rates are abstracted from 3 'similar' projects. The rates are then treated as follows:

1. Where rates for one item is available from two or three projects the average rate is used.
2. Where rate is available from one historical project only, the single rate is used.

* In both cases adjustment is made to the rate to cater for market conditions - e.g. inflation, state of the construction market, etc.

3. Where no rate is available for the item the estimator may:
   a. work out a rate for the item - a tedious process.
   b. use rate obtained from published price book - an unreliable source.
4. Rates are abstracted from the winning tender only.

The design office is concerned with the accuracy of estimates. In choosing projects, consideration is given to the following:

1. Location - Geographical location of historical project and proposed project and site constraints.
2. Project size

3. Date - to minimise price adjustments
4. Source of price data - It is thought that the source of data affects the accuracy of predictions.
5. Type of project
6. Number of bidders
7. State of the market - It is noted that the construction market was less buoyant pre 1986 than it is after January 1986.

Rates can be obtained from the three estimators only after paying for each project desired. The office wants to minimise cost and will only pay for 3 sets of rates. The quantities for the projects are not stated. The new estimator thinks that Project 11 is a medium sized project and that the price should be around £1.1m.

The Task

Choose three projects for which you think rates should be obtained for the purpose of predicting price for Project 11. Enter the Project Numbers on the sheet below in order of preference (i.e. best project first). State your reasons for choosing each project below it in orde(of considerations given. Also state any considerations that affected your choice other than those given in the information above.

Thank you for your cooperation.

O. Ogunlana
Room (R014)

1. Project Number ______________

----

2. Project Number ______________

----

3. Project Number ______________

Rate yourself as an estimator.

Good | Average | Novice

Will your choices change if the estimator's guess is £250,000.00?

Yes | No

Thank you.

O. Ogunlana

PROJECT NO	1
PROJECT TYPE	Motorway slip roads
YEAR	1987-88
DESIGN	Traditional
SIZE	Medium
LOCATION	Junction 23
NO OF TENDER	6
ESTIMATOR	John
DURATION	6 months
OTHER DETAILS	Traffic control on site

NO	Description	Estimate	Tender
1.	Gen. Preliminaries	60,000.00	25700.00
2.	Site Clearance	27844.00	18009.68
3.	Fencing	17000.00	35066.86
4.	Drainage	125000.00	115532.63
5.	Earthworks	196000.00	190412.15
6.	Subbase and Roadbase	90000.00	76734.50
7.	Flexible surfacing	249000.00	259515.88
8.	Kerbs and Footways	45000.00	55985.87
9.	Traffic signs Road mrkgs	33015.95	48301.27
10.	Extension to culvert	1255.31	2042.29
11.	Water main protection culvert	81000.00	49350.32
12.	Dayworks	34500.00	34500.00
13.	Emergency telephones	11782.00	1306.00
	Total	971397.26	912507.45

PROJECT NO	2
PROJECT TYPE	Town centre Roudabout
YEAR	1988
DESIGN	Traditional
SIZE	Small
LOCATION	Shepshed
NO OF TENDER	6
ESTIMATOR	Olu
DURATION	1 month
OTHER DETAILS	Heavy traffic around site

No	Description	Estimate	Tender
1	Gen. Preliminaries	1000	-
2	Ste Clearance	2491.00	1526.70
3	Fencing	8106.00	8998.94
4	Drainage and serv. ducts	7246.00	5972.64
5	Earthworks	1070.00	874.29
6	Subbase and Roadbase	4900.00	4216.68
7	Flexible surfacing	12609.00	10032.87
8	Kerbs and Footways	9120.00	9243.45
9	Traffic signs mrkgs lighting	8263.00	8937.69
10	Public utilities	760.00	806.84
11	Site clearance	616.00	91.51
12	Drainage and servive ducts	1050.00	786.69
13	Kerbs and footways	6596.00	7208.31
14	Traffic signs	65.00	117.14
	Total	63892.00	58813.75

PROJECT NO 3
PROJECT TYPE ROAD

YEAR 1987

DESIGN Traditional

SIZE Small

LOCATION Kiswick Dr. Lo'bro

NO OF TENDER 5

ESTIMATOR Steve

DURATION 1 month

OTHER DETAILS none

No	Description	Estimate	Tender
1	Preliminaries	3326.50	1600.00
2	Site Clearance	1007.00	1096.99
3	Drainage	4213.93	5172.40
4	Drainage	-	399.50
5	Earthworks	2578.05	2602.20
6	Subbase and roadbase	6850.08	7473.80
7	Flexible surfacing	7578.67	9018.15
8	Kerbs and footways	7584.13	8861.64
9	Traffic signs & markings	126.00	124.08
	Total	33265.01	36349.36

