A STUDY INTO THE EFFECTS OF DESIGN PARAMETERS ON BUILDING COST OF PUBLIC BUILDING PROJECTS IN KENYA

By

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DECLARATION

I, PETER KATHURIMA MIRITI, hereby declare that this thesis is my original work and has not been presented for a degree in any other university.

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DECLARATION OF SUPERVISORS

This thesis has been submitted for examination with my approval as University Supervisor.

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DEDICATION

This project is dedicated to my beloved mother, Julia for her support and late father Stephen whose continued memory has inspired me in my studies.

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ABSTRACT

This study looks at the effect of design parameters on building cost of public building projects in Kenya. Four elements have been selected for examination. The four elements are substructure, walling, roofing and finishes. The study has established that design parameters can be used to express building cost by elements and therefore can be used in cost advise in the early stages of design process. The design parameters considered in the study are size, storey height, total height, shape and specification and building cost index.

Both correlation and regression analyses were used to test the strength of the relationships between the cost of buildings by elements and the design parameters.

A total of forty three buildings qualified for study out of a population of two hundred and eighteen.

Substructure exhibited strong correlation coefficient of 0.7295 with size of building at student t-test confidence level of 99%. Roofing showed correlation coefficient level of 0.600 with building cost index and finishes recorded 0.5318 with size of building.

The regression analyses showed even better results by including several design parameters in the equation. Substructure was better explained by size, building cost index and storey height, achieving a multiple correlation of 0.800. Similarly walling was explained by size and storey height giving a multiple correlation coefficient of 0.716. Roofing was explained by building cost index and storey height giving a multiple correlation coefficient of 0.69 and finishes was explained by size, storey height and building cost index giving a multiple correlation coefficient of 0.65.

In determining which design parameter to include in the element cost equation, stepwise regression was used. Only those design parameters, which satisfied the criteria for selection using stepwise regression was included thus minimising the standard error and increasing the strength of the relationships.

The findings of this study show that building cost can be explained by their elements and the

design parameters that affect the cost of the elements. In so doing vital information during design stage can be accessed in order to keep to the budget limits given by clients.

This study is divided into five chapters.

The first chapter of this study outlines the evolution of cost models in the evaluation of building costs over time, where we find traditional models being blamed for not controlling building cost. This problem can reasonably be reversed by introducing the concept of design parameters in the estimation of building costs at early design stages.

The second chapter looks at the concepts associated with implementation of public building projects, cost control and cost planning together with design method and cost planning.

Chapter three looks at cost consequences of building elements on design parameters and the study model. The design parameters considered are size of buildings, its shape, total height and storey height.

Chapter four is on data analysis and presentation. It is concerned with the gathering of data, how it was transformed for analysis and finally how it was interpreted and presented.

Finally, Chapter five covers conclusions and recommendations of the study together with recommended areas of further research.

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LIST OF ABBREVIATIONS

A. STATISTICAL

	Symbol	Meaning	Reference page
1.	a	Population regression intercept or intercept on Y	14-15,66
2.	b,B	Population regression slope or the slope Y on X	14-17, 21,66
3.	d.f.	degree of freedom	23
4.	e,SEB	error term in regression model	15, 112-119
5.	F	F-statistic or F-ratio	21
6.	H_A	Alternative hypothesis	10
7.	H_o	Null hypothesis	9
8.	K, k	Number of regressors	110,118
9.	r	coefficient of simple correlation	18,19
10.	r^2	coefficient of determination	22
11.	R	coefficient of multiple correlation	22,110-118
12.	R^2	Multiple determination	22,23,110-118
13.	Σ	Sum of	21,22
14.	S^2	Residual Variance	14
15.	t_{n-k}	Student's variable on (n-k) d.f	15-17,111-117
16.	U	Population mean	9,10
17.	X,Z	Independent variables	14-17,66
18.	X_k	Independent variable with K number of regressors	10
19.	Y or y	Dependent variable or the response y	14-17,22,66

