AN INVESTIGATION INTO FACTORS THAT AFFECT THE ACCURACY OF COST ESTIMATES FOR BUILDINGS : CASE STUDY OF PRIVATE RESIDENTIAL AND OFFICE PROJECTS IN THE CITY OF NAIROBL

BY

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DECLARATION

This research project is my original work and has not been presented in any other University.

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(ii)

DEDICATION

To my dear wife Catherine for her love, support and encouragement; and to my sons Denis, Kelvin and Alex for their inspiration.

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This study and the entire course would not have been possible without the patience and help of the Almighty God.

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ABBREVIATION

BICS - Building Cost Information Services

C.V - Coefficient Variation

IQSK - Institute of Quantity Surveyors of Kenya

IT - Information Technology

SMM - Standard Method of Measurement

ABSTRACT

The purpose of all pre-tender estimates is to provide an indication of the probable cost of the new construction. Decision-making at the early stages of a project, initial appropriations and economic feasibility studies are based upon the preliminary or pre-design cost estimates. It is apparent that predicting costs accurately is a problem in construction industry especially at the pre-tender stage. The methods used to predict project building costs include the unit method, floor area method, approximate quantities, elemental analysis and pricing of bills of quantities before tender.

This research sought to determine the magnitude of the influence of cost estimating methods used in the prediction of construction costs. It also identifies other factors that cause inaccuracy and their magnitude of this effect on overall accuracy. The study hypothesis is that cost estimates do not accurately project pre-design stage costs used as a guide for investment decision making process.

This work adopts a survey research design and concentrates on private residential and office buildings in city of Nairobi. The population of which is the number of projects handled by professional quantity surveying firms. The resultant data is then analysed by the SPSS software to derive correlation, regression and resultant statistical parameters.

This research examined the problem of the quality of conceptual estimating. It assessed the usage of historical and empirical information which had been used in the pre-tender cost estimates, and ascertained whether it is possible to get an appropriate initial assessment of the expected accuracy and reliability of a cost estimate. This is then compared with successful bidder or the lowest tender figure awarded the contract.

The findings of this research is that pre-design cost estimates as currently used in the industry do not significantly project the actual construction costs and this negates their reliance as a guide for investment decision making process. The research recommends that a more elaborate database be developed and other building parameters such as building type, and project scope, which the study found significant should be incorporated.

The study concluded that the building type and scope/size of projects are the major determinants of cost estimating functions. The study recommends that the quantity surveying firm must be critical on the type and scope /size of the office and residential buildings when doing their cost estimations.

Chapter One

INTRODUCTION

1.1 Background of The Study

Cost information on buildings is normally based on "unit rates" which assume that costs bear a simple and direct relationship to units of finished work such as the area of a wall (Morton and Jagger 1995, p 27). This is the genesis of a fundamental problem of accuracy and reliability. Morton and Jagger (Morton and Jagger 1995, p 27) suggests that this method does not accurately reflect the way costs are generated in the building process, as the method is a considerable barrier to accurate prediction and control. A study of the evolution of building elements reveals a general aim to improve cost efficiency through design and construction (Ashworth 2004, p 98). It is becoming increasingly apparent that to predict costs accurately is a problem which is common to all industries.

It therefore emerges that there is need for pre-tender price estimation with reasonable accuracy that helps the client decide whether to build or not. The purpose of all pre-tender estimates is to provide an indication of the probable cost of the new construction. The single most important intention of the estimate is its accuracy (Ashworth 2004, p 97). Floor area method is perhaps the best known product-based cost model and provides the data upon which initial estimates are based. This techniques is currently used by the quantity surveying firms at large, in spite of a number of failings which have become apparent over the years. Ferry et al (1999, p 121) argue that a process that actually generates the costs as they are incurred is likely to be more accurate. However, using the floor area method, the construction process cannot be modelled until the form of the building has been postulated and therefore the process based model has little place in its application. The floor area method takes no account of the configuration, or details of the building design, and is only simply based upon one of the following (Ferry et al 1999, p 120):

- The floor area of the proposed project (gross or net)
- The volume of the proposed project or
- Some user parameter such as number of pupil places for a school or number of beds for a hospital.

The method automatically excludes site works from the single price rate calculation and estimates them separately. This is because their cost has no relationship to the size of the building. The engineering services are also sometimes treated in the same way with rather less justification.

Cost control is something which the design team tries to achieve using various cost estimation methods, by trying to keep the cost of building within the limits of the predetermined estimate, throughout the design and construction stages of the project (Seeley 1991). Cost planning and control begins at the pre-design stage using this method. Pre-design estimating refers to computing the probable cost of the new works at some stage before the complete drawings and bills of quantities are prepared, which act as the basis for final estimating preparation.

Decision-making at the early stages of the project, initial appropriations and economic feasibility studies are based upon the preliminary or pre-design cost estimates. The method therefore chosen to come up with a cost estimate should not deviate from accuracy a lot so that figures close to the actual construction costs are realized.

1.2 Problem Statement

A number of cost estimating methods are used to ascertain and possibly project building costs at the pre-tender stage. These include the unit method, floor area method, cube method, approximate quantities, elemental analysis and pricing bills of quantities before tender.

The most commonly used cost estimating method was the floor area method (The Quantity Surveyor 2001). This is largely a post second world war method, which had application in public building facilities that were identified such as schools and residential developments (Ferry et al 1999, p 121). Such an estimate merely attempts to forecast that a building of a certain size can be built for a certain sum of money. It cannot analyze whether a particular design is going to meet that cost. It is possible to weight the estimate subjectively on the grounds that the proposed solution looks to be at the expensive end or the low-cost end of the market, but this subject the work into the realms of guesswork. The other methods of cost estimation require more information at the design stage.

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1.3   Objectives of the Study

The main objective of the study is:-

i.   To establish the variation between costs estimates derived form the various estimation methods.

ii. To establish factors that have direct influence on the cost of residential and office projects in Kenya

iii. To establish the deviation of construction cost estimates from actual tenders received

1.4   Research Questions

i.   What is the magnitude of variation between preliminary costs estimates derived from the various estimating methods?

ii. What are the factors that have a direct influence on the cost of a project?

iii. What is the level of deviation of cost estimates to those derived from the tendering process?

1.5   Hypothesis

The Null Hypothesis: Cost estimates do not accurately project pre-design stage costs used as a guide for investment decision making process.

The Alternative Hypothesis: Cost estimates do accurately project pre-design stage costs used as a guide for investment decision making process.

1.6 Scope of the Study

The study was limited to residential and office buildings. This is because they comprise the bulk of construction work in Nairobi. In addition, the preliminary cost estimating methods has the large applications in the residential and office building projects. The scope of this study is limited to case studies of private residential projects in Kenya, in five forms of low-rise apartments, residential maisonettes, bungalows, low and high rise office blocks. Only private residential building projects are considered in the study. The rationale for this decision is that there is a general economic and social need to provide housing and office accommodation for the increasing urban population in Kenya. Hence, findings of this study have theoretical and practical applications in a more liberalized construction market for estimating residential houses and office buildings.

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Only projects in the city of Nairobi were included in the study sample. Nairobi accounts for over 60% of the cost value of the private building projects in the main towns of Kenya (Republic of Kenya 1991 - 95). Further most quantity surveying practices are located in Nairobi, even for projects located outside the Nairobi City. Residential and office buildings started and completed within the last ten years (1996 to 2005) were included in the sample. This period was considered long enough to reveal the behaviors of cost trends in the Kenyan building industry and explain costs distributions of private building projects.

1.7 Assumptions

This study made the assumption that the main aim of preliminary cost estimation is to forecast the future cost of a project; and to control its building design to ensure that the estimated figure is close to the tender figure and probably the final project cost.

1.8 Significance of the Study

This study seeks to avail information for use by the various construction industry stakeholders; clients professionals, contractors, investors and researchers.

The study has identified areas that cause estimating inaccuracies when using various cost estimation methods and make recommendations on how to improve on the methods. With inaccuracies and variations being reduced, it is expected that the clients would start actual financial planning with greater certainty. The results of this study will have practical application in the cost estimating and cost planning practice. The study is a step towards the development and establishment of a cost estimating model system to be used in the building industry in Kenya. In addition, it is hoped it will lead to development and refinement of computer software to be used for cost estimates for putting up residential and office buildings in Kenya. An insight of applicability and relevance of the preliminary estimating methods to the Kenyan situation would be availed. This would act as a catalyst for further research in the field of cost modelling.

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1.9 Structure of the Study

This research project has five chapters and their contents are briefly outlined below.

Chapter one discusses the problems of preliminary cost estimating. It discusses the effects of implications of potential avenues of inaccuracies. It includes the objectives, hypothesis, scope and significance of the study.

Chapter two discusses the concept of accuracy and its difficulty especially because of non-availability of required information in early stages. It formulates a domain of reasonable accuracy which envisages availability of estimates for the purpose for which it is required. It discusses the various forms of estimates at different stages of the project and their levels of accuracy depending on information available.

Chapter three gives the methodology to be used in the study. The research design, the Population, sample, data collection instruments and methods employed.

Chapter four handles the analysis of the independent and dependent variables. The data interpretation and presentation in the forms of descriptive and inferential statistics is made and their explanations thereof.

Chapter five covers the conclusions of the research findings, gives recommendations of the study and finally suggests possible areas of further study.

Chapter Two
LITERATURE REVIEW

2.1 Introduction

This chapter gives an overview of the past findings covering the wider aspect of cost estimation. It further discusses the various forms of estimates, area of application and their limitations. Cost estimation methods are elaborately discussed together with related researches done by others in this domain. The chapter builds up the main approach of the study through its understanding of the concept of 'estimation' is formulated and used to define problem areas of estimation.

2.2 The Brief

"Design" may begin even before a full brief is established as soon as the client who is the person or Institution for which the building is to be built makes a decision to construct a building in a particular way in a particular place. At this first stage, as the brief is considered and developed, some idea of cost has to be established quickly. There may already be a budget limit but if not the client will need to know what order of cost is likely to be involved the "cost bracket" (Morton and Jagger 1995, P 19). Feasibility studies involve financial as well as functional and technical requirements (Figure 2.1). Although there is bound to be much rethinking in the early stages, it is critically important to settle on major decisions as it become increasingly expensive and unrealistic to make changes to the design as building proceeds (Morton and Jagger 1995, P 19).

The Cost Determinants: The two most obvious determinants of the overall cost of a building are its function and size. The floor area method is "crude" and simple way of estimating what a building is going to cost, often used by Architects and Quantity Surveyors as a first guess — and sometimes surprisingly accurate (Morton and Jagger 1995, p 36). It takes the proposed size of a building (in square meters of floor area) and multiplies that by the average current costs per square metre for buildings of that type in that region (Figure 2.2).
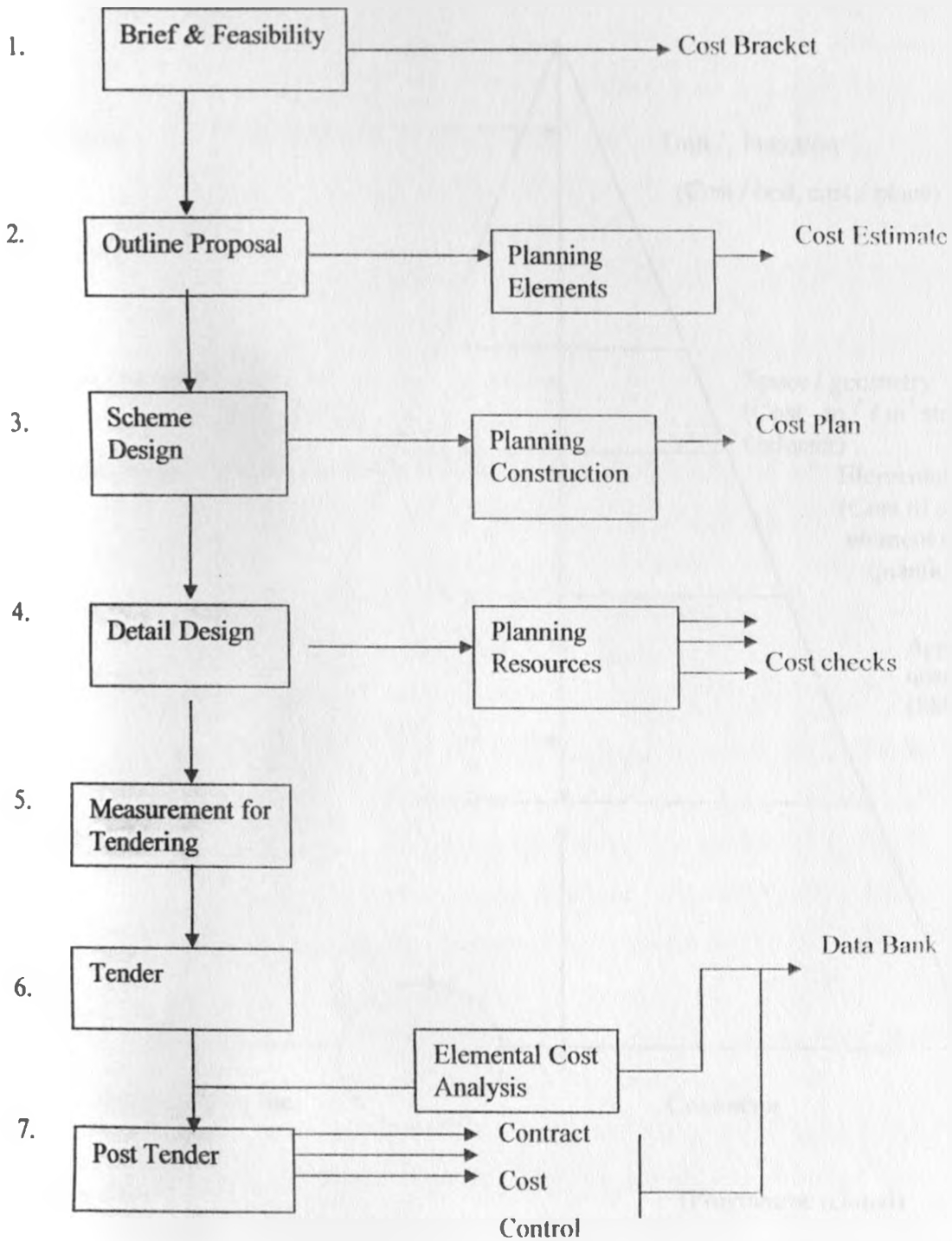
Figure 2.1   RIBA Plan of Work – Cost Stages
(Source: Morton and Jagger 1995, p 19)

The figure shows a triangular (pyramid) diagram representing traditional cost modeling, with design stages on the left side and cost model types on the right side.