PROJECT NO 4
PROJECT TYPE Road junction improvement

YEAR 1985 December

DESIGN Traditional

SIZE small

LOCATION Lougborough cemetry

NO OF TENDER 6

ESTIMATOR Olu

DURATION 3 months

OTHER DETAILS Heavy traffic control

No	Description	Estimate	Tender
1	Preliminaries	38300	30760
2	Site clearance	5000	3886
3	Fencing	15000	11703
4	Earthworks	19900	17781
5	Drainage	29000	41912
6	Subbase & roadbase	28000	31799
7	Surfacing	47200	56189
8	Kerbs and footways	22100	34361
9	Traffic signs	1500	4839
10	Streeet lighting	4500	3049
11	Subway	155000	93514
12	Dayworks	31500	26500
	Total	397000	356292

PROJECT NO	6	PROJECT NO	5
PROJECT TYPE	Road	PROJECT TYPE	Road (Bye-pass)
YEAR	1985	YEAR	1986
DESIGN	Traditional	DESIGN	Traditional
SIZE	Large	SIZE	Large
LOCATION	L'bro Forest road	LOCATION	Stanford
NO OF TENDER	6	NO OF TENDER	8
ESTIMATOR	John	ESTIMATOR	Steve
DURATION	10 months	DURATION	10 months
OTHER DETAILS	Heavy traffic control	OTHER DETAILS	A first part of a two stage contract.

No	Description	Estimate	Tender
1	Preliminaries	180330	185848
2	Site Clearance	10943	9948
3	Fencing	14466	13151
4	Eartworks	323915	294468
5	Drainage & sev. ducts	257164	233787
6	Subbase & roadbase	266223	242021
7	Flexible surfacing	321605	292368
8	Kerbs & footways	50678	46071
9	Movement joints	14853	13503
10	Traffic signs	14699	13363
11	Road markings	6975	6341
12	Road lighting	48659	44235
13	Accom. works	47993	43630
14	Additional works	-	-
15	Balancing item	-	-21912
16	Structures	906380	826217
	Total	2464883	2243039

No	Description	Estimate	Tender
1	Preliminaries	87000	498165
2	Site clearance	3504	10469
3	Fencing	4583	5104
4	Earthworks	864250	498862
5	Drainage	218984	234431
6	Main carriageway	714963	778684
7	Sideroads	76557	92261
8	River frame bridge	187301	392222
9	Traffic signs,markg,light	31162	24255
10	Ancillary works	25287	20308
11	Accom. works	52017	42962
12	Dayworks	50000	72370
	Total	2315608	2670093

PROJECT NO	7	PROJECT NO	8
PROJECT TYPE	Road	PROJECT TYPE	Road Construction
YEAR	1986	YEAR	1986
DESIGN	Traditional	DESIGN	traditionl
SIZE	Medium	SIZE	Medium
LOCATION	Wood House Eaves	LOCATION	Shelthorpe L'bro
NO OF TENDER	5	NO OF TENDER	3
ESTIMATOR	Steve	ESTIMATOR	Olu
DURATION	8	DURATION	6
OTHER DETAILS	None	OTHER DETAILS	None

NO	Description	Estimate	Tender
1	Preliminaries	116615	185548
2	Site clearance	17138	10173
3	Fencing	19855	18132
4	Eartworks	86213	130990
5	Landscaping	22550	19453
6	Drainage	127050	64422
7	Subbase and Roadbase	272029	201294
8	Flexible surfacing	143660	132018
9	Concrete pavement	22627	22776
10	Kerbs and footways	103895	117456
11	Traffic signs	13750	24247
12	Road markings	3509	5574
13	Road lighting	56650	38332
14	Pelican crossing	33000	8215
15	Structures	168495	15425
16	Accommodation works	11000	17588
18	Works for Stats services	-	1812
19	Dayworks	-	5000
	Total	1218036	1018455