	Symbol	Meaning	Reference page
20.	Y	Mean of independent variable	20-22
21.	Y_c	Fitted independent variable by regression	20-22

B.OTHERS

1.	a	Element cost intercept i.e elemental cost per unit floor area that is independent of X_i's.	94
2.	B_i's	Coefficients for X_i's.	94,95
3.	C	Cost of the building per unit floor area	10,63,94
4.	E	Element of a building	63
5.	E_c	Elemental cost per unit floor area	113,115,117,119
6.	h	Slab thickness between two consequtive storey heights.	96
7.	H_i	Storey at each floor where;i = number of storeys	95
8.	I	Integer between 1-4.	65
9.	K	Number of Building Components.	65
10.	MSE	Mean squared error.	23,110
11.	n	Number of floors.	95,96
12.	N	Number of cases studied.	110
13.	q	Quality adjustment.	63
14.	qu	Quantity adjustment.	63

	Symbol	Meaning	Reference page
15.	R	Either the element unit rate or the cost of the element expressed per unit gross floor area.	63
16.	Σ	Sum of.	63,69
17.	Sig. T	t-value at level of significance set by the test.	63
18.	t	time adjustment.	63
19.	VAR 1	Ratio of element cost to floor area.	101
20.	VAR 2	Ratio of wall area to floor area.	102,104
21.	VAR 3	Ratio of perimeter to floor area.	102,104-119
22.	VAR 4	Storey height.	102,104-119
23.	VAR 5	Total height also code-named Theight.	102,104-119
24.	VAR 6	Building Cost Index.	102,104-119
25.	V1	Locality Index.	64,65
26.	V2	Price Index.	64,65
27.	V3	Building Index.	64,65
28.	V4	Height Index.	64,65
29.	V5	Quality Index.	64,65
30.	V6	Technology Index.	64,65
31.	X_i's	Design variables.	94

CHAPTER ONE

INTRODUCTION

1.1 Estimating Methods

From time immemorial man has sought to know what a new building was going to cost before commissioning work on it. The new English Bible[1] says

> "Would any of you think of building a tower without first sitting down and calculating the cost, to see whether he could afford to finish it? Otherwise if he has laid its foundations and then is not able to complete it all the onlookers will laugh at him "There is the man' they will say "who started to build and could not finish".

The desire to forecast the probable cost of a building prompted the development of cost models. A cost model in this context is defined as the symbolic representation of a system, expressing the content of that system in terms of the factors, which influence its cost[2]. Building cost modelling has its origin from man's desire to forecast probable cost of the building before commissioning work on it. Various cost models have since been developed and used in order to achieve that end. An attempt to represent building cost models in a time context was made by Raftery (1984)[3] where he argues, can be considered in three main categories. These are referred to as first generation models, second generation and third generation models. He further states that these generations are hierarchical in terms of reliability as forecasting tools. The first generation models being the least reliable forecasting tools compared to the other two, which have not been fully exploited. These models will be considered in detail in later chapters.

1.2. Problem Statement

The Ministry of Public Works has the main objective of providing client ministries with suitable accommodation[4]. The Ministry is also responsible for implementation of the Government's annual programme of building and construction works. The Ministry thus creates standards, designs, invites tenders, supervises construction and advises the client ministries on the cost of works and the disbursements to be made[5].

Any Ministry whose request for specified accommodation is accepted by the Ministry of Public Works automatically becomes a client Ministry. The Ministry of Public Works then assumes the role of project adviser to the respective client ministries. For services rendered to the client ministries, strict control over expenditure must be exercised to ensure public accountability. Government control over capital building expenditure is exercised on the long-term capital programme, which normally covers a period of five years, and also on the annual capital budget done on yearly basis. The Government sets a policy for the distribution of the total national resources and decides on the amount to be expended on the building sector and also on the other sectors of the economy. The treasury then approves the expenditure of each Ministry and distributes the money to the various ministries and takes steps to ensure that value for money is achieved on individual schemes[6]. Here cost control is exercised among the Ministry of Public Works, the client ministry and treasury. Each of these parties has an important role to play in the control of capital expenditure. However it is the Ministry of Public Works which deliberates on the viability of the project as proposed by a client ministry and once accepted by the client ministry, then the design team is appointed to deal with the design process. It is evident from the foregoing observation that adequate control of expenditure is essential for the success of any project. More so the contribution of the building and construction industry on the total Gross Domestic Product ranged from between 4% to 5% at constant (1982) prices from 1988 to 1993. For instance in 1988 it was 5%, in1991, 4.7% and in 1993, 4.2% (Statistical Abstract- 1995)[7]