Left side labels (top to bottom):
- Feasibility
- Outline Proposals
- Scheme design
- Detail design
- Operations on site
- Resources

Right side labels (top to bottom within the triangle):
- Unit / Function (Cost / bed, cost / place)
- Space / geometry (Cost m^2 / m^3 storey endorser)
- Elemental (Cost of element – element unit quantities)
- Approximate quantities (SMM related)
- Detail quantities (SMM related)
- Activities programme related
- Contractor
- (Programme related)

Feedback limited to contractor interest.

Figure 2.2   Traditional Cost Modeling

Source: Adapted from Ferry and Brandon 1999, p 113

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Simple and conventional ways of analyzing a buildings cost are varied. There are thus many different, but equally valid, ways of defining the total cost of a building, depending on the perspective from which the problem is being viewed; whether from the contractor or the client. (Morton and Jagger 1995 p 289) argue that the analysis of costs by element, based on bills of quantities, cannot reflect truly the way costs are actually incurred or generated, mainly because it ignores the interaction of one element with another and take insufficient account of the actual process of construction, which consists of bringing resources together under particular conditions.

2.3 The Need for Cost Estimation

How can all the parties engaged in the building process ensure that maximum value for money in all senses of value is achieved – or approximated as closely as possible – in a world of great uncertainty? Despite how sophisticated the systems become, there remain two certain difficulties which are inherent in the building process itself, and which explain why accurate cost reduction has always been such an intractable problem. The initial difficulty is that accurate estimate of a buildings cost cannot be made until the details of the designs are known expect to some extent in the case of standard repeated building types. Nonetheless, the client needs knowledge of cost before commitment to the contract and its detailed design. The techniques developed over the years to overcome these central difficulties though criticized as relatively crude have remained in use. The fact that a hundred years of ingenuity has ultimately failed to come up with a perfect solution indicates the depth of the problem.

The Initial Estimate: The cost-prediction and cost planning, techniques developed make the best use of information available at each stage in the development of the design. Striving to achieve optimization in cost is only a part of the total objective of initial cost-predictions (Ferry et al 1999, P 105). While all consultants would like to achieve optimization in their own sub-system of activity, it is the performance of all systems acting together that determines the degree of initial cost accuracy.

At the very beginning, even before the brief itself has been formulated, clients may be approaching their decision from one of two different directions or from somewhere in between. First they may have a clear idea of the building required in terms of its function and size and

need to know how much it is likely to cost, having been given a rough estimate they can then adjust their expectations of the buildings specification or raise the budget.

Alternatively, a client may have a very firmly fixed budget and want to know the kind of building to expect for a given amount of money or perhaps also what trade offs are possible between aspects such as quality of finish and size before making a decision.

Cost Planning and Cost Control: The percentage deviations of residential and office building project from achieving the specified time and cost targets observed when the building is completed are normally used by researchers and practitioners in the building industry to measure the level of the client's satisfaction with the performance of the project team (Baradyana 1996, Mbatha 1986, Mbeche 1994, Sidwell 1985). A key process by which the project team strives to achieve this time-cost-quality-utility goal is the process of 'cost control' which mainly falls in the domain of Quantity Surveying and Construction Project Management. Cost control refers to all methods used in controlling the cost of a building project within the limits of a predetermined estimate, throughout the design and construction stages of the project (Seeley 1991, p 14). Building cost refers to the amount which the client will have to pay the main contractor and sub-contractors to construct the building or procure a facility immediately upon completion.

Cost block control aims at keeping the total cost within the amount agreed with the client, by doing pre-design estimating, cost planning, cost checking and taking remedial action where element costs exceed the planned target during the design and construction further the control of aims at achieving a balanced and logical distribution of the available funds between various elements of building.

Project cost planning at the design stage entails the preparation of a cost estimate and a cost plan and carrying out of cost checks. Cost planning and control begins at pre-design otherwise referred to as preliminary or approximate estimating. Pre-design estimating refers to computing the probable cost of new works at some stage before the bills of firm quantities, which acts as the basis for final estimates can be prepared. This estimating sets the cost ceiling within, which the design and construction of the building should proceed.

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Decision - making at the early stages of the project, initial appropriations and economic feasibility studies are based upon the preliminary or pre-design cost estimates. In the Kenyan building industry, single price rates estimating, rate per square metre, elemental cost planning, approximate quantities, operations and resources planning are the methods commonly used by Quantity Surveyors in forecasting and planning building costs. These method needs to be re-examined to ascertain whether they have been predicting building costs to within acceptable levels. In practice, the most commonly used pre-design costing is calculated from analysis of previously completed buildings. To facilitate thorough cost updating for variations in design and construction (time, quantity, quality and utility) in the new project as compared to the previous job, the overall superficial unit cost is broken down into elements and sub-elements using elemental cost analysis of the previous job as the basis for the breakdown.

The 'updating' for time, quality, quantity and utility is carried out using straight-line adjustments for difference in floor area and applying building cost indices for adjustments in time, and "professional judgement" for adjustments in quality and utility (Raftery 1991, p 169). As more design information becomes available, approximate quantities can be measured and quality adjustments be made more accurately and more objectively. To the approximate cost estimate which is obtained using approximate quantities is normally added or deducted to account for market considerations such as the likelihood of increased costs occurring between the date of preparing the estimate and the date of letting the contract. The adjustment for quality and utility is based on expert intuition; there are no clear guidelines for making the adjustment.

The importance of professional experience and expert judgment that are applied in the cost prediction method described above are not disputable. Expert intuition has been considered and correctly used, as a significant ingredient in the practice of cost prediction (Kous Kaulas and Koehn 1974, p 590, Raftery 1991, p 185, Seeley 1992, p (iii). This notwithstanding, the use of the traditional method of cost forecasting causes a serious discomfort in the building industry. The pre-design and even final building cost estimates have quite often been observed to deviate significantly from tenders, leaving the quantity surveyor who is the estimators frustrated. As an example, Thuo's cost forecast "through" price enquiries and mathematical analysis, indicated that the predicted costs bear no close relationship with the actual; but he

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seems to suggest that this situation is attributable to the fact that he was "forecasting during recession"(2000, p 11). This is highly debatable; a good reliable forecasting model should factor-in the influence of national or sectoral economic boom and recessionary forces. Existing cost estimating methods fail to take into account of economic down turn in a country and its effect on building costs

Gitau attributes Thuo's situation to the lack of reliable database for the building costs (2000; p 15). However, a more refined technique of cost modeling is highly likely to increase significantly, the gain from the existing cost data (Raftery 1991, p 184).

The building cost estimate carries a lot of unpredictable uncertainty and is likely to be detrimental by the decision maker and owners financing a project. Pre-design cost estimates need to be adequately accurate because as stated earlier initial appropriations and economic feasibility studies are based on such estimates. The impact of information technology (IT) has brought potential for improvement in cost modeling techniques. This coupled with new procurement methods will lead to reduced building costs, more predictions of likely costs and less period for carrying out initial cost estimates.

Ideally, the model cost for use in pre-design cost estimation should be inexpensive quick and reasonably accurate. Kous Koulas and Koehn (1974, p 589) observe that detailed quantity takes-offs and accurate cost estimates are too expensive to the clients and contractors and time consuming to the estimator. Nonetheless, the degree of accuracy will very much depend on the type of information provided to the quantity surveyor and the quality of pricing information and judgment that is used (Ashworth 2004, p 265)

Importance of Cost Estimation: There has in recent years been a great need for an understanding of construction economics and cost control, particularly during the design stage of projects. The importance of this is due largely to the following according to Ashworth (2004, p 5): -

- The increased pace in society in general has resulted in clients being less likely to tolerate delays caused by redesigning building when tenders are too high.

- The client's requirements today are more complex than those of their Victorian counterparts. A more effective system of control is therefore desirable from inception up to the completion of the final account, and thereafter during costs-in-use.

- The clients of the industry often large organisations and financial institutions have had an increased emphasis on accountability in both the public and the private sectors of the industry. The efficiency of these organizations at construction work is only as good as the type and quality of information used in the analysis.

- There has been a trend towards modern designs and new techniques, materials and methods of construction. The designer is able to choose from a far wider range of products and this has produced variety in construction. The traditional methods of estimating are unable to cope in these circumstances to achieve value for money and more balanced designs.

- There has, in general, been a move towards the elimination of waste, and a greater emphasis on the use of the world's scarce resources. This has necessitated a desire for improved methods of forecasting and control of costs.

The Cost Feedback Mechanism: The traditional principle of gathering site performance data from previous project known as feedback is predominantly in application. The estimator uses standard outputs, influenced by size, complexity, quality and the like, to estimate the costs of work to be performed (Ashworth 2004, p 55). If the contractor is successful in submitting the accepted tender then the work is put into practice and during construction, is monitored by site management staff. The monitoring is frequently carried out incidental to other purposes such as incentive calculations. These calculations require quantities of work to be measured against the labour and time that have been expended. However, the practice is that such information is not routinely used by estimators or quantity surveyors in calculation or revision of outputs for the following reasons:

- It is very variable in terms of the output it generates.
- There is insufficient confidence, by estimators, in the site recording system.
- The information is often not compatible with future estimating needs.
- There is a difficulty in reusing the data because of the unique circumstances under which the work has been carried.

The traditional method used for estimating purposes has been to develop a classification system against which to record costs. The outputs achieved on similar work from previous projects should be the major source of information used in estimating. However, construction work requires a complex system against which to record this information. Research has shown that the reliability of any cost recording system substantially deteriorates when the number of cost codes exceeds 50 (Ashworth 2004). The cost code system used in the construction industry is a four-digit system.

The complexity of construction work and the fact that most projects are bespoke one-off designs (Ashworth 2004 p 56). Even projects that are considered to be "identical" record different actual outputs and costs and that makes the process difficult to achieve in practice. Evidence indicates that different sites record different feedback values for apparently similar items of work.

Production standards, for both labour and plant, are likely to be influenced by a whole range of project characteristics. Estimators when adapting a standard output need to assimilate these different factors in order to arrive at a best estimate for the work. Some of the characteristics that need consideration:

- Location and accessibility of the work
- Amount of repetition in the work
- Intricacy of the design
- Need for special labour skills
- Quantity of work involved
- Quality of materials used
- Standard of workmanship
- Working environment such as safety, temperature, cleanliness etc

When using bills of quantities, analysis of costs by elements is done. But this cannot truly reflect the way costs are actually incurred or generated as they ignore the interaction of different buildings elements. The analysis of costs by element, based on bills of quantities, cannot reflect truly the way costs are actually incurred or generated, mainly because it has ignored the interaction of one element with another and takes insufficient account of the actual

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process of construction, which consists of bringing resources together under particular conditions.

Design decisions take account of the relative costs of different ways of combining those resources in determining the material to be specified, the form of the building, the structural system to be used and the way the internal environment is to be controlled (Ashworth 2004, p 56).

However, carefully the initial designs are costed and however buildable the design, there is still scope for major discrepancies between estimates and actual cost if the basis of the cost analyses and system of cost planning and control do not reflect the realities of construction.

2.4 Cost Estimating Methods

The cost prediction and cost-planning techniques that have been developed try to make the best use of information available at each design development stage (Murton and Jaffer 1995).

At the very beginning, even before the brief has been formulated clients may be approaching their decision to build from one or two different directions. They may have a clear idea of the building required, in terms of its function and size and need to know how much it is likely to cost. Having been given a rough estimate, they can adjust their expectations of the building specification. They may look again at the budget to see if it can be raised. Clients may also have a very firmly fixed budget and want to know what kind of building can be expected for the money.

Obviously estimates made at this stage cannot take account of any specific characteristics the design of the form that the building might have. There are certain methods that are used to get an initial estimate and they include the following discussed below.

Unit Method: Estimates based on function or performance related. This is extremely simple and can be used when minimal information is available. It is not however, applicable where the function of proposed building is new, unique or its proposed design very different from the conventional. The principle is to use information available on other buildings of similar function to identify some kind of unit cost- for example cost per student for a college, cost per

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be space for a hospital, and the population to be served by a library. Its major disadvantage is lack of precision and thus it's just a blunt tool for only establishing general guidelines.

Superficial Area Method: It is the most commonly used method for early price estimation. As it is easy to calculate, easily understood by people in the construction industry. The area of each of the floors is measured and multiplied by a cost per meter squared. While using this method, there are certain aspects which should be considered, like, items of work which cannot be related to the floor area need to be priced at separate all inclusive rates. Secondly, if a client expresses the project only in terms of the usable space, if necessary to add to this area circulation and other non-usable space to make the building functional.

Storey Enclosure Method: The problem with the first two techniques is that they take no account of the building shape in plan or sections that are significant determinants of cost. This is solved by storey enclosure method. However, before any cost model of this sort can be used, design proposals have to be developed with some details. Another method called the cube method that had been used for a long time has become obsolete.