No	Description	Estimate	Tender
1	Gen. Preliminaries	131661	153340.87
2	Ste Clearance	1650	18596.00
3	Fencing & Hedges	7832	8149.60
4	Drainage	17359	29279.10
5	Eartworks	229867	188374.26
6	Subbase & Roadbase	20099	29632.90
7	Flexible surfacing	19407	13026.33
8	Kerbs & Footways	7834	9924.82
9	Traffic signs & Markings	1760	408.63
10	Street lighting	5280	4939.00
11	Bridge Foundations	55330	61166.80
12	" Substructure	38642	42717.11
13	" Superstructure	31349	34656.56
14	" Finishings	14438	15961.13
	Total	582507	610173.11

PROJECT NO	9
PROJECT TYPE	Road maintenence
YEAR	1988
DESIGN	Traditional
SIZE	Medium
LOCATION	L'bro Thorpe Acre
NO OF TENDER	6
ESTIMATOR	John
DURATION	7 months
OTHER DETAILS	None

NO	Description	Estimate	Tender
1	Preliminaries	186493.21	165618.00
2	Site clearance	3755.72	3.934.90
3	Fencing & Fencing	66749.71	52032.60
4	Drainage	75742.34	81594.84
5	Earthworks	104773.39	115999.16
6	Subbase and Roadbase	219626.40	187346.39
7	Flexible surfacing	87698.04	91006.44
8	Kerbs and footways	37888.43	32485.89
9	Traffic signs & markings	6411.96	4255.07
10	Street lighting	14732.15	23545.82
11	Riv. Bridge Parapet works	157119.91	138486.67
12	Rail Bridge water proofing	46430.32	48494.37
13	Other bridge works	2922.75	4072.30
	Total	1218036	1018455

PROJECT NO	10
PROJECT TYPE	Road Improvement scheme
YEAR	1988
DESIGN	Traditional
SIZE	Large
LOCATION	Shepshed
NO OF TENDER	6
ESTIMATOR	John
DURATION	10 months
OTHER DETAILS	Heavy traffic around site

No	Description	Estimate	Tender
1	Gen. Preliminaries	260000	436735
2	Ste Clearance	13350	8403
3	Hedges	420	768
4	Fencing	41660	49396
5	Drainage	71000	76693
6	Earthworks	447450	304729
7	Subbase & Roadbase	187400	196342
8	Flexible surfacing	222000	133217
9	Kerbs & Footways	69750	50285
10	Traffic signs	35000	9841
11	Street lighting	36000	37702
12	Works for S.U.'s	35000	17324
13	Accom. works	40000	34988
14	Railway bridge	622000	467944
15	River Culvert	204000	221611
16	Canal Culvert	134000	111342
17	Pedestrian subway	108000	82206
18	Stream culvert	47000	41108
19	Retaining walls	228000	195352
	Total	2795030	2475995

PROJECT NO	11
PROJECT TYPE	Roundabout reconstruction
YEAR	1988
DESIGN	Traditional
SIZE	Medium
LOCATION	Lo'bro Epinal way
NO OF TENDER	6
ESTIMATOR	Myself
DURATION	8 months
OTHER DETAILS	Heavy traffic control

No	Description	Estimate
1	Preliminaries	
2	Site Clearance	
3	Fencing	
4	Earthworks	
5	Drainage & sev. ducts	
6	Subbase & roadbase	
7	Flexible surfacing	
8	Kerbs & footways	
9	Traffic signs	
10	Road markings	
11	Road lighting	
12	Accom. works	
13	Gutters	
14	Bridge Structures	
15	Bridge Foundations	
16	Pelican crossing	
17	Works for Stat. Under.	
	Total	About £1.1m

APPENDIX E

Cost Data Form

Project Type(e.g. housing, road, etc) ____________ Size (small, medium, large) ________
Year ____________ Design (Innovative, Traditional ________
Code for the Project ____________

		Estimate, Bids and Project cost							
			CONTRACTORS						
No	Element Description	QS/ Engineer	1	2	3	4	5	6	Final cost
1	Preliminaries								

Any other details (Claims, Dayworks, Variations, etc.)

Use two or more forms if necessary.

APPENDIX F

Construction Cost Estimating

This research is a student research designed to find out the opinion of pratising Construction Cost Estimators (Quantity surveyors and Engineers) and offices about certain issues that affect the accuracy (precision) of cost estimates. Responses to the questions will be treated as confidential. An annonymous summary will be prepared and sent to each respondent.

1. Do you normally make an element by element comparison of your estimates with tender figures / Final account figure:
   a. When predictions are close to tender figures ?
   b. When predictions difer significantly from tender figures ?