The need to control building cost is further highlighted by the increase in overall construction cost index. Taking 1972 as the base year, building cost index in March 1991was 967, while the same rose steadily to a peak of 1995.4 in March 1993. Within a period of about two years such a big increase was noted[8].

Apart from the rising cost in building as noted in the building cost index, cost control of building has become more important due to four main pressures: -

The first pressure is that client's requirements are complicated due to the fact that buildings have become more complex with time thus calling for close collaboration of all the parties involved in the project, a fact that is hardly achieved due to the way the construction industry is structured. The structure separates the design and production functions. In addition to this an increase in technical complexity of a project means that there are many more opportunities for the cost control of the project if economy is to be realised.

The second pressure is that construction of buildings is increasing. This has led to time having a measurable value to an increasing number of clients to the extent that clients are less willing to tolerate the delay caused by redesigning buildings when tenders seem to be too high. This anomaly could be avoided if designs were properly estimated. Professional Offices on the other hand are handling many other projects from different clients such that too much time spent on one project may not be preferred especially when a fear of abortive design effort is envisaged. This pressure calls for a technique, which therefore produces designs within cost limits.

The third pressure is the increase in size of organisations. Here an indirect relationship can be shown where expenditure limits are overstretched by a demand emanating from a constituent of the organisation. For instance the 8-4-4 system of education requires additional educational facilities in order to accommodate the increase in the number of students on the one hand and also to cater for the changes in syllabi: - provision for workshops must be catered for. The effect of such a system being introduced is that the expenditure by the Ministry of Education on capital development rises in response to the education policy adopted. So that the client organisations achieve control over expenditure on building projects, building professionals are normally asked to forecast the cost of a building before drawings and specifications are produced[9]. Once the first estimate has been provided, the client organisations require the building profession to keep to the estimate. However, this requirement is rarely achieved. More often than not the actual cost of the project ends up to about 10% more than was originally estimated[10].

The fourth pressure is on the choice of materials and types of buildings. There is a wide variety of materials and types of buildings today than in the past. This fact has been made possible due to innovations in building materials industry. Traditional methods of costing have thus been rendered less reliable since past records have shown that the first estimate rarely equates the final cost of the building[11].

Given these pressures facing the modern client, costs of buildings are scrutinised more closely and with greater skill and accuracy[12]. Building clients have therefore become more assertive in their requirements for cost control. In public sector projects this requirement is further enhanced by the need to exercise more discretion and more so, for purposes of public accountability in the management of projects.

We may define cost control as:

"All methods of controlling the cost of building projects within the limits of a pre-determined sum throughout the design and construction stages[13]".

Going by this definition, we may state that the purpose of a good cost control system as: -

1. To give the client good value for money;
2. To achieve the required balance of expenditure between the various parts of the building;
3. To keep expenditure within the amount allowed by the client.

Basically there are two ways in which the design team may decide on a first estimate for a project.

First, the client fixes his cost limit. The design team then, examines the feasibility of keeping the first estimate within this amount. This method is referred to as designing to a cost.

Secondly, the client gives the design team a detailed brief of the building he requires. The client then asks the design team to submit an estimate. This method is referred to as costing a design.

The two ways of establishing a first estimate are extremes, with most projects lying between them. Once the first estimate is established it is the onus of the design team to satisfy the three purposes of a good cost control system which will be based on three principles that: -

1. There must be a frame of reference;
2. There must be a method of checking;
3. There must be a means of remedial action.