Approximate Quantities: This one provides a more detailed approximate estimate than any of the other methods. They represent composite items, which combine and group together typical bill measured items. In practice, only the major items that are of cost importance are measured. It provides a more detailed and reliable method of approximation.

Elemental Cost Estimating: In this method it analyses the cost of the project on an elemental basis, attempting to make use of the cost analyses from other similar projects.

Pricing Bills of Quantities: In this method, the quantity surveyor prices a complete bill of quantities to predict contractors tender.

Each of the methods summary described before produces a single-figure estimates, such a figure becomes quickly fixed in the minds of clients, finance provider, designers and quantity surveyor. It would probably be much sensible, though more difficult and costly, to present the early estimates as a range of probabilities, showing the sort of features or circumstances which would tend to push cost up or down.

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The choice of the method to use in preparing the cost estimates depends on certain factors which include:-Time available, Project information, Cost data, Preference and familiarity and Experience of the quantity surveyor

2.5 The Fundamental Problems of Cost Estimation

The first difficulty is that a really accurate estimate of a building's cost cannot be made until the details of the design are known except in the case of standard repeated building types. However, the client wanting to have a building constructed needs to know how much it is going to cost before committing him or herself to the contract and its detailed design (Ashworth 2004).

The second difficulty is that the information about the building as presented by designers and analyzed by the Quantity Surveyor does not relate directly enough to the process of construction as perceived by the contractor. The techniques developed over the years to overcome this difficulty may be criticized as relatively crude but the fact that a hundred years of ingenuity has ultimately failed to come up with a perfect solution perhaps indicate the depth of the problem. With the development of integrated computer models and more coordinated information systems, success may be nearer, but it will still require mutual understanding and considerable determination on the part of the people involved if any real advance is to be made.

Despite the advances made in modeling techniques and the use of microcomputers for assessing alternatives more quickly, it can still be argued that the issues which reflect the real cost of buildings are not fully taken account of in current approaches to building economics.

The reason is that the sources of cost information, primarily generated through the use of bills of quantities reflect the product rather than the process of construction. The bills of quantities and the Standard Method of Measurement (SMM) use units of measured work in the main to convey costs rather than identifying the resources needed to achieve the finished work.

The location of the element in the building is ignored. In a multi-storey structure it is obvious that it will cost more to cast the concrete floor slabs at the top of building than at the bottom.

More fundamentally, there is a mis-match between the way the design is represented in the bills of quantities and the contractor's approach to planning and controlling the cost of construction. The contractor will attempt to identify the various activities and their sequence, the time required for each activity and the various resources needed.

The information in the bills of quantities does not help the contractor directly to establish the construction programme. The two fundamental difficulties in using bills of quantities as the basis of cost models are: - the real cost generators, that are the resources are not identified; and most of finished work represents an amalgamation of resources, which are not subject to the same variables.

The purpose of these cost estimates is to provide an indication of the probable cost of construction, as it is an important factor to consider in the client's overall strategy of the decision to build. The estimate also provides a basis for his budgeting and construction cost control can also be used for comparison as a basis for the evaluation of different design solutions. This shows the importance in which estimates are to the whole construction process. (Ashworth 2004, p 99)

Importance of Accurate Cost Estimates: With a good pre-tender estimate, budgeting is enabled and this decides whether the project should proceed as envisaged. If the project costs are widely underestimated companies can be "locked in" to uneconomical investments. The client company for the knowledgeable comparison of bids also requires estimates, where contractors are involved, with low bids being a much course for concern as high bids. This concern is because of certain reasons. If a contractor underestimates the cost to him of carrying out a project at the bidding stage on fixed price contract, the consequences can be catastrophic to him.

Accurate estimating is important throughout the life of a project to evaluate proposed changes, alternative ways of carrying out the work and as a basis for effective cost control. These are the basis for decision-making and control of work in progress for both client and contractors. Due to many factors like lack of information at initial stages there is a problem of completing of project to its initial estimate. This therefore leads to escalation of costs that can be defined as "The difference between the final cost or latest estimate of final cost and the original definitive estimate" (Morton and Jaggar 2003). It can also be defined as "The change in

estimated costs over time". With high cost escalations, many companies can be trapped by the "sunk costs principles". Therefore when making initial cost estimates allowances for cost escalation should be included.

2.6   Tender Patterns And Bidding Strategy

2.6.1   Tender Patterns

Contrary to general belief, a typical distribution of competitive tenders for the same contract is almost symmetrical. In fact it is closely approximated by the normal distribution. There is a very slight skewness to the right but this is so small that it can for practical purposes be ignored (Beeston, 1983).

On rare occasions there are about 25 bids for a single contract to provide a good indication of shape, and then the characteristic indication of conformity with the normal distribution are seen. Conformity with the normal distribution with only negligible skewness is not what would be expected from most people's mental model of tendering. In this model the tenderer's who most want to win the competition estimate carefully and bid low. Their bids can be expected to be close to each other and include the winner. Those less keen estimate less carefully and pitch their tenders higher. Their bids should be higher than the others and more scattered. Some of them would not be properly estimated but pitched high enough to ensure that the bidder would not win and intended only to avoid telling the client that he was not interested in tendering for the project. The total effect of such model would produce a distribution very strongly skewed to the right.

The additions or subtraction could represent differences in keenness and estimating error. Because the shape of distribution is close to being normal, it suggests that estimating error is the major cause of deviations. It does not mean that bidders consciously aim for the centre of the list. They use methods, which on average, put them in the middle, and the ones that they win are those where their downward errors are greatest. So, saying that error makes a greater contribution than keenness is not saying that variability due to keenness is necessarily very small (Beeston 1983).

2.6.2   Non-Serious Tenders and Cover Prices

A tender may be submitted by a contractor who has been included in a restricted tender list and feels that he ought to bid even though he does not want the contract. Such a bid can be called a "non-serious tender" and a special case of it is the "cover price". A cover price is not arrived at by careful estimating but by asking another tenderer for a figure that is safely higher than his bid will be. Other non-serious tenders result from rough estimation and a very high mark-up.

In a sense these bids are genuine tenders because the contractor would do the work somehow if by any chance his high bid were accepted. The high bid, like any other high bid, reflects a low level of keenness. Such bidders do not want to be regarded as being reluctant to tender but neither do they want to get reputation for high prices, because they feel that both would reduce their chance of being included in future tender lists. This probably helps to keep their tenders within the same normal distribution as the others (Beeston 1983).

2.6.3   Bidding Strategies

Some bidding strategies offered to contractors depend on analysis of the contractor's performance against specified competitors (Beeston 1983). They are however unlikely to be successful due to the following reasons:-

- Specifying competitors greatly reduces the data upon which the strategy can be based.
- The strategy cannot be applied to two or three competitors in any one tender list little chance.
- It is not always possible to discover the competitors before having to tender.
- An individual competitor may change his bidding strategy thus rendering past data about him misleading.
- Such strategies seldom take account of keeners to win.

Special knowledge about one or more competitors is useful and best used to adjust a bid that has been constructed in a consistent way without using that knowledge. The higher the numbers of tenders submitted by contractors, the lower the lowest bid. With high competition, contractors try to reduce their prices to win the tender. This actually leads to more instances of skewed tenders, which are hard to predict their true value.

2.7   The Accuracy Of Estimating

2.7.1   Measuring Performance

Few practitioners objectively measure their estimating accuracy (Beeston 1983). When they do they are usually unpleasantly surprised. Because of the optimistic idea that most have of their own performance, they too easily reject a new method for which accuracy has been quantified. They find it hard to believe that they cannot do better than the figures quoted for the new method.

To measure estimating errors, a definition of error must be decided upon. From the client's estimator, the obvious one is the difference between the estimate and the lowest tender. A convenient way of expressing the error is the ratio of estimate to target.

The contractor's estimator may have more difficulty in defining his target and measuring his errors. He may aim to be in a particular place. Such as second or third in the ranking of bid for a contract, in that case he would be allowing his estimating errors and those of his competitors to produce the required proportion of lowest tenderer's. When bids are published, he could compare his bid with that of the one in the target position, sometimes him, and call the difference his errors.

As the actual costs can only be known for contracts that are won, there is a danger of tending to judge the estimating method when it has performed successfully. On the other hand, it can be argued that the time measure of effectiveness of an estimating method is the profitability of contract won, so only these are relevant. This is difficult to rationalize because if a different method has been used, different contracts would have been won, so comparison between methods could be biased (Beeston 1983).

As well as measuring the error by comparison with the actual target, it may be interesting to compare the estimate with a more stable hypothetical target. Reducing the contribution of target movement to the variability of the error brings us closer to measuring the inherent error of the estimate. For example, the average bids for a contract is more stable than the lowest, so it is quite reasonable to aim at this and then make an adjustment for the difference between the average and the lowest, taking into account the number of tenders.

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An estimator who can show that the correlation between his estimates and average bids is good (that is, the difference does not vary much) is entitled, in one sense, to claim good performance; even though it is little consolation to a client whose lowest tender has come in for above the estimate. Because of occasional wildly erratic bids, the median is a preferable average to arithmetic mean. Also, it is easily calculated because bids are likely to be arranged in order of size for presentation to the client.

The idea of measuring error in relation to various targets brings out the importance of distinguishing between average error, however measured, and dispersion errors. Quality of an estimate can best be judged by the dispersion of errors and not the long-run average error, which can easily be corrected and may even, be deliberate. Another reason for using the dispersion of errors about their average separately from the average error is that the effects on dispersion of choosing various defined points in the tender list as hypothetical, or initial, targets can be compared. The dispersion of errors can be thought of as either the standard deviation of percentage errors or the standard deviation of the percentage ratio of estimate to target.

2.7.2   Present Achievement

Although slightly skewed to the right, the distribution of estimating errors can be regarded as conforming to the normal distribution (Beeston 1983). A typical standard deviation of percentage errors made by client's estimators was found by Morrison and Stevens (1981) to be 12%. Specializing in a particular type of work can reduce it to 10%. Beeston (1983) has seen no documented evidence of lower standard deviation than the above figures measured over enough estimates to be convincing.

In this connection, the standard error of the standard deviation must be remembered. It is O/V / (2n) where O is the population standard deviation and n the number of estimates. Therefore, if the population standard deviation is taken to be 12%, the numbers of estimates need to be at least 50, giving a standard error of 1.2, before a sample standard deviation of 10% can be regarded as significantly better.

Contractors' estimators seem to do better but their task is different. It is not easy to interpret the meaning of their ability to provide a basis for bids whose dispersion has a coefficient of

variation (CV) of 6%, but it is certain that their methods produce results which agree with each other more closely than with those of the client estimator. One factor that would contribute to a better performance by contractors' estimators is that they take into account construction methods more realistically than clients' estimators (Beeston 1983).

When contractors estimate their costs, their variability is presumably less than that exhibited when their mark-up is included. Therefore the variability of contractors' estimates of their costs is probably a little less than the variability between bids for the same contract.

Clients' estimators could reasonably hope to reduce the variability of their estimates to close this if they used the same methods as contractors when estimating their costs. To calculate the resulting estimating errors requires the addition of the variability of the winning contractor's mark-up, which is presumably very small. Wining bids are likely to have a less variable mark-up than other bids.

Clients should be made aware of the dispersion of estimating errors. The proportion likely to be within 10% would be a suitable way of doing so. The limit of estimating accuracy should be borne in mind when deciding whether to proceed with a design. It would be a pity to reject a good design, which seems too expensive when it would be acceptable if the estimate were too high by about one standard deviation of the distribution of errors. Equally, the client should be prepared for the lowest tender to be the same amount or more above the estimate. Being aware of the distribution of estimating errors also help when deciding whether to accept a tender as the best obtainable or to call for more.

2.7.3 Improving Estimating Performance

The performance of an estimate can be improved by improving certain tasks thus making it reliable (Beeston 1983). These include:

- An improvement requiring no new technique but more effort would be obtained by use of more than one project as a price analogue. It is more productive of accuracy to spend time on making repeated estimates than on refining any one of them. A minimum of four projects should be the aim, but even two or three are much better than one.

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- Making several estimates and averaging them is a powerful way of improving long term performance, because the standard error of the average is proportional to $1/\sqrt{n}$ provided that the estimates are independent.

- Another simple procedure to improve estimating performance is to use several methods for each estimate and to keep records of errors so as to select the best method or combination of methods. A minimum of 30 projects need to be analyzed.

- Moving towards contractors' methods of estimating was suggested as a way of improving clients' estimators' performance. This would include not only learning from them how to take account of construction methods but also emulating their way of arriving at a mark-up.

- Whatever method of estimating is used, it will be improved by better data. With more estimators having access to computers, large data banks should become easier to handle.

2.7.4 Computer Methods

With the advent of the computer work has been made easy through speeding up the work being undertaken. In addition, it reduces the instances in which errors can be committed, this increases accuracy. The use of computers can improve the accuracy of estimating in two aspects. One they can make available a large bank of data so that estimates can be based on more projects. The other improvement is that they allow the consistent application of quite involved methods. Consistency of methods is helpful because it facilitates objective monitoring of performance, improves the development of the user's judgment and provides the basis of a bidding strategy.

2.8 Cost Data

The published information received by quantity surveyors usually relates to a typical building in a typical location with only a brief summary of the contributing factors to such a cost. The feedback of such cost information centre rotates around the bills of quantities (Morton and Jaggar 1995). Information on wages, materials and plants collected on site and fed to contract manager of the contractor who passes the data to estimator who uses this together with data from other projects to estimate the next tender price. The consultant quantity-surveying firm

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analyses this data from the new tenders and uses it to forecast the cost of the next similar building and control its costs during the design development. This data that is obtained from the site feedback has its shortcomings.

In reviewing traditional cost models, the methods used are merely structures around which cost adviser's judgment is applied to make them work. The models are ill equipped to produce a reliable answer on their own. If a right cost figure is applied to any single price method, they give better results than more sophisticated techniques with wrong cost data applied to them (Ferry 2003).