2. Which of the following do you compare estimates with ?
   Lowest Bid
   2nd lowest bid
   Median/Mean of bids
   Final Account figures
   Any other bid (Please Specify) ....

3. Do you think comparing estimates with any of the following will serve any useful purpose ?
   Lowest bid
   2nd lowest bid
   Mean/Median of bids
   Final account figures
   Any other bid (Please specify) ....

4. Please rate each of the following as they affect the accuracy of estimates (from your experience) on a 7 point scale. (eg 1-least effect on estimate accuracy, 7- most effect on estmate accuracy)

Number of Bidders
Design informaion available
Historical cost data
Project complexity
Project size   Estimator's expertise
Project location
Project type
Market condition
Project duration

5. Do you think setting a target e.g. low bid, median of bids, etc will help in improving accuracy ?
   Yes
   Cant say
   No

6. What level of accuracy is appropriate for design phase cost estimates ? Use office or/and personal standards.

+\-5%   +\-10%   +\-15%   +\-20%   Over +\-20%

7. What should be the datum for measuring the accuracy/precision of design phase cost estimates ?
   Low bid
   2nd lowest bid
   3rd Lowest bid
   Mean / median of bids
   Others (Please specify).......................

8. Please describe what you think helps you in improving the accuracy of your estimates. You may use the back of the paper if necessary.

9. Please indicate if you would like to receive a free copy of the programme for assessing estimating accuracy.

Yes   No

Thank you for your help with this research.

Stephen O. Ogunlana

ACCEST

ESTIMATING ACCURACY SOFTWARE

Olu Ogunlana 1989

ACCEST USER MANUAL

1.0 ABOUT ACCEST

ACCEST is a program written to:

1. assist the construction client's cost consultant in assessing the 'accuracy' of estimates; and
2. serve as a learning package for improving the accuracy of future estimates through continuous calibrations aided by outcome feedbacks. The results from the program may also be used for selecting project data for cost estimating, and for assessing the suitability of a tender.

*** ACCEST is not an estimating package.

1.1 The program

The ACCEST program is written in Fortran 77 language, compiled and linked on Micsrosoft Fortran 77 Version 4.10. The program runs on IBM PC XT/AT and IBM PS/2 and compartibles.

1.2 Installation

1.2.1 Hardware Requirements

The current version of ACCEST works on IBM PC XT/AT and IBM PS/2 and compartible machines. ACCEST can be installed on machines with Hard Disks or double disk drives monochrone or colour monitor. The memory requirement is 180k bytes. ACCEST runs on MS-DOS operating system.

1.2.2. <u>System Requirements</u>

Before running ACCEST on your machine, make sure that th Config.sys file on your machine contains the following instructions

1. File=x (x must be equal to or greater than 12. Find out how change this value from your DOS manual).
2. Device=ansi.sys (This will allow the ACCEST program to

theANSI characters available on most PCs. Reboot your machine after adding these instructions to the Config.sys file).

1.2.2 Installation Procedure

1.2.2.1 Installing ACCEST on the Hard Disk

1. Create a directory called for the program (e.g. EST) in your Hard Disk by typing **MD EST** at the C> prompt.
2. Enter the directory by typing **cd\est.**
3. Insert the ACCEST disk in drive A.
4. Copy the ACCEST program to the current directory by typing
   copy a:accest.exe
   or copy all files on the disk by typing **copy a:*.***
5. ACCEST should now work if you type ACCEST.

1.2.2.2 **Installing ACCEST on Double Disk Drives**

1. First make a working copy of your ACCEST disk by using the Diskcopy or the Copy facility in MSDOS (Copy ACCEST.EXE to one disk and the sample data to another disk [Data disk]).
2. Insert the copy of the ACCEST disk in drive A and the disk containing your data (see section 2) in drive B.
3. Change to drive B and start the ACCEST program by typing
   A:ACCEST

The ACCEST program should now start running. All new files will be stored on your data disk.

2.0 DATA ENTRY

The ACCEST program receives data both from the keyboard and through files.

2.1 Data entry through files

ACCEST accepts three data files:

- Project cost file (PCF)
- Project element description file (PDF)
- Final account file (FAF).

2.1.1 Project Cost File (PCF)

The project cost file should contain cost data for entry through the NEW option when running ACCEST. The file should contain numeric characters only.