A frame of reference is composed of two stages:

a] Establishing a realistic estimate

b] Planning how this estimate should be spent among the elements of a building[14].

The design team has over the years attempted to forecast the probable cost of a building before commencing construction. In so doing the design team has attempted to fulfil the requirement of a good cost control system. There are two main traditional estimating techniques that have been used. These are approximate quantities and single ratio estimates.

(a) Approximate quantities

This technique is concerned with the measurement of all the work in a proposed building based on the price of labour and materials, and not with the function or use of a building. This technique has been criticised for presupposing availability of a design for the building while the design might undergo many alterations yet the same is used to obtain an estimate. Secondly it is not compatible with the way the architect builds up his design since in designing the architect is not thinking in terms of quantities of concrete or brickwork but in terms of how to enclose the building shape, roof, floor and other design factors[15].

(b) Single rate estimating

This technique is concerned with measurement of works prior to detailed drawings and specifications. Unit rates are built up which comprise cubic, superficial method, linear metres etc. These methods have been criticised for not relating the cost of the work shown on the drawings to the estimate during subsequent progress of the design.

Thus, the client and the design team have lost favour with traditional cost forecasts for not exercising any control nor incorporating all the three principles of cost control.

There is therefore a need to investigate other ways of expressing the cost of buildings in a manner that will enable the architect to build up his design while simulating the effect of various design solutions on cost.

It is clear that the foregoing requirements can be achieved by considering the total cost of a building in detail of the various parts, which make up the whole. This is the cost of element.

An element is defined as a major component of a building, which usually fulfils the same function or functions irrespective of its construction or specification[16]. In addition, studies done on building cost have shown that it is at the design stage where high proportion of building cost is committed. Finbarr (1972)[17] asserts that about 85% of the total cost is estimated on a basis which gives absolutely no guidance to the architect on how the design should be carried out to come close to the estimated figure. And Ferry (1987)[18] on a study of cost of buildings found that about 80% of the total cost had been committed even before the sketch design had been produced. This suggests that the design stage provide a good avenue for cost control to be exercised given the high proportion of building cost committed at this stage. While traditional methods may not assist during this stage, other methods have been suggested as being capable of offering solutions in cost estimating at initial stages such as regression models. Traditional methods make use of cost planning from previously completed similar buildings to provide an estimate for the proposed building. Traditional view of cost planning is that it moves through stages of increasing accuracy beginning with fairly low accuracy at the inception stage and as sketch designs are produced elemental cost planning takes place and eventually cost plans from approximate and then firm quantities. It is from firm quantities that likely cost of the project can be stated with accuracy[19].

As a follow up from what we have discussed above, the press and technical journals have highlighted how public sector projects have been delayed beyond the completion time. Various reasons have been attributed to this anomaly. On a study of building contract performance in Kenya, Mbatha (1986)[20] found that time and cost overruns in public sector projects were not necessarily related and for that reason recommended a study be done on factors that affect building cost separately from those factors that affect construction time.

The Daily Nation of January 20 1990[21], quotes the Minister for Planning and National Development saying:

"The government is taking a serious view of delays in projects through which a lot of money is lost due to cost overruns".

`Prevention is better than cure' is a jargon in medical circles. It is no exception in the construction industry. Once the symptoms of poor cost control are discovered it is only wise to provide preventive measures to avoid what would otherwise be abortive design efforts or worst still final cost being far much higher than was initially envisaged. Due to the fact that cost control is a continuous process from inception to completion of a building project, this research intends to limit its scope at the design stage where we noted with concern that about 80% of cost of building is committed. It is not surprising that building cost forecasts based on single rate methods have been treated sceptically by public as well as private clients and have been responsible for disruption in long term investment plans. It is also noted that government has been pressing for adequate control of building costs when capital investment of building amounts to between 4% and 5% of gross domestic product as noted earlier.

1.3 Hypotheses

1.3.1 The null hypothesis

"The mean elemental cost per unit floor area remains the same with simultaneous changes in all values of design variables interacting together in the model".

Thus, ($H_0/U_1 = U_2 = U_3 \ldots = U_n$).