Reliability of cost information give estimators prevailing market conditions at time of tender rather than conditions at time of making the estimate more reliable as a tool of predicting costs to be incorrect as market trends are defeated. The root of forecasting and cost control activity, there is need for cost data to supplement the numbers, areas, and volumes etc, which have been used to describe the building. It is this data that is critical in determining whether an estimate is reliable or not.

2.8.1 Uses of Cost Data

Uses of data can be classified into four main headings as follows:

Forecasting of Cost: Provides information on cost per square metre, elemental unit rates, bills of quantities rates and all-in unit rates. This information is sourced from analysis of past projects or historic costs. The figures would be updated by the use of a building cost index, and would be projected forward to the proposed tender date by an intuitive or calculated prediction technique.

Comparison of Cost: In this use of data, the need is not so much to discover what the building or component will actually cost at the time of tender, but to make comparison between items with similar function, or buildings of different design, to decide which the better choice is.

Balancing of Cost: In determining a budget for the cost control of a building, it is necessary to breakdown the overall cost into smaller units. These smaller units are used not only for

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checking purposes but also to allow a cost strategy for design to be developed. This strategy will attempt to spend money in accordance with the client's requirement, by allocating sums of money to the various major components of the building.

Analysis of Cost Trends: By looking at the way in which costs for different items are changing in relation to one another, or changing between one point in time and another, it is possible to have a better chance of selecting the specification which will suit the client's requirement over the short and long term. Cost data also allow us to obtain a more reliable prediction of what the market price to the client will be when the job eventually goes out to tender. When data is used for the detection of cost trends, the cost is very often related to a base-year cost, in which case the presentation of the information is in the form of a cost index.

2.8.2 Problems with Analysis of Bills of Quantities

The vast majority of the information used by cost planners arises from the bills of quantities. The Bills of Quantities are subject to incorrect assumptions (Morton and Jaggar 1995). Among these include: -

Variation in Pricing Methods: When different contractors' tenders for the same project are broken down into smaller units, it's very common to find variations in each sub-sector. The reasons for these variations include: -

- The rates in bills of quantities are not true costs, but neither are they true prices in the sense of a price in a supermarket shelf. Rates are simply a notional breakdown of the total price for commercial and administrative purposes.
- Contractors prices preliminary items differently. Some will place preliminaries in the preliminaries section while others will include them, in whole or in part, in the measured work rates as they see a commercial advantage in not identifying them too explicitly.
- It may be in the contractor's best interest to 'load' the prices of those parts of the building which are executed first, such as excavation and earthworks, to improve the projects' cash flow
- Where a contractor anticipates variations to the contract, he may lower the unit rates for them to be omitted items and increase rates for other items.

- Estimations make different assumptions in regard to resource requirements. The assumptions made will relate to the estimators view of the firms expertise and economic structure.
- Errors in estimating often cancel each other, but once in a while an error of significant cost in a single item may occur.

Variations in Bills of Quantities Rates for Different Projects: The following play an important role in price variations in bills of quantities of contractors tendering for different projects.

- Site conditions : Certain site conditions affect the rates in a bill of quantity, these include: Problems of access: Boundary conditions especially adjoining buildings, Soil bearing capacity and consistency, Topography and orientation of building.
- Design variations : Has effect on efficient use of resources production method and time. The design of a building affects the efficient use of resources time and method of production.
- Contract conditions: Any contract which requires more working capital for the project, or additional risk, is almost certain to incur a cost penalty which will be passed on to the client. Conditions relating to the length of the construction period, particularly shortening of time, and the phasing of works, may both result in uneconomic working hours and will influence the estimator's rates and particularly the preliminary items. Their impacts are difficult to anticipate especially with regards to their effect in unit rates.
- Size of contract : Each firm depending on its size has an optimum size of contract that suits its resources and structure. This affects its approach to the estimate when bidding for certain contracts. The unit rates for a large project should make allowance for the economies of scale that could be expected, but certain aspects like site working conditions and nature of the industry don't allow for such economies to be made.
- Location : This factor affects the problems of accessibility to the production resources. The transport of materials, workpeople and plant to site, accommodation of the workforce on remote sites etc. affects tender rates. On top of this local climate may affect the starting on site, degree of protecting required and interruption of work programme.

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With these variations affecting the data obtained from bills of quantities rates, success depends upon the skill of the user in determining what rate to use against a particular measured quantity.

The Contractor's Bid Price: While estimating process is theoretically adopted, it is infact very often used to justify a total that the contractor has in mind from the very beginning. Contractors bid at what they consider to be a socially acceptable price. This price is not well defined, but it is considered to be the price which society is prepared to pay for a particular type of building.

By bidding at this value, the estimator overcomes the problem of being unable to predict resource requirement for the project. As the client's anticipated cost is probably based on what has been successfully built before, it is therefore likely that the estimator will have put forward a reasonable estimate, and the labour and material 'constants' are used to justify this.

Despite the wide variation in individual bills of quantities rates the final tender figures are often considerably closer than one would expect. This is the non-deterministic notion of pricing that is often used by contractors.

This notion is assisted by certain aspects that influence the pricing which are:

- The name of the project appears to influence the cost
- Constants of labour, plant and materials are not reliable
- Chances of contracts being won.
- Estimates are tailored to suit the market.

If the estimation of cost really were a deterministic exercise, then the constants used in the estimate would be absolute and unchanging, unless they were awarded as the result of ascertained cost feedback.

In order for a firm to survive after losing a number of bids in succession, they reduce the rates in the next tender. This practice suggests that the estimate does not mean very much in terms of an accurate prediction. If the firm does get the job and they think it will be 'tight', they put their best management team on the project and very often get a better return than a job where

the foresaw a large profit and did not maintain such tight control. Doubt has been cast on the deterministic estimating process and thus should influence the way in which we look at and use cost data. Obviously the factors of supply and demand related to the capacity of the industry, and its workload, will influence the level of the contractors bid, and the relationship between these factors and the socially acceptable price – which has not yet been defined. It is important to realize that market conditions reflect the economic standing of the country and this aspect may well have more impact on 'historic' cost data, and the price society is prepared to pay for its buildings, than any other.

2.8.3 Sources of Data

Present data sources available in the industry have allowed the development of simple and reasonably effective system of cost forecasting and control that the various parties are familiar with. For the cost adviser of a client, information can be obtained from two sources:

Own data: In most cases cost advisers usually prefer using data that they have prepared. This is due to the discussed following reasons. The data will be from a project background they know and therefore are familiar with all the problems associated with the projects like location complexity. Further detailed breakdown of any structural information is available in published data. If it is so required therefore accessibility problems are not encountered. The data will refer to the geographical area in which the firm carries out most of its work. Compared with published data, there is a shorter time lag between receiving raw data, processing it and being able to use the structured information in the office. This is particularly relevant to cost indices. The choice of classification and structure of the processed data is under the control of the firm. It is therefore possible to ensure that the details that are most relevant to that particular practice are emphasized and identified rather than having to accept a standardized published format.

The disadvantages of own data sources are that the variety of specification location, size and shape of project is so large, that it is unlikely than an office will have up-to-date information, which it can apply to all its new projects.

Published Cost Data: While the cost planner can probably make initiative assessment, particularly of cost per square metre, it is reassuring to have a check available in the form of published information. It is the primary role of published information to provide data which

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enables practitioners to check on their own knowledge and to provide a context for their own decision-making.

Sources of Published Data: There has been a steady improvement in the quantity and quality of cost information appearing in journals and magazines concerned with design and building management. Largely due to demand from clients for better-cost control, editors have found it necessary to devote more space to cost analysis and forecasts. With the rapid changes in level of resource costs and measured rates over very short time-spans, the technical journals, published at weekly intervals, have largely replaced the traditional annual standard price books as a source of quick reference material.

A traditional source of useful information has been the price books which are normally published normally by several long established organizations. In periods of rapid inflation or market changes, they have suffered the drawback of having to prepare their information well in advance of the year of publication. This problem has more recently been overcome by the publishers offering on-line computers access to updated information.

The Institute of Quantity Surveyors of Kenya (IQSK) publishes cost information in their quarterly journal in which they give prices of various items in the East African Countries of Kenya, Uganda and Tanzania. The Kenya bureau of statistics has also been publishing a quarterly cost index since 1997 that is available at their library at a fee.

Most of the government literature in Kenya is sourced by the Kenyans who use data from different government departments like Ministry of Public Works to come up with an index that can be used from their offices. The problem with this data is that it is very outdated. For example, the Kenya bureau of statistics still uses 1972 as its base year when formulating a cost index, which has been subsequently overtaken by economic events such as inflation and economic growth.

Information Services: With the advent of cost planning techniques and the need for a wide range of information on different types of project, it was realized that most offices would require information additional to the data normally found in one particular practice. It was suggested in UK that if firms could be persuaded to supply their own elemental cost analyses, to a central body, then a large pool of information could be gathered which could then be

disseminated to the subscribing members. If those analyses could be supplemented with other more general information, on treads and economic indicators, then a useful service would be provided to the profession.

Building Cost Information Service (BICS) : BCIS is a subscriber-based service which collates and analyses data submitted by its subscribers and incorporates materials from other sources. Since 1984, BCIS has been operating a computer based service which gives subscribers unlimited access to the entire BCIS databank from their own personal computers. It can be accessed from anywhere in the world. Simple but powerful selection tools to cut out time-consuming browsing to locate for example the cost analyses needed for a project have been developed. This ensures that users have access to the widest possible range of examples as well as the most up-to-date information – particularly important when the market is volatile. The package is designed to replicate the process that a quantity surveyor would follow when working by hand, but can be amended if desired.

2.9 Cost Indices

One of the most important items of cost data, particularly in connection with forecasting techniques that rely on historic information, is a cost index. Its object is to measure changes in the cost of an item or group of items from one point in time to another. All index numbers require the selection of a base year, which is a date in which all the other numbers in a series can relate. This number is usually 100 which allows for an increase or decrease in the value of data.

2.9.1 Uses of Index Numbers

The index numbers are used to:

- Update elemental cost analyses that is the tender information of past projects can be brought upto current costs for estimating and budgeting purposes.
- Update for research that is bringing cost information, obtained at a number of different point in time, to a common date by use of an index, a much larger sample of data can be examined.

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- Extrapolate the existing trend that is by plotting the pattern of costs measured by an index, it may be possible to extrapolate a tread into the future. Extrapolation based purely on present-day trends is very risky.

- Calculate the fluctuations that is by applying an index to the cost of work undertaken during a specified period, it is possible to evaluate the increase in cost of resources to the contractor more speedily and with less ambiguity than by using the previous laborious method of comparing every invoice price with the base date cost of the same item

- Identify the changes in cost relationships that is if a cost index is prepared for the different components of a building, or for alternative possible solutions to design problem for example reinforced concrete frame then it is possible to see the changes in the relationship between one component and another over time.

- Assess market conditions that are if the index will measure the market price, as opposed to the change in the cost of resources, then a measure of current market conditions can be obtained which is of enormous benefit in updating and forecasting costs.

- Analyze of unit price for buildings of similar function this is done if the data could be found giving, say, the cost per metre squared of all schools of a certain type being built in the country at one point in time, then the average of these costs cold be used to provide the basis of an index. If the exercise were repeated at regular intervals for that type of building, then a regular index could be established.

2.9.2 Types of Index Number

There are two types of index numbers; factor cost index and tender based index.

The Factor Cost Index: This uses changes in the cost of resources to build up a composite index. It can also be referred to as a building cost index and mostly measures changes in the contractor's cost. It's constructed on a combination of actual wage rates material costs and plant and overhead charges. Due to its complexity, it is based on the principle of basket of goods in order to represent typical rates (Ashworth 2004). This type of index can be constructed for total cost of a building or type of building; an elemental e.g. external wall within the building process; or for a single material e.g. cement.

In the construction of a concrete block wall, blocks, contribute 10 times more than mortar hence in calculation a composite index; resources need to be weighted in accordance with their

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importance. The effect of weighting is to reduce an index value because mortar which has increased most in price does not share equal status with blocks and labour. Changes in labour efficiency, although affecting the cost to the contractor and possibly the client will not be represented in the index unless the weightings are changed.

There is a very real difficulty with the factor cost index because it is not easy to judge productivity over time, particularly with regard to the construction of whole buildings (Ashworth 2004). In fact in the majority of cases, weighting in building factor cost indices are assumed to remain constant until a revision of the index is undertaken and further analysis of the importance of each resource is made.

The selection of representative or typical items is also difficult. This is because of wide variation constructional methods and materials than can be used. Other problems include the quantity of data needed to be collected in order to provide some statistical reliability. The profit and overheads can be function of market conditions and it would be difficult to devise a reliable quantitative measure for this variable.

It is important to realize that factor cost index is actually measuring the change in the cost of resources to contractor for a typical building, thus it has little or no account of the tendering market. It also does not directly measure the change in the price the client must pay, and although the "market conditions" allowance attempts to rectify this situation, the source may not be reliable. Further Factor cost index does not measure the change in cost of a specific building under consideration by a quantity surveyor. It is unlikely that the "typical building" will have the same mix of resources as the clients' project; however, on many occasions the difference will not be cost significant.

Despite these drawbacks, the factor cost index is very suitable for identifying treads in resources and relationships. It was particularly useful for evaluating cost fluctuations in contracts which allowed for reimbursement of any changes in cost to the contractor that occurred during the contract period, as was common practice at times of high inflation.

The Tender-Based Index: This type of index is based on what the client is prepared to pay for the building. It takes as its source of information the tender document itself i.e. the bills of quantities. This should record what is happening in the market place and therefore should be

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much more useful in updating prices for a design budget. It may or may not include fluctuations in price, depending on the terms of the contract.