The data contained in the PCF are estimates of cost made by the consultant for individual elements/cost headings followed by contractors' prices for the same element. Single spaces separate individual cost data. The data should be entered in real form to two places of decimal. In it's present mode ACCEST accepts a maximum of ten characters (e.g. *******.**). An example is shown below:

Data for Project AAA

*No.	Estimate	Cont. 1	Cont. 2	Cont. 3	Cont.4	Cont.5
*1	23000.19	22000.51	23054.67	24435.90	25550.09	20033.34
*2	10987.00	9087.23	11000.35	8978.90	13324.00	6987.98
*3	876876.98	893456.12	948765.23	1027649.35	772874.06	9428746.45

* Not included in the file.

Data Structure in PCF

23000.19 22000.51 23054.67 24435.90 25550.09 20033.34
10987.00 9087.23 11000.35 8978.90 13324.00 6987.98
876876.98 893456.12 948765.23 1027649.35 772874.06 9428746.45

Ideally, a carriage return <CR> separates data for two cost items.
*** Note that the number of entries for each element (on each line in this case) are the same. Where a figure is missing from the data, a rogue value may be entered. The user should note that the results for the element are then unlikely to be accurate.

2.1.2 Project Description File (PDF)

The project description file contains a description of the elements/cost items for which data has been supplied in the PCF. It accepts alphanumeric codes. The maximum length of each line is restricted to 40 characters.

For project AAA above, the following descriptions are possible:

Preliminaries
Site clearance
Concreting

Each line should contain a description of the corresponding item in the PCF.

2.1.3 The Final Account File (FAF)

The FAF, unlike the PCF and PDF, is entered through the OLD option in the Opening Menu. It contains numeric characters, like the PCF, representing the final cost recorded against each cost item in the project.
ACCEST asumes a one to one correspondence between items in the FAF and those in the PCF or/and PDF.

2.2 Data entry through the keyboard

ACCEST is fully interactive. The program is menu driven. Each menu requires input of number options through the keyboard followed by a carriage return <CR>.

****

The procedure outlined in this section will be best understood by running the ACCEST program with the sample data provided. The instruction assumes that this is your approach to learning to use ACCEST. Your keyboard entries are in **Bold** characters.

****

2.2.1 Data entry using the NEW option

2.2.1.1 Requirements

Before selecting the NEW option from the opening menu, ensure that the following are available:

1. The PCF - Cost file stored on the computer. See section 2.1.1
2. The PDF - File containing the description of elements. See

section 2.1.2
3. Detail information on the project to be stored. The details are listed below under Data Entry Routine.

2.2.1.2 Test Run
The opening menu of ACCEST appears thus.

```
1.  NEW PROJECT INPUT
2.  OLD PROJECT VIEW
3.  END THIS SESSION
```

Select number option:

**** All ACCEST menu are similar to this opening menu ****

When the NEW option is selected at the opening menu, ACCEST assumes that the user wishes to add a new project to the list of projects.
Below is a stepwise description of how the program runs after selecting the NEW option from the opening menu:

1. Type Selection
The program displays a list of project types and requests a number between 1 and 9 (inclusive). If a double digit number is entered, only the first digit is accepted.

Test run : 9 <CR>

2. Size selection

Projects under each type code are stored according to sizes. This menu **and** all other menus resemble the opening menu dispaled above.

Test run : **1** <CR>

3. **Data Entry Routine**

At this stage, ACCEST starts the Data Entry Routine. All options in this routine will show, in reverse video, the number of characters expected.

Number of Bidders

The first prompt is for the number of bidders. ACCEST currently allows up to 10 bidders (This may be increased on request). Type the appropriate number of bidders. Be sure that this conforms to the data in the PCF and PDF.

Test run : **4** <CR>

Prediction Date

A date should be entered for monitoring the age of the estimate. This date may be needed for updating later or for deciding on what projects are outdated. Enter the date as specified i.e. DD-MM-YY

Test run : **01-01-87** <CR>

Expiry Date

The expiry date will help the user to decide whether the accuracy of a prediction is affected by time overruns. Specify a date later than the prediction date.

Test run : **01-06-87** <CR>

Project duration

Enter the number of months (2 numeric characters max.) the estimator expected the project to run at the time predictions were made.

Test run : **6** <CR>

Estimator code

The estimator code allows the user to enter a unique code for the estimator. This allows indvidual estimator's perfomance to be assessed. 18 Alphanumeric caharcters are allowed.