This implies that there is no relationship that exists between cost of element per gross floor area and the design parameters.

1.3.2 The Hypothesis

"The mean elemental cost per unit floor area does not remain the same with simultaneous changes in all values of design variables interacting together in the model".

Thus, $(H_A/U_1 \neq U_2 \neq U_3 \ldots \neq U_n)$.

This implies that there is a relationship that exists between cost of element per gross floor area and the design parameters.

Assumptions:

(1) There is multi-variate normal distribution because all the variables are interacting and changing simultaneously.

(2) Each variable X_k will be assumed to take several values. Around each of these values are normal distributions and that the values observed in the model is just one of those that could have been sampled.

This is the condition referred to as heteroscedasticity, where all the X_k are stochastic.

(3) The regression relationship defines a hypersurface for the values of C determined by all values of X_k interacting together as shown in the model.

1.4 Objectives of the Study

This research has the following objectives:-

1. Obtain elemental cost implications of design parameters; thereby express these implications as forecasting tools at an early stage in the design process.
2. Enable the client to realise the effect of his brief on building cost as early as possible so that he can realise his potential commitment before detail design can be produced.
3. Explore other techniques of expressing building cost other than the ones currently used, so as to provide more reliable cost information which will introduce more assurance into the decision making process.

1.5 Research Methodology

The Ministry of Public Works handles most government building projects. All records pertaining to a project are entered in job cards. Before projects are entered in job cards, forward planning unit enters for each new project a work programme number and the job number so that any correspondence concerning the projects can be referred to. In other words a file is opened for the project. Job cards become records for all the projects handled by the ministry. It is from these job cards that one can obtain data. Job cards alone are not enough especially where one is also interested in contract drawings and Bills of quantities. Whereas the job cards will enable one to draw the list of projects for study, one has the task of obtaining the contract drawings and bills of quantities from the project architect or from the contracts documentation office. The separation of this contract documents poses a major problem encountered in the field, which reduces the number of cases that can be studied. Thus, from the list of cases selected for study one may find contract drawings but cannot get the bills of quantities or vice versa . The effect is that one cannot obtain all the information necessary in this research. Another problem is where project files have been closed and taken to strong room for safekeeping. It becomes difficult to obtain such projects for study due to long delays before authority is granted to retrieve such files. One file alone may take six months even years to retrieve rendering the whole process of data collection difficult. The total number of cases this research was able to gather was forty three. In arriving at the number both random sampling and systematic sampling was used. The study covered projects ranging from 1979 to 1990 as the year of tendering. This is because after a ten-year period, most files are closed and taken to strong room.

To start with, the job cards are arranged in order of the date tenders were received regardless of type of building, size or any other considerations. In total there were 218 job cards representing the population. The job cards were given numbers and these numbers written in small pieces of paper from 1 to 218. These pieces of paper were folded, shuffled in a box, from which the first paper numbered 3 was randomly drawn. The job card numbered 3 automatically became the first case to be studied. From the first job card drawn, systematic sampling was used with every fourth card being drawn one after the other. Altogether a sample of 54 job cards was drawn. Owing to the problem highlighted above, only 43 projects could be studied. The list of projects drawn for study is shown in appendix 1.

This study proposes to consider only four elements for investigation since it is not possible to study all elements. These four elements are capable of demonstrating the effectiveness of cost modelling as a forecasting tool for building cost. They are substructure, walling, roofing and finishes. They are also the enclosing elements in a building morphology responsible for keeping out elements of weather.

1.5.1 Regression Analysis

Regression analysis is a basic technique used in social research to determine how changes in certain independent variables affect the values of certain dependent variables. Regression analysis provides the following information.

First, the regression equation shows explicitly the association between the dependent variable and the independent variable. The raw data from the variables is fitted in a line or space using least square method, while at the same time assuming a linear relationship.

Second, a regression analysis provides statistics of reliability which shows how good the regression equation is, i.e. how much of the variation in the dependent variable is explained by variation in the independent variable(s).