A tender-based index can be obtained by pricing and re-pricing a bill of quantities at various required intervals. To obtain a more accurate index, data should be repriced repeatedly. The larger the sample size, the greater is the reliance that can be placed on the results.

From a client's quantity surveyors view, a tender-based index has certain advantages compared to the factor cost index (Morton and Jaggar 1995). These include: -

- It measures the change in the cost to the client of a particular project over time, taking full account of market conditions in addition to the change in cost to the contractor.
- It is relatively simple to operate once a base schedule of prices has been obtained.
- It allows comparison of the price obtained by tender for a specific project with the national or regional building price trend.
- It allows the relationship between the market for building of different functions and locality to be plotted.
- It is not based on other indices and therefore any interest inaccuracies are not compounded.

With all these advantages it also has some problems compared to the factor cost index as follows:-

- A large number of projects are required for each index due to variability of price rates in Bills of Quantities. At least 50 projects are required for a suitable sample (Morton and Jaggar 1995).
- The index relies heavily on the base year schedule, which will have to be regularly revised to take into account new products and new methods of measurement. This is a time-consuming and costly task.
- Lack of suitable projects at any one time. This makes evaluation of the projects difficult thus reducing reliability of the index.
- While the factor cost indices indicate a gradual increase in line with the index of retail prices the movement of the tender-based index is much more erratic.

Despite these problems there are no doubt that the tender-based index represents a major break through in the measurement of trends in market prices to the client.

The procedure for preparing and using a tender-based index is as follows:-

- Prepare a priced list of typical bills of quantities items at the prevailing base year pricing levels possibly with an allowance for preliminaries included. This is a time-consuming task.
- Take the priced document for the lowest tender received and note the format e.g. work section, elemental.
- For each section of the format, e.g. excavator, concrete work etc, pick up the largest value item in the section, then the second and so on, until a total of 25% of the section value is achieved. It is the extended value and not the unit value that is important. Leave Prime Cost sums and profit.
- For each of the items selected, find the corresponding unit price in the base schedule of prices. The difference as an addition or subtraction from the base year rate is then obtained by comparing the bills of quantities unit price of each sample item with its equivalent base year price.
- The extended base year value is calculated for each item (i.e. weighted by its quantities). The total of all the extended items at base year prices is then compared with the total of all the extended items for each section to obtain an index.
- The index obtained for each section is then weighted according to the value of that section as proportion of the whole tender bills of quantities for the project being considered; less preliminaries, prime cost and provisional sums and contingences and a combined index for all sections obtained.
- The preliminaries are usually dealt with by considering them as a percentage addition to the other items in the bills of quantities, excluding day works and contingencies.

To obtain an average index for publication rather than for one particular job, the index numbers for all the tenders which have been sampled in a specified time period are averaged by taking either the geometric or arithmetic mean. The difference between the mean of the current and preceding quarters is used to gauge the movement in tender prices.

2.10 Other Factors Affecting Cost Estimate of Project

Factors that directly influence the estimated cost of a project can lead to unrealistic cost estimates before construction actually starts. They can be gathered into two groups: estimator-specific, and design and project-specific factors.

2.10.1 Estimator-Specific Factors

Most of the estimator-specific factors, like clerical errors and wrong production rates, are controllable and can be managed by checking the calculations and providing relevant information to the estimator. However, less controllable factors related to an estimator still exist at the project level. Those factors are composed of estimator biases. Estimator, like other people, can be biased in performing their work depending on their background and incentives. Even though some of these biases can be controlled by changing the incentive system, one cannot completely control estimators' biases on a project with project management tools in the same way one manages productivity in the field (figure 2.3).

Estimator's Biases: In general people are biased in performing their work depending on their background and incentives. Capen (1976) has made three observations about the behaviors of technical people under uncertainty:

- A large number of people have little idea of what to do in uncertain situations.
- A large number of technical people overestimate the precision of their knowledge. As a result, he has concluded that, in general, people with technical backgrounds are over-confident when putting ranges on their knowledge in uncertain situations.
- Motivational and cognitive biases are major causes of this overconfidence in people (Smith 1991). Motivational bias occurs when people feel that they are going to be rewarded depending on their prediction. For example, when estimators feel that their rewards depend on their confidence in their estimates.

Cognitive bias occurs when a thought process causes incorrect assessments of uncertainty and risk. Smith (1991) and Birnie and Yates (1991) describe several types of cognitive biases:

- Adjustment and anchoring bias occurs when a person starts from some initial estimate and then adjusts that estimate until it seems reasonable. Construction cost-estimating techniques create a suitable environment for this bias. Estimators choose a production rate that they think is representative of a particular kind of task, and then they adjust it according to certain project-specific conditions. This results in too much emphasis on the initial number. A better thought process would be to start from a range of production rates that cover most of the possibilities and then choose the most likely rate accordingly.

- Representative bias occurs when people concentrate just on recent projects in assessing the risks of an upcoming project. In identifying risk factors and assessing risk, the most easily remembered factors are those that occurred recently. The extent of this similarity becomes a dominant factor in the cost estimate, and all other available data such as differences in quantity, location, or market conditions tend to be overlooked.

- Availability bias occurs because of the limited memory capacity of people. Previous bad construction experiences of estimators make them estimate the cost of certain items conservatively. For example, previous experience with a material shortage can lead to higher estimate for that material cost.

- Clairvoyance (risk definition) bias occurs when people have an incomplete definition of uncertainties. They tend to include only risks that are within the responsibility of the project team, like labour availability, subcontractor performance, etc., and exclude risks for which the project team is not responsible, such as changes in scope. To overcome this bias, uncertainty and risk should be defined clearly. In formal decision analysis methodologies, a clairvoyance test, which requires that a variable be defined so clearly that an answer about it would be unambiguous, is used to prevent the presence of clairvoyance bias.

- Estimators, like many people, have motivational and cognitive biases, and these biases can lead to distorted and inaccurate cost estimates.

Notes:

Estimator Specific factors consist of motivational and cognitive biases.

Design and project specific factors consist of project size vagueness scope, and design complexity this is a function of constructability of the design, utilization of advanced technology, specialized equipment and methods, and the integration of multiple disciplines.

Construction specific factors consist of unknown geological conditions, weather conditions, client generated and subcontractor generated risk factors.

Economic and political environment specific factors consist of economic and political risk factors

Contract specific factors consist of contract type and legal context of a contract.

Figure 2.3 Uncontrollable Factors Affecting Contractor's Risk of Cost Overburden

Source: Pack, J. H. (1994)

2.10.2 Design and Project - Specific Factors

Another group of factors that affect the cost estimate of a project are design and project specific factors, which include vagueness in scope, design complexity, and project size.

Vagueness in Scope: Project scope describes the work to be performed; hence a cost estimate heavily depends on this scope definition. In fact, lack of proper scope definition has been stated to be a major source of bad estimates (Cowie (1987). Vagueness in scope has two implications for cost control:

- It decreases the accuracy of cost estimates; and
- It creates a potential for changes in scope during the construction stage, which generally results in a increase in cost to both owners and contractors.

  The accuracy of a cost estimate is highly dependent on the level of detail in the scope definition. A cost estimate based on a detailed design should be more accurate than one without any design information. Peurifoy and Oberlender (1989) have divided the accuracy of an estimate into three levels depending on the preciseness of scope definition.

- A conceptual cost estimate prepared from a project scope definition that does not include design information is usually accurate within +40 and – 10% of the actual cost.
- A cost estimate prepared upon completion of the preliminary design is usually accurate within +25 and – 5% of the actual cost.
- A detailed cost estimate prepared upon completion of the final design is expected to be accurate within +10 and -3% of the actual cost.

The figures given above show that conceptual cost estimates suffer most from vagueness in scope. Construction faces three major risks in conceptual estimating (Pack (1994). First, risk is involved in the pricing of materials to be furnished. Material information is often not available early on, and the materials that quantity surveyor thinks might work during the bidding process are sometimes very different from the materials included in the final design. Secondly, there are schedule and time risks. As the scope of a project is continuously emerging, the duration of the project is hard to estimate. This mainly affects the estimation of overhead costs. Moreover, liquidated damages clauses for late completion in a project put additional risk on the contractor during the conceptual cost-estimating stage. Finally, (Pack 1994) also mentions the presence of risk in subcontracting in conceptual cost estimates. In this stage, there are fewer competitive subcontractor quotes than at bidding time, since most subcontractors do not want to give a firm lump sum price or take the risk of quantity overruns

Hetland (1994) mentions vagueness in scope as one of the major factors that resulted in cost overruns. Vagueness in scope on these projects also increased the resource consumption during construction. This alone resulted in a 29% cost overrun. In addition to this adverse effect on the accuracy of cost estimates, lack of proper scope definition creates a potential for change or growth in scope during construction. Changes in scope result in the addition of new activities that will increase the actual cost of a project. Cowie (1987) has observed that the majority of cost growth during the construction period derives from scope growth. Another problem with changes in scope is that additional work scope, which will have to be added later, is generally required to be carried out without extending the original contract delivery date. Increase in scope can only be executed by increasing the resource intensity over and above the planned level. This often leads to increased unit cost and hence increased total cost of a project (Hetland (1994)].

Design Complexity: Design complexity is a function of the constructability of the design, the use of advanced technology, specialized equipment and specialized methods, and the integration of multiple disciplines (Rusteika and Boomer 1992). The risk involved in the use of advanced technology and specialized methods depends largely on the newness of the technology and its performance history in stimulate and actual use (Napier and Chang 1988). The contractor who has prior experience with the use of specialized method or advanced technology faces less risk. On the other hand, if that method or technology represents a first-of-a-kind use, the contractor will bear more risk due to increased uncertainties.

In general, in complex design, an estimator will have a harder time visualizing the construction process and hence will not be able to estimate the quantities, production rates, and unit costs related to that project accurately. This will lead to a cost figure that is obtained as a result of guesswork rather than a systematic estimating approach.

Project Size: Past empirical studies have shown that project size also influence cost-overrun rates (Jahren and Ashe 1990); Skitmore 1988); (Randolph et al. 1987; Rowland 1981) However, there are two contradictory conclusions on how project size effects cost overrun rates in construction. Randolph et al, conclude that cost-overrun rates decrease as contract size increases (1987). On the other hand, Rowland concludes that cost overrun rates increase as

contract size increases (1987). An explanation of Randolph's result is that as the stakes are higher on larger projects, more care is exercised during the bidding and planning stages. However, at the same time large projects are generally more complex and this leads to an increase in cost overruns as found by Rowland (1981).

Recently, Jahren and Ashe (1990) investigations revealed that cost overrun rates of 1-11% are more likely to occur on larger projects than smaller ones. However, cost overruns greater than 11% mostly occur on smaller projects. An explanation for this result is that projects become more complex as they become larger which leads to the occurrence of larger cost overruns. At the same time, however, special care is given to large projects by managers. This will prevent the cost overruns from becoming excessively larger. As a result, it is hard to tell how project size affects the risk for cost overruns.

2.10.3 Conceptual Estimates as Dependent Variables

Conceptual estimates are critical inputs for owners' decision-making in the early planning stages of a construction project. Owners or clients have to make planning decisions based on cost figures that are estimated under a high level of uncertainty about the project's future. An assessment of the expected quality of this input is as important as knowing the expected cost of a new project. This can be considered as a way of measuring the cost risk of the project.

To the decision-maker or owner, quality means the expected accuracy and reliability of the estimate figure.

Figure 2.4 shows a model of the conceptual estimating problem, where the estimator has to determine an approximate cost to accomplish the new project based only on a set of predictors about what the project would be when finished. The quality and quantity of these predictors will impact on the capability of the estimator to estimate the future project cost accurately. Conceptual estimating requires extensive knowledge and expertise (Shen et al. 2001) and requires extensive use of judgement to produce a meaningful result (Rush and Roy 2001).

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CLUES

Real project   Estimating System

Accuracy   of Estimate
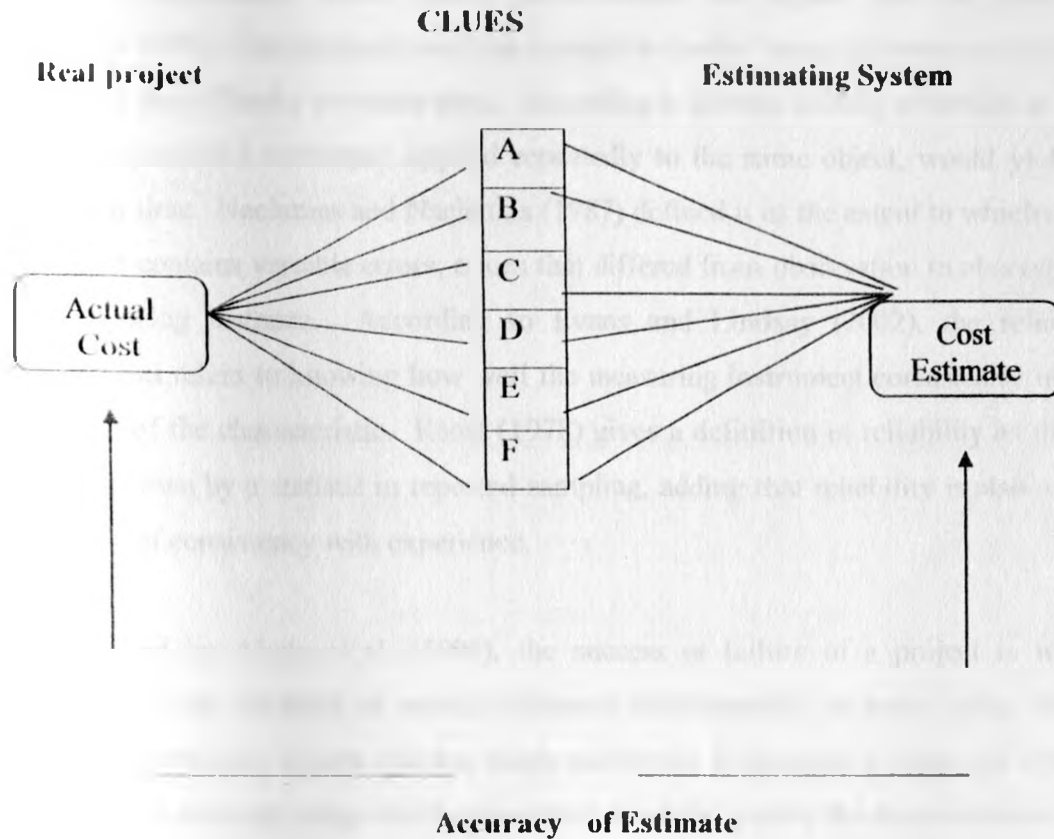
Figure 2.4 Estimate's Accuracy Problem

Source: Adopted from Hoarth, R. M (1980)

Conceptual Cost Estimating Accuracy and Reliability

Accuracy can be defined as nearness to the truth (Rebata 1978). Something is accurate if it is exact and free of errors and mistakes. In the case of construction conceptual estimates, accuracy reflects the closeness of estimate to the actual reference cost of a project. The difference between the estimate and reference values is the estimating error. For an owner, this reference cost is normally the lowest bid received for a project. Accuracy can be defined as the percentage difference between the estimated values of the product or work when compared with the price for which the product or work is contracted (True 1988).