Test run : **Steve** <CR>

Estimating method

State the method used for estimating. 72 Alphanumeric characters.

Test run : **Floor area method** <CR>

Time spent for estimating

The approximate number of days spent for preparing the estimate should be stated. (2 numeric characters)

Test run : **5** <CR>

Client description and Location

A description of the project may be entered. This description will be used later in the selection of projects. 40 alphanumeric character e.g. Civil Engrg, Southfields, Loughborough.

Test run : **County Council No 1, 1987** <CR>

Documents

The documents prompt allows you to enter a list of documents used in predicting costs for the project. Although a limit of 10 documents is provisionally set, it saves time, cost and space to limit the number to 2, 3 or less.

****

To quit the routines with number counts, type **ok. There must be at least 1 entry before typing ok.** Type **none** as the first entry if you do not wish to store any details here.

****

Information rating

The estimator is allowed to make a subjective assessment (rating) of the information used for estimating. It is expected that the accuracy of estimates should improve with the quality of information (in theory).

Test run : **s** <CR>

Unusual conditions

Conditions in the project situation which makes accurate cost forecasting difficult should be entered. e.g. absence of information on ground conditions.

Refer to Documents for quiting prodecure

Test run : **Poor subsoil** <CR> **ok** <CR>

Price level

A description of the prevailing price level in market when the estimate was prepared is expected. Select a letter option.

Test run : **u** <CR>

Source of price data

The sources from which cost data were collected should be stated e.g. in-house data, Wessex Dbase, Market research, etc..

Test run : **In-house data** <CR> **ok** <CR>

Refer to Documents for quiting procedure.

Bid Parameter

Usually in making cost predictions, the estimator should have in mind a parameter that is being predicted e.g. Low Bid, Final Cost, Mean Bid, etc. Specify a parameter and use this to judge the closeness of predictions to predicted parameters.
A maximum of 20 characters allowed.

Test run : **Low Bid** <CR>

Need for the estimate

The purpose for which the estimate was prepared should be stated for future reference e.g. to advise designers, budgeting, etc..

Test run : **Advice to designers** <CR> **ok** <CR>

Refer Documents for quiting procedure

Assumptions

The assumptions option allows the input of a list of assumptions made by the estimator at the time of predictions e.g. the roof will be redesigned, the project will be executed in 1988, Cement prices will fall soon, etc. Assumptions should not be mere repetions of what has be included under other options.
Refer Documents for quiting procedure.

Test run : **Keen competition for this job will reduce tender sum** <CR> **ok**

Element Description Filename

Enter the name of the file containing the description of elements (Cost headings) PDF. Refer to Section 2.1.2 for the description of this file.

ACCEST allows 6 Alphanumeric characters for the filename
Test run : **olu1e** <CR>

Element number
Enter the number of elements (Cost headings) for which data are available in the PCF and PDF.
Test run: **13** <CR>

Element Data Filename
Enter the name of the file containing the cost data (PCF).
Test run : **olu1d** <CR>

Results
If you have successfully gone through the data entry routine, the program should now produce some results. Refer to Section 3.0 to continue.

2.2.2 Data Entry through the OLD option

2.2.2.1 Requirements
The only requirement for using the OLD option is that at least one project should have been stored using the NEW option.

2.2.2.2 Procedure

1. Select Old in the opening Menu.
   Test run: **2** <CR>
2. Select an appropriate project type from the type menu
   Test run : **9** <CR>
3. Select an appropriate Project size from the size menu.
   Test run : **1** <CR>
4. If there are no old projects stored for the type and size selected, the program returns you to the type selection menu.
If there are projects stored under the code, the projects will now be listed under the code C + type + size e.g. C91

Project selection menu

Select the appropriate project. If a wrong number is input, the program should state so and allow another choice.

Test run : 1 <CR>

Project File Selection

This menu allows the user to view or/and output information stored on the computer about the project selected. The divisions are as follows:

1. General information

All information on the project entered manually through the NEW option.

2. Element description file

The description of the elements as stored by the program.

3. Data File

The PCF - file containing cost data.

4. Final Cost File

The final cost of the project if already stored in the program.

5. Input final cost file

This option allows you to input the final cost file (FAF).

There are 3 further prompts:

i. Final account filename (6 characters). See section 2.1.3

ii. Prompt for the number of bidders (Must correspond with section 2.2.1.1).

iii. Prompt for number of elements (Must correspond with section 2.2.1.1)

If you are successful, the program will create a new file and return you to the File selection Menu.