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Reliability is a very general concept that is applied to several different domains. The concept is more common in fields such as materials and structural engineering, equipment performance and test measurement, where precise experimental and actual data are easy to obtain (O'Connor 1985). The application of this concept to 'softer' areas has been much more limited because of the difficulty to obtain data. According to Babbie (1983), reliability is a matter of whether a particular technique, applied repeatedly to the same object, would yield the same result each time. Nachmias and Nachmias (1987) defined it as the extent to which a measuring instrument contains variable errors; errors that differed from observation to observation during any measuring instance. According to Evans and Lindsay (2002), the reliability of a measurement refers to knowing how well the measuring instrument consistently measures the true value of the characteristic. Rebat (1978) gives a definition of reliability as the degree of variance shown by a statistic in repeated sampling, adding that reliability is also a measure of the degree of consistency with experience.

As described by Ahuja et al. (1994), the success or failure of a project is in great part dependent on the accuracy of several estimates. Unfortunately, in many cases, estimates are used as deterministic figures and too much confidence is assigned to them (O'Connor 1985). The expected accuracy range and its associated reliability enable the decision-maker to analyze different possible scenarios according to different cost figures. This information helps planners establish contingency level on a sounder basis and manage uncertainty better. In addition, it assists management in predicting the cash flow for the life of a project more realistically and develops confidence in the estimating function (Clark and Lorenzoni 1985).

2.11 Summary

Any method of preliminary cost estimation of construction projects should be as accurate as possible so as to ensure the reliability and the usefulness of the data obtained from these estimates. Most estimates usually vary to a certain extent with the contractors' bid prices showing that there is a margin of error in the quantity surveyors estimates. The difference between an early price estimate and the accepted tender from a contractor represents an inaccuracy.

This review has established that the factors that have some influence on the accuracy of estimating the costs of the construction work include:-

- The effects of differing availability of design information.

- The amount, type and quality of cost data that is easily accessible.

- The type of project – some types of schemes can be estimated with a greater degree of consistency.

- Project size in terms of value. The accuracy tends to improve by a small amount as projects increase in size

- The number of bidders on competitive projects

- The stability of market conditions

- Personal factors like familiarity with a particular type of project a client has been associated with a substantial improvement in forecasting accuracy.

- Proficiency in estimating is said to be a result of skills, experiences, judgement, knowledge, intuition, academia background and enthusiasm

Chapter Three
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents methods for assessing the expected accuracy and reliability of conceptual estimates. It discusses the research design, the population, sampling design and research tools. The way the data was analyzed is also presented.

3.2 Research Design

The research strategy used to accomplish the study objectives conforms to ethical standards and legal safeguards for research participants. Cost issues are sensitive and therefore it was necessary to assure the respondents that the information given will be treated with confidentiality.

The study was a case study where data was collected from quantity surveying firms

3.3 The Study Area

Cost estimates obtained from residential and office building projects tendered for between 2000 and 2005 inclusive was used. The data was collected from projects for which pre-tender estimates and competitive tendering were employed. These were purposively sampled from private quantity surveying firms operating in the city of Nairobi. These firms were all based in various parts of the city of Nairobi: the Central Business District, Westlands, Upper Hill, Hurlingham, Community, along Ngong Road and Kilimani Areas. The reasons for the choice of the city were basically that nearly 90 percent of all quantity surveying practices in Kenya are located in Nairobi. The city is thus adequately representative of the construction industry cost estimation practices.

3.4 The Population

There is evidence that construction industry activities in developing countries are concentrated in capital cities, and most firms involved in construction activities are located in the capital cities (Habitat 1982, p 31).The population of projects considered in this study was within the geographical boundaries of the city of Nairobi. This is because Nairobi being the capital city

of Kenya, and in comparison to other parts of Kenya, it has the highest number of active construction sites.

The focus of the study is on private residential and office building developments.

3.5 Sampling Technique and Sample Size

Researches on construction projects have in many cases worked with relatively small sample sizes for various reasons. Nkado (1992) investigated information system for the building industry with a sample of 29 cases; Ogunlana, et al (1996) investigated the causes of delay in projects in Thailand basing their research on a sample of 12 projects. Uher (1996), investigated the cost estimating practices in Australian construction industry using a sample of 10 projects. This researcher has used a sample of 68 projects which is therefore well above what has been used in other studies in the construction industry elsewhere. The sample size determined the type of statistics applied. Therefore, by using a suitable statistical tool, some of the problems that could be associated with the sample size are minimised (Gall et al 1996; Lapin 1982).

Gall et al (1996) argue that the non responding data represents bias if they are in some measurable way different from the responding one. Such differences could normally be associated with the project characteristics of size and client. This has not been the case with this study because the different project characteristics identified will be represented. The sample of 68 projects comprised of residential types and office buildings.

Given also the constraints of time and resources, a sample size of 68 projects from quantity surveying firms was found to be adequate for the study. This was in order to be above the recommended minimum of 30 members (Mugenda and Mugenda 1999)

3.6 Research Variables

Most of the variables were identified through literature review specifically variables relating factors that affect cost estimates. The variables are grouped into a number of broad categories to ensure easy analysis. The groupings consider variable relationships with each other as well as similarity in characteristics (Appendix A).

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3.7 Research Tools

Questionnaire Design: The questionnaire was designed in such a way that the stratification of the data for analysis. The questions involved recording the costs that each variable produced in estimating the project cost. These were later ranked on a rating scale. Usage of both closed ended and open ended questions was employed. The open ended questions are specifically for the purposes of harnessing in cases where there is need for further clarification about the variables. The questions concentrated on past phenomena on the projects.

3.8 Administration of the Questionnaire and Data Collection

Initially before data collection, the research participants were identified and approached. Permission to collect the necessary data was given by the University. Letters requesting permission to gather information about the project were hand delivered to the consultants involved in the projects. The introduction letters explained the purpose and usefulness of the research and the type of the information needed. The research assistants involved in the field data collection were trained on how to use a checklist to record data from cost estimates and tender received from contractors. They were also trained on how to conduct personal interviews. The study involved visiting each quantity surveying firm so identified. This approach was adopted because of the need for collecting certain data accurately without ambiguity in their description to the interviewees.

3.9 Measurement of Variables

A variable is a measurable characteristic that assumes different values among the subjects. It is therefore a logical way of expressing a particular characteristic in a subject. Variables can be expressed quantitatively for example height in metres and others in categories like gender expressed as male or female (Mugenda and Mugenda 1999). The independent and dependent variables are discussed.

3.9.1 Independent Variables

An independent variable is a variable that a researcher manipulates in order to determine its effect or influence on another. It is a variable whose available categories are designated in advance by the researcher. Normally these variables are selected because they are seen to be causative or very important to the particular logical purpose of the research project. The term

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independent means the categories of the variables are chosen by the researcher independently in the measurement taken in the project and normally prior to it. In this study the level of accuracy of cost estimates evidenced through the functions of project statistics was viewed as the independent variable. The project statistics included project scope/size, construction time, cost estimating methods, project organization, building type and professionals involved in giving the estimate. The measurement of the components of these independent variables was done in an ordinal scale as can be derived from the descriptive nature of the study.

An ordinal scale groups subjects into categories and ranks them into some order with numerals reflecting increasing amount of the characteristics but not at intervals. The numerals are used to represent relative position or order among the values of the variable. However, the order indicated in an ordinal scale does not imply a quantitative diction (Mugenda and Mugenda 1999)

Thus, based on the responses from the questionnaire, a scoring system for each of the components of the independent variables was developed to indicate its performance in that aspect as shown in Tables 3.1, 3.2, 3.3, 3.4 and 3.5.

Project Scope/Size: The project scope/size can be measured in terms of value of the project or construction area. It is a measure of how the project is perceived to be either small or large. This independent variable was given a scaling based on the value of the project. The larger the project the more complex it is to give an accurate cost estimate.

Table 3.1: Scoring for Project Scope/Size

Project Value Kshs.	Score
0 – 50 million	1
50 – 100 million	2
100 – 200 million	3
200 – 500 million	4

Source : Author

Construction Time: The construction time or Contract period is the time a building contractor gives for completing the project at the time of tendering. It is normally given in days, weeks or months (Table 3.2). This independent variable was a given scaling based on the contract period. The more the construction time, the higher the risks and hence inaccuracies of the cost.

Table 3.2 Scoring for Construction Time

Contract Period (Weeks)	Score
9 – 12	1
12 – 15	2
15 – 18	3
18 – 24	4
24 and over	5

Source : Author

Cost Estimate Method Used: This independent variable was given a scaling based on the design information available (Table 3.3).

Table 3.3 Scoring for cost estimate method used

Method Used	Maximum Score
Pricing complete bills of quantities	1
Pricing approximate bills of quantities	2
Elemental cost analysis	3
Square meter rate	4

Source : Author

Project Organization: Project organization refers to the procurement method used for managing the project. This independent variable was given scaling based on risks of price increase to a client during construction stage. The design and build procurement method is more accurate in firming up a tender figure as the contractor assumes most of the risks associated in performing the contract. The other procurement methods were ranked in the order that they are likely to bring variability in the final construction cost to a project. (Table 3.4)

Table 3.4 Scoring for Project Organization

Procurement Method Used	Score
Design and build	1
Project Management	2
Traditional (Architect as Lead Consultants)	3
Management contracting	4
Others (BOOT etc)	5

Source : Author

Professional Involved: Various professionals can be used to derive a cost estimate as noted in the questionnaire. This independent variable was given a scaling based on the number of professionals involved in arriving at a cost estimate. It was generally assumed that the more professionals are involved, the more accurate would be the estimate (Table 3.5)

Table 3.5: Scoring for Professionals Involved in arriving at a Cost Estimates

Number Of Professionals Involved	Score
8	1
7	2
6	3
5	4
4	5
3	6
2	7
1	8

Source : Author

3.9.2 Dependent Variables

Dependent variables are so named because their results are presumed to depend upon differences in the independent variables. The variation in them is seen as being related to, caused by, or in some way influenced by differences in the independent variable.

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A dependent variable therefore varies as a function of the independent variable. In this study the level of accuracy of a cost estimate was viewed as the dependent variable because it should vary in some relationship to the independent variables. Its measurement was also based on ordinal scale. The accuracy of the cost estimate when compared with the awarded tender figure was ranked on a scale of one (1) to four (4). For example based on the questionnaire a scoring basis was established as in Table 3.6.

This dependent variable was given a scaling based on the margin of error noted in the cost estimate when compared to the lowest tender figure awarded the contract. An error of 5 percent was given the lowest number.

Table 3.6 Scoring for Accuracy Levels

Error	MAXIMUM SCORE
5%	1
10%	2
20%	3
60%	4

Source : Author

3.10 Hypothesis Testing

The null hypothesis H_O, states that there is no relationship between each of the independent variables and the dependent variable. The alternative hypothesis H_A states that there is a casual relationship between the independent and the dependent variable. The F statistic was be used to test the existence or otherwise of a relationship. The F statistic is given by the tables provided by the NIST/SEMATECH e-Handbook of Statistical Methods-http://www.itl.nist.gov./div898/handbook (Accessed on Friday 8th July, 2005)

There was a comparison of F values made from values obtained from the computer printout in the regression models that is: calculated F values and the F values tabulated in the statistics table at appropriate degrees of freedom. If the null hypothesis was rejected in this case where the F value calculated exceeded the F value expected from the tables at the same degree of freedom; then the alternative hypothesis is accepted.

From NIST/SEMATECH table (Available at http://www.itl.nist.gov/div898/handbook Accessed on Friday 8th July, 2005) the null hypothesis was rejected for the cost estimate.

Some reasons why a F – statistic test might fail to uncover statistical significance even if the independent variable is actually related to the independent variables are: inadequate sample size, type II error, specification error and restricted variance in X. Another possibility is high multi-co-linearity, but this is ruled out in these results because the contingency table of correlation coefficient showed that none of the variables in the final model had a high correlation to each other. With a larger sample, a given coefficient is more likely to be found significant. In very large samples of over 1,000, the statistical significance may actually be "too easy" to find since tiny coefficient can be statistically significant. In studies where the samples size is limited as a result of difficulties in obtaining case studies (Nyagah, 1989: p. 145-146), the size of the sample could make the results not significant at the prescribed confidence internal.

Where the null hypothesis would have been accepted as a result of type II error this would have implied that the null hypothesis is accepted while in fact it is false. In a case where the sample size is fixed the problem of choosing a significance level becomes important. The significance test in principle can be set at any level between 0 and 1. Most social scientists set at 0.05 or 0.01. One of the convenient levels is usually selected at the beginning of a study. One might select a level of 0.025 prior to the investigation only to find that the significance at 0.05 is less demanding. In this case one may prefer to accept the results at the lower test. What this explains is that the significance at a lower test level may be evident which at a higher test level is not. What this explains is that the significance at a lower test.

3.11 Methods of Data Analysis
The variables selected for the prediction of the cost estimates are those that could be easily, inexpensively and conveniently be defined and measured at the pre-design (or sketch design) stage of the building development process. The analysis of the data was done using a computer package - Statistical Programme for Social Sciences (SPSS) for windows - and involved the following procedures: - descriptive Statistics (mean, mode, medium, skewness, kurtosis, maximum & minimum correlations and regressions.

Regression analysis was used for data analysis. Descriptive statistics have been used to explain the various outcomes and relationships. To achieve this, the responses in the questionnaire were assigned numerical values a process refereed to as coding) for ease of analysis. This was facilitated with the items in the questionnaire being mainly close ended. Inferential statistics (using SPSS Software) has been applied to assist in testing of hypothesis. The testing of hypothesis followed regression and correlation analysis between two major variable sin the study namely the accuracy of cost estimate and the building type. The inferential statistics is applied to help in generalization of the findings. The hypothesis is tested at 95% confidence level.

Chapter Four

DATA ANALYSIS AND PRESENTATION

4.0   Introduction

In this chapter data that was collected from quantity surveying firms is analyzed. Tables and description derived from the data is used to explain the findings from the survey. The hypothesis that cost estimates do not accurately project pre-design stage cost used as a guide for investment decision making process is also tested. Out of the 68 targeted projects, each with a questionnaire irrespective of the quantity surveying firm involved, only 46 were returned, representing 68 percent. The researcher considered 46 projects provided reasonable and sufficient response rate for proceeding with the data analysis. The firms were visited several times before they could fill the questionnaire due to the involving task of filling the detailed elemental analysis of costs. The good responsiveness was mainly due to the fact that the firms purposively selected had data from previous projects. With a few quick telephone calls the respondents agreed to give the information to the research assistants. Responses were received from the 27 participating quantity surveying firms is shown in Tables 4.1 – 4.3. The breakdown of the 46 projects analyzed is also as shown. Only one bungalow type project was received the reasons being that most firms have not handled any project of this nature for the last five years.

Table 4.1 – Frequency of Residential Buildings

	Types of Residential Buildings	No.	Percentage
1.1	Low Rise Flats	13	54
1.2	Maisonnettes	10	42
1.3	Bungalows	1	4
	TOTAL	24	100

Source : Author

Table 4.2 – Frequency of Office Buildings

	Types of Office Buildings	No.	Percentage
2.1	Low rise office blocks	12	55
2.2	High rise office block (with lift)	10	45
	TOTAL	22	100

Source : Author

Table 4.3 – **Summary Of Frequency Of All Building Types**

	Type of Residential Buildings	Frequency	Percentage
1.1	Low rise flats	13	28
1.2	Maisonettes	10	22
1.3	Bungalows	1	2
1.4	Low rise office block	12	26
1.5	High rise office block (with lift)	10	22
	TOTAL	46	100

Source : Author

4.1 Analysis of Independent Variables

The analysis of the various components of the independent variables are discussed in this section.

Types of Contract Used: The study sought to find out the most frequently used contracts (Table 4.4). Most of the project, 85 percent were awarded to contractors as lump sum fixed price. It seems most of the consultants are comfortable with fixed price contracts where contractors takes the risks for increases in prices of materials, labour and plant during the construction period. Most of the contract periods are within one year (12 month construction period). Hence it fairly easy to predict price increases and take the risks. However, the study did not investigate why lump sum fixed price are the most popular type of contracts. Fluctuating price contracts at 4 percent are only being used for larger projects with construction period of over two years. The other types of contracts labour contracts and contract management account for 11 percent of the total project studied.

Table 4.4- Observed Frequency Types of Contracts Used and Building Type

	Lump Sum Fluctuating price	Lump Sum fixed price	Schedule of Rates	Others	Total
Low Rise flats	1	11	-	1	13
Maisonettes	-	10	-	-	10
Bungalows	-	1	-	-	1
Low Rise Office Blocks	-	8	-	4	12
High Rise Office Blocks	-	9	-	1	10
	2	39	-	5	46
Percentage	4	85	0	11	100

Source: Field survey

Cost Estimating Methods: From the results, the most commonly used estimating method is pricing approximate quantities at 43 percent followed by pricing a complete bills of quantities before tendering at 33 percent. It seems quantity surveying firms require more detailed drawing and information to give firm cost estimates to client. The results show that unit and cubic methods for estimating building projects are not used in Kenya (Table 4.5). As noted in the literature review, the study results reconfirms that the cubic method is obsolete and no longer being used by the industry.

Table 4.5 -Observed Frequency of Cost Estimating Method Used and Building Type

	Cubic Method	Unit Rate Method	Square metre rate	Elementary cost Analysis	Approximate quantities	Pricing bills of quantities	Total
Low Rise flats	-	-	2	3	7	4	16
Maisonettes	-	-	-	1	5	3	9
Bungalows	-	-	-	-	1	-	
Low Rise office Blocks	-	-	1	2	4	3	
High Rise Office Blocks (with lift)	-	-	-	2	3	5	
TOTAL	0	0	3	8	20	15	46
PERCENTAGE	0	0	7	17	43	33	100

Source : Author

Project Organization: The most frequently used project organization at 61 percent is tradition approach (design separate from construction) with the architect as the lead consultant for both design and project supervision of the projects. Project Management approach at 26 percent of the analyzed projects is the second most popular especially for office blocks and low rise residential flats. Management contracting and design and build account for 4 percent and 9 percent respectively which indicates the industry has not fully embraced the new management approaches. This analysis shows that cost estimates accuracy follow the stage reached in production of design information for use by quantity surveyors in the estimating process (Table 4.6).

Table 4.6 – Observed Frequency of Project Organization Approaches and Building Types

	Project Management Approach	Traditional – Architect as Lead Consultant	Design & Build	Management Contracting	Turnkey	Others	Total
Low rise residential flats	1	10	1	1	-	-	13
Maisonettes	1	7	1	1	-	-	10
Bungalows	-	1	-	-	-	-	1
Low rise office blocks	5	5	-	2	-	-	12
High rise office blocks (with lift)	5	5	-	-	-	-	10
TOTAL	12	28	2	4	-	-	46
PERCENTAGE	26	61	4	9	0	0	100

Source : Author

The more information is provided, the more accurate the cost estimate for the particular project

Consultants Used in Cost Estimating: The results indicates that quantity surveyors, electrical and mechanical engineers are the most used professionals in cost estimating of project at 29 percent, 24 percent and 23 percent respectively. Quantity surveyors are also used 100 percent on all the cases analyzed followed by electrical engineers at 83 percent (Table 4.7).

Table 4.7 – **Observed Frequency of Consultants used in Cost Estimating and Building Type**

	Project Manager	Architects	Quantity Surveyors	Civil/ Structural Engineers	Electrical Engineers	Mechanical Engineers	Land Scape Architects	Others	Total
Low rise flats	2	5	13	5	12	11	3	1	52
Maisonettes	2	3	10	1	6	6	-	-	28
Bungalows	-	-	1	-	1	1	-	-	3
Low rise office Blocks	-	-	12	1	9	9	2	-	33
High rise office blocks (with lift)	1	6	10	6	10	10	1	-	34
TOTAL	5	14	46	13	38	37	6	1	160
Professional usage (percentage)	3	9	29	8	24	23	4	1	100
Usage on 46 projects analyzed (percentage)	11	30	100.00	28	83	80	13	2	

Source : Author

Project Managers and architect normally provide information for use by other professionals in the cost estimation function.

Other Independent Variables: The respondent felt that the plot areas and construction plinth areas were covered in the project scope and size for purposes of cost estimating. The scarity information provided was not useful for the study similarly the quality of materials, components and workmanship was not a factor in the cost estimating function, hence the data was not used.

4.2 Analysis of Dependent Variables

The study also set out to establish the extent of accuracy variability of the cost estimate and lowest enders received for the projects studied (Table 4.8).

Accuracy of Cost Estimates: From the results of the accuracy analysis, the majority margin error was 30 percent at the accuracy level of 5 – 1 percent. Projects with an accuracy level of 0-5 percent were only 2 percent.

Table: 4.8 Observed Frequency of Accuracy of the Cost Estimate and Building Type

Percentage Error	Low Rise Residential Flats	Maisonettes	Bungalow	Low Rise Office Block	High Rise Office Block	Total	Percentage
0 - 5	1	-	-	-	-	1	2
5 - 10	2	3	-	3	6	14	34
10 - 15	3	1	-	3	3	10	22
15 - 20	3	3	-	5	1	13	28
20 - 25	3	-	1	1	-	4	11
25 - 30	-	2	-	-	-	2	4
30 - 35	1	1	-	-	-	2	4
35 - 40	-	-	-	-	-	-	0
Over 40	-	-	-	-	-	-	0
TOTAL (Percentage)	13	10	1	12	10	46	100

Source : Author

4.3   Quantitative Analysis

This section presents the results of the quantitative analysis. Usage is made of Pearson's product moment correlations to assess multi-co-linearity in order to determine whether the independent variables are highly correlated among themselves. The computed correlations on all the variables in the model show that there is a minimum level of the problem of multi-co-linearity. The method used for analysis is step-wise regression. The independent variables undergo testing for their strength in predicting the dependent variables using the regression coefficients.

4.3.1 Correlations

This was to determine the relationship between the variables understudy. A correlation coefficient above + 0.7 shows that variables are highly correlated. Correlation performed on the independent variables show only how values relate among themselves. This is necessary because any two variables having a correlation of more than 0.7 implies that one of the independent variables is redundant and hence should be dropped from the model. The analyzed correlation data is in Table 4.9. This had usage in the identification of the independent variables that were highly related to each other. Inclusion of such interrelated variables would have had a combined effect, which affects the results. Thus to avoid multi-colinearity, interrelated variables would be removed (Table 4.9). In this analysis, there was no independent variable with correlation figure more than 0.7, thus all the independent variables were regressed with dependent variable (Tables 4.9 and 4.10). Stepwise regression analysis method was used.

Table 4.9 – Correlations of independent and dependent variables

	Variables	Cost Estimate	Project Scope	Construction Time	Method Used	Project Organization	Professional Used	Building Type
Pearson Correlation	Cost Estimate	1.000	-.127	-.161	.131	-.041	-.104	.243
	Project Scope	-.127	1.000	.646	-.084	-.234	-.148	.527
	Construction Time	-.161	.646	1.000	-.173	-.047	-.390	.360
	Method used	.131	-.084	-.173	1.000	-.307	-.214	-.205
	Project organization	-.041	-.234	-.047	-.307	1.000	.047	-.041
	Professional used	-.104	-.148	-.390	-.214	.047	1.000	-.189
	Building type	.243	.527	.360	-.205	-.041	-.189	1.000

Source : Author

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Table 4.10 – Coefficients of Independent Variables

Model	Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	1.578	.474		3.331	.002			
	Building Type	.218	.131	.243	1.660	.104	.243	.243	.243
2	(Constant)	1.597	.456		3.505	.001			
	Building Type	.385	.148	.429	2.592	.013	.243	.368	.365
	Project Scope	-.325	.152	-.353	-2.135	.038	-.127	-.310	-.300
3	(Constant)	1.043	.602		1.732	.091			
	Building Type	.424	.150	.473	2.836	.007	.243	.401	.395
	Project Scope	-.331	.151	-.360	-2.198	.034	-.127	-.321	-.306
	Method Used	.225	.162	.198	1.389	.172	.131	.210	.193
4	(Constant)	1.191	.654		1.822	.076			
	Building Type	.424	.151	.473	2.815	.007	.243	.402	.395
	Project Scope	-.265	.187	-.288	-1.419	.163	-.127	-.216	-.199
	Method Used	.209	.165	.184	1.269	.212	.131	.194	.178
	Construction Time	-.125	.206	-.113	-.608	.547	-.161	-.094	-.085
5	(Constant)	1.641	1.086		1.511	.139			
	Building Type	.408	.155	.455	2.624	.012	.243	.383	.371
	Project Scope	-.241	.194	-.262	-1.241	.222	-.127	-.192	-.176
	Method Used	.176	.178	.155	.992	.327	.131	.155	.140
	Construction Time	-.180	.233	-.163	-.773	.444	-.161	-.121	-.109
	Proffesional Used	-.051	.098	-.087	-.521	.605	-.104	-.082	-.074
6	(Constant)	1.858	1.306		1.423	.163			
	Building Type	.409	.157	.456	2.603	.013	.243	.385	.373
	Project Scope	-.256	.203	-.279	-1.264	.214	-.127	-.198	-.181
	Method Used	.159	.189	.140	.843	.405	.131	.134	.121
	Construction Time	-.174	.236	-.158	-.739	.464	-.161	-.118	-.106
	Professional Used	-.052	.099	-.089	-.523	.604	-.104	-.083	-.075
	Project Organization	-6.353E-02	.207	-.048	-.308	.760	-.041	-.049	-.044

Source : Author

4.3.2 Stepwise Regression Analysis

All the independent variables were entered for regression. Step-wise regression method was adopted because it showed only the variables that were important at the set confidence level of 95 percent. The only model which met this criteria was model 2. This means that the two major predictors of accuracy of cost estimates are building type and project scope/size. The

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predictors are able to explain 14.9 percent of the variation of the cost estimate in the building. This model 2 is the only combination of the variables that is significant at 0.05 level which is the set confidence level. The rest of the variables combined can only explain 5.9 percent as presented in Table 4.11.