6. All project files.

This option allows you to output all files 1, 2, 3 & 4 in that order. A pause follows the output of each file.

7. Exit option.

Allows you to exit the routine and commence further processing.

3.0 RESULTS

3.1 Available Results

1. Percentages - A display of the distribution of project costs (Estimate and tenders) under each cost heading as a percentage of total cost.
2. Accuracy Calculations
3. Final Account Comparisons
4. R-values

3.2 Using the results

3.2.1 Screen and Paper Outputs

All the results listed in Section 3.1 are displayed on the screen. Paper versions can be produced by using the facilities provided on MS-DOS. To produce a hard copy of the result, make sure that the printer is properly connected to the computer and ready for printing. Use the PrtSc button to print results as shown on the screen.

3.3 How ACCEST helps you

3.3.1 Percentages

The percentages show the distribution of prices under each cost heading (element). This facility may be used in assessing whether a bidder has loaded a particular element for his own gains. The relationship between individual bidder loadings and the opinion of the consultant on how costs should be distributed can be used to determine the suitability of a bid.

The estimate for each element is shown under column headed 1 in the program output.

3.3.2. Accuracy Monitoring

ACCEST allows the user to relate prices on these levels:

1. Price Relative to Low Price

This facility relates, on an elemental level, the prices submitted by the individual bidders to the lowest price for the element. The parameter calculated is:

$$D = \frac{\text{Bidder Price - Low Price}}{\text{Low Price}} \times 100$$

2. Price relative to the Mean Price

This facility relates, on an elemental level, the prices submitted by the individual bidders to the mean price for the element. The parameter calculated is:

$$D = \frac{\text{Bidder Price - Mean Price}}{\text{Mean Price}} \times 100$$

3. Price Relative to the Median Price

This facility relates, on an elemental level, the prices submitted by the individual bidders to the median price for the element. The parameter calculated is:

$$D = \frac{\text{Bidder Price - Median Price}}{\text{Median Price}} \times 100$$

These relations allows the user to monitor the movement of prices around the three parameters.

4. Estimate Relative to Bids

Another facility provided through the accuracy option is the relationship between the estimate and the bids. The parameter calculated is:

$$D = \frac{\text{Esimate - Bidder Price}}{\text{Bidder Price}} \times 100$$

The estimator sets a target and asseses the ability to hit the target correctly. This can be used in conjuction with the other figures ACLOW, ACMEAN, ACMEDN, etc. in forecasting probable bid distribution for other projects.

5. Accuracy Level

The values headed AC... show the result of the estimator's predictions when different parameters are taken as the 'true cost'. The expalnations are as follows:

ACLOW	- Accuracy in predicting the Low Value
ACMEAN	- Accuracy in predicting the Mean Value
ACMEDN	- Accuracy in Predicting Median Value

EXAMPLE:

3.3.3 Final Account Comparison

The final account option allows the user to assess the accuracy of the estimate and bids assuming that the final cost is thc 'true cost' for the project. The assessment is done at the element level. The parameter calculated being

$$D = \frac{X - \text{Final Value}}{\text{Final Value}} \times 100$$

X may be the estimate, low bid, mean, etc.

3.3.4 R-Values

R or Residual values allow the user to monitor the movement of bids from the estimate. The parameter calculated is

$$R = \frac{X}{\text{Estimate}}$$

X may be the low bid, final value, etc.

Studying the movement of the bids over time allows informed setting of targets for estimating. For example: By using Fig 1, Bid distributions may be constructed around the targets (Mean in this case) using other results from the program e.g. Standard deviation (SD), Mean, etc.

** In all cases, the last value is the overall figure for the project.

4.0 HOUSE KEEPING

1. You may wish to delete the PCF, PDF and the FAF after the program has created its own files from them.
2. Be sure to make a working copy of the ACCEST disk for day to day use.
3. It is safer to put your program and the data files in different directories if you are using the Hard Disk. The program can be run from the directory containing the data by using the PATH statement in MS-DOS. You may wish to add a path statement with the name of the directory containing the program to the AUTOEXEC.BAT file. The program will then create all files in the data directory.

Final Note

It is hoped that by using ACCEST the accuracy of estimates can be improved by monitoring error levels and systematic adjustment of predictions for new projects.

Last Line

If you experience any difficulty in using ACCEST, you may wish to phone me on Loughborough (0509) 263171 ext 4133.