The implication of this finding is that these other variables; construction time, method of construction, project organization and profession used in the building construction projects have minimal impact on the estimated cost. Probably the reason for this occurrence is that our project and construction management has remained conventional and these variables reflect more or less the practised management in quantity surveying firms. What we are saying is that almost all construction firms have minimal variation when it comes to application of among these variables in their practice. Hence the findings show that probably the most critical variables that quantity surveying firms should consider when doing cost estimates are the type of building and the scope/size of project.

Table 4.11 – Regression Models Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.243	.059	.038	.99	.059	2.755	1	44	.104
2	.386	.149	.110	.96	.090	4.560	1	43	.038*
3	.432	.187	.128	.95	.037	1.929	1	42	.172
4	.440	.194	.115	.95	.ss007	.369	1	41	.547
5	.446	.199	.099	.96	.005	.272	1	40	.605
6	.449	.201	.078	.97	.002	.095	1	39	.760

Source: Author

R squared=0.149   F=4.560   Significant F=0.038   * Significant level at 0.05

   a. Predictors: (Constant), BLDD_TYP

   b. Predictors: (Constant), BLDD_TYP, PRJ_SCOP

   c. Predictors: (Constant), BLDD_TYP, PRJ_SCOP, MET_USED

   d. Predictors: (Constant), BLDD_TYP, PRJ_SCOP, MET_USED, CON_TIM

   e. Predictors: (Constant), BLDD_TYP, PRJ_SCOP, MET_USED, CON_TIM, PROFF_IN

   f. Predictors: (Constant), BLDD_TYP, PRJ_SCOP, MET_USED, CON_TIM, PROFF_IN, PRJ_ORG

   g. Dependent Variable: COST_EST

4.4   Hypothesis Testing

The Null Hypothesis: Cost estimates do not accurately project pre-design stage costs used as a guide for investment decision making process.

The Alternative Hypothesis: Cost estimates do accurately project pre-design stage costs used as a guide for investment decision making process.

Testing using the F-statistic

Tabulated F is 2.449 at 95% confidence level (Appendix B)

Computed F is 4.560 (Table 4.11).

Null hypothesis is rejected hence we accept the alternative hypothesis that states that cost estimates do accurately project pre-design stage costs used as a guide for investment decision making process. As explained in stepwise regression analysis, the building type and project scope/size were found to influence the cost estimate of building project significantly.

Chapter Five
CONCLUSIONS

5.1   Introduction

This chapter gives the findings on the accuracy of cost estimates when compared with the results of the successful tenders or lowest bidders awarded the contract. Conceptual cost estimates are critical inputs for owners' decision-making in the early planning stages of construction projects. However, a recurrent problem associated with conceptual estimating is how to assess the quality of the estimates, that is, the expected accuracy and reliability of cost figures given the uncertainty and risk that every project will face during its development. One of the approaches used to assess the quality of an estimate is the application of expertise opinion and experience. This research examined the problem of the quality of conceptual estimating. It assessed the usage of historical and empirical information which had been used in the pre-tender cost estimates, and ascertained whether it is possible to get an appropriate initial assessment of the expected accuracy and reliability of a cost estimate. This is then compared with successful bidder or the lowest tender figure awarded the contract.

5.2 Results

The findings of the study can be summarized as follows:-

- The main objective of this study was to establish the variation between the cost estimates derived from the various estimation methods. The research established that cost estimating methods contribute 43 percent of estimating errors.

- The second objective was to establish factors that have direct influence on the cost of residential and office projects in Kenya. The study has shown that building type and project scope size are other major factors contributing 24.3% of the estimating errors. The study also tried to discover whether there are other factors that have a direct influence on the cost of project that are omitted by the pre-tender cost estimation methods. The findings was unable to account for more than 20% other factors that may influence the accuracy of cost estimates. Other factors were identified in the literature review as estimator's biases. However these factors were not covered in this research.

- The third objective of the study was to establish the deviation of construction cost estimates from actual tender received. The findings noted that cost estimates accuracy falls between 5-10% of estimated costs.

From the finding and analysis of this study, it can be concluded that their exist a large variability between cost estimates and the successful bidder or the lowest tender figures awarded the contract.

Based on stepwise and regression analysis, building type and project scope/size variables were found to major predictors of the cost estimates of building projects, hence these variables explains the inaccuracies therein. The outcome of hypothesis testing confirmed that at 95% confidence level (S.F =0.05 and 42 degrees of freedom). The outcome is supported with strong correlation (0.877) between level of cost estimate and cost estimating methods. This is statistically significant at 0.01 level (that is, it would occur by chance less than one in a hundred times) generalized to the whole population and thus apply to all building projects considered in this study. The implication of the findings is that construction cost estimates in Kenya will continue to experience variability unless adequate attention is not paid by quantity surveyors firms in addressing major predictors in the cost estimating of building projects.

The other implication of this findings is that the variables which do not constitute the significant model 2, must be given attention by the quantity surveying forms since they would improve the accuracy of the building cost estimate. Since they seem to be surrogates of project and construction management, then it is important the professions and evaluate their management techniques as they have bearing cost of building.

5.3 Recommendations

It is recommended that the quantity surveying firms need to consider the building type and scope /size of building more critically when they are doing cost estimate in projects of office and residential buildings.

5.4 Suggested Areas of Further Study

- Performance of a cost model for estimating preliminary cost of building costs before the design proceeds to a more advanced level.

- Establishment of a building cost index in Kenya that can be used for comparing cost generated by different time period (years)

- Elemental distribution of cost for residential and office building projects in Kenya.

- Reasons why fixed price types of contracts are most used for construction projects in Kenya.

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An Investigation Into Factors That Affect The Accuracy Of Cost Estimates For Building: Case-Study Of Private Residential And Office Projects In Kenya

Questionnaire For Quantity Surveying Firms

PART 1

Kindly assist in providing the data required in this research study, by completing this questionnaire. Your assistance will be highly appreciated. Answers to the questions contained in the questionnaire shall be kept confidential

Please provide the following details of Residential building project selected from your quantity surveying firm

1	PROJECT PARTICULARS	Fill in this column
A.	Type of residential building project (please tick)	
	1. Residential – Low Rise flats	
	2. Maisonettes	
	3. Bungalows	
B	Type of Contract (please tick)	
	1. Lumpsum fluctuating price	
	2. Lumpsum fixed price	
	3. Schedule of rates	
	4. Other (specify)	
2.	PROJECT SCOPE & COMPLEXITY	
A.	Plinth area Square metres	
B.	Height - Total number of storeys	
C.	- Storey height (average) Metres	
	- Total height (including parapet walls, roof etc) Metres	
D.	Length of frontage Metres	
E.	Size of site (plot) Square metres	
F.	Roof pitch (please tick)	

	– pitched roof		
	– flat roof		
G.	Total Area of:-		
	(i) External wall	Square metres	
	(ii) External Windows	Square metres	
	(iii) External Doors	Square metres	
3.	**CONSTRUCTION TIME**		
A.	Date of cost estimate		
B.	Date of tender opening		
4.	**COST ESTIMATE**		
A.	A.1 Preliminary Cost Estimates		
	A.2 Lowest tender figure recommended for contract award		
B.	COST ESTIMATING METHOD USED		
	(i) cubic method		
	(ii) Unit rate method		
	(iii) Square metre rate		
	(iv) Elementally cost analysis		
	(v) Approximate quantities		
	(vi) Pricing complete bills of quantities		
5.	**PROJECT ORGANIZATION**		
A.	Procurement Approach (please tick)		
	1. Traditional – Architect being designer & contractor)		
	2. Non-traditional – design & build		
	- project management		
	- management contracting		
	- turnkey		
	- Other (please specify)		
B.	Which of the following professionals were involved in giving cost estimates for this project (please tick)		
	1. Project managers		
	2. Architects		
	3. Quantity Surveyors		

	4. Civil / Structural engineers				
	5. Electrical engineers				
	6. Mechanical engineers				
	7. Landscape architects				
	8. Others (specify)				

6.	**QUALITY OF MATERIALS, COMPONENTS & WORKMANSHIP**				
	Using the scale described below, rate the quality of materials and workmanship in the following components of the building.			Tick the correct ratio	
	Component/ Scale	*Fair* (1)	*Average* (2)	*Good* (3)	*Very Good* (4)
A	Foundations	Strip foundation			
B	Structural Design	Minimum design loads	Average design loads	Above average design loads	Many extra design loads
C.	External wall	Masonry	Masonary and/or Glass cladding	Glass cladding, Curtain wall, precast concrete panels/sunbreakers	Monumental (marble)
D.	Floor Finishes	Cement screed	PVC and/or Granolithic	Ceramic tiles terrazzo, parquet.	Granite, marble
E.	Internal Wall finishes	Plaster & paint	Plaster & paint, timber panels	Plaster & paint timber panels, ceramic tiles	Aluminum panels, Marble
F.	Ceiling finishes	Plaster & paint painted celotex	Plaster & paint, painted chipboard, soft wood T & G boarding	Plaster & paint, painted chipboard, hardwood T & G boarding	Suspended aluminium panes

G.	Sanitary fittings	Squatting type WC, Plastic cisterns	White fittings, stainless steel taps.	Coloured conventional shape fittings, brass plated taps	Coloured non-conventional shape fittings, gold plated taps
H.	Electrical	Fluorescent light, poor quality ceiling	Fluorescent light, average quality suspended ceiling	Fluorescent light, above average quality ceiling	Fluorescent light, excellent quality ceiling
I	Ventilating and air conditioning	Below average quality	Average quality	Above average minimum	Above average quality

APPENDIX B

F Distribution Table

V_1 / V_2	1	2	3	4	5	6	7	8	9	10
1.	161.4	199.5	215.7	224.58	230.16	233.98	236.76	238.88	240.54	241.9
2.	18.513	19.00	19.16	19.247	19.29	19.330	19.35	19.371	19.385	19.4
3.	10.128	9.552	9.277	9.117	9.013	8.941	8.887	8.845	8.812	8.786
4.	7.709	6.944	6.591	6.388	6.256	6.163	6.094	6.041	5.999	5.964
5.	6.608	5.786	5.409	5.192	5.050	4.950	4.876	4.818	4.772	4.735
6.	5.987	5.143	4.757	4.534	4.387	4.284	4.207	4.147	4.099	4.060
7.	5.591	4.737	4.347	4.120	3.972	3.866	3.787	3.726	3.677	3.637
8.	5.318	4.459	4.066	3.838	3.687	3.581	3.500	3438	3.388	3.347
9.	5.117	4.256	3.863	3.633	3.482	3.374	3.293	3.230	3.179	3.137
10.	4.965	4.103	3.708	3.478	3.326	3.217	3.135	3.072	3.020	2.978
11.	4.844	3.982	3.587	3.357	3.204	3.095	3.012	2.948	2.896	2.854
12.	4.747	3.885	3.490	3.259	3.106	2.996	2.913	2.849	2.796	2.753
13.	4.667	3.806	3.411	3.179	3.025	2.915	2.832	2.767	2.714	2.671
14.	4.600	3.739	3.344	3.112	2.958	2.848	2.764	2.699	2.646	2.602
15.	4.543	3.682	3.287	3.056	2.901	2.790	2.707	2.641	2.588	2.544
16.	4.494	3.634	3.239	3.007	2.852	2.741	2.657	2.591	2.539	2.494
17.	4.451	3.592	3.197	2.965	2.810	2.699	2.614	2.548	2.494	2.450
18.	4.414	3.555	3.160	2.928	2.773	2.661	2.577	2.510	2.456	2.412
19.	4.381	3.522	3.127	2.895	2.740	2.628	2.544	2.477	2.423	2.378
20.	4.351	3.493	3.098	2.866	2.711	2.599	2.514	2.447	2.393	2.348
21.	4.325	3.467	3.072	2.840	2.685	2.573	2.488	2.420	2.366	2.321
22.	4.301	3.443	30.49	2.817	2.661	2.549	2.464	2.397	2.342	2.297
23.	4.279	3.422	3.028	2.796	2.640	2.528	2.442	2.375	2.320	2.275
24.	4.260	3.403	3.009	2.776	2.621	2.508	2.423	2.355	2.300	2.255
25.	4.242	3.385	2.991	2.759	2.603	2.490	2.405	2.337	2.282	2.236
26.	4.225	3.369	2.975	2.743	2.587	2.474	2.388	2.321	2.265	2.220
27.	4.210	3.354	2.960	2.728	2.572	2.459	2.373	2.305	2.250	2.204
28.	4.196	3.340	2.947	2.714	2.558	2.445	2.359	2.291	2.239	2.190
29.	4.183	3.328	2.934	2.701	2.545	2.432	2.346	2.278	2.223	2.177
30.	4.171	3.316	2.922	2.690	2.534	2.421	2.334	2.266	2.211	2.165
40	4.085	3.232	2.839	2.606	2.449	2.336	2.249	2.180	2.124	2.077
50	4.034	3.183	2.790	2.557	2.400	2.286	2.199	2.130	2.073	2.026
60	4.001	3.150	2.758	2.525	2.368	2.254	2.167	2.097	2.040	1.993
70	3.978	3.128	2.736	2.503	2.346	2.231	2.143	2.074	2.017	1.969
80	3.960	3.111	2.719	2.486	2.329	2.214	2.126	2.056	1.999	1.951
90	3.947	3.098	2.706	2.473	2.316	2.201	2.113	2.043	1.986	1.938
100	3.936	3.087	2.696	2.463	2.305	2.191	2.103	2.032	1.975	1.93
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.93
	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.80

Upper critical values of the F distribution for V2 numerator degrees of freedom and V1 denominator degrees of freedom 5% significance level.

Source: NIST/SEMATECH e-Handbook of Statistical Methods –

http://www.itl.nist.gov/div898/handbook (accessed 3.02 2003)