Regression analysis can therefore be used as a forecasting tool or model while maintaining logical assumptions and hypothesis concerning the relationship.

(a) Simple Regression

In simple regression only one variable influences the behaviour of the other.

It can be expressed as

$$y = a + bx_1$$

where:

y = dependent variable or the response y

x = independent variable or the regressor x

a = intercept on y

b = the slope on y on x.

(b) Multiple Regression

Multiple regression is simply the extension of simple regression, to take account of more than one independent variable X. It is the appropriate technique when we want to investigate the effects on Y of several variables simultaneously. Even when we are interested in the effect of only one variable, it is usually wise to include the other variables influencing Y in a multiple regression analysis, for two reasons: -

(1) to reduce stochastic error, and hence reduce the residual variance S^2. This makes confidence intervals more precise.

(2) Even more important, to eliminate bias that might result if we just ignored a variable that satisfactorily affects Y.

It can be expressed as follows:

$$\boxed{Y = a + b_1 X_1 + b_2 X_2}$$

With regressors X_1 and X_2 being measured as deviation from their means. Geometrically this equation is a plane in the three-dimensional space.

The difference between the observed and expected value of Y is the stochastic or error term e. This means any observed value Y may be expressed as its expected value plus this disturbance term.

$$\boxed{Y = a + b_1 X_1 + b_2 X_2 + e}$$

Where

Y	=	dependent variable
X_1, X_2	=	independent variables or regressors
a	=	intercept on Y
b_1	=	the slope of the plane as we move in the X_1 direction, keeping X_2 constant OR marginal effect of X_1 on Y.
b_2	=	the slope of the plane as we move in the X_2 direction, keeping X_1 constant OR marginal effect of X_2 on Y.

This regression equation sets out the general form of our study model.

(c) Regressors to be retained in the Equation

Consider four regressors, whose t-values have been calculated at 5% level of confidence as shown in the figure below. Assume also that there were 25 observations. In a one tailed test $t_{.05}$, 25-4-1 = 1.72

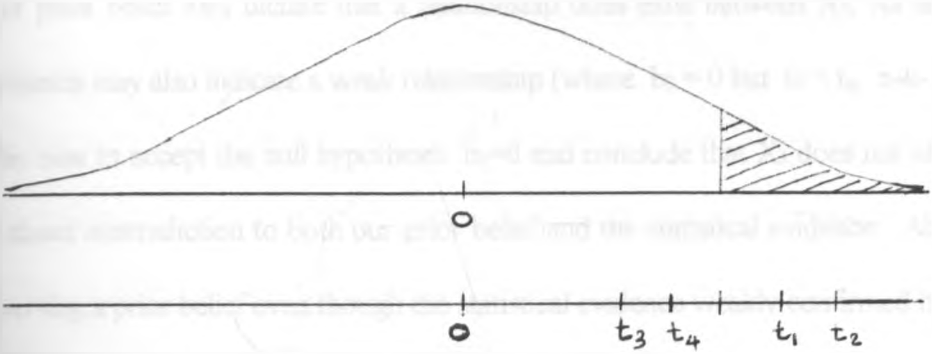

Fig. 1.1 One tailed t-test of four regressors.

Source: Wonnacott and Wonnacott (1979)

Let b_1, b_2, b_3, b_4 be the regressors whose t-values are indicated in the figure and take B_1, B_2, B_3, B_4 be the corresponding slopes for X_1, X_2, X_3, X_4.

We have seen that null hypothesis is rejected when observed t-value is greater than the t-value at level of significance as obtained from student - t tables. This means, for our example, null hypothesis would be rejected in favour of X_1 and X_2 : such that a relationship between X_1 and Y and X_2 and Y exists, while null hypothesis would be accepted in favour of X_3 and Y and X_4 and Y.

As a rule of thumb, the regressors to be retained in the model would be those where the null hypothesis is rejected. Thus, X_1 and X_2 would be retained and X_3 and X_4 dropped. However, our prior belief may dictate that a relationship does exist between X_3, X_4 and Y. Statistical evidence may also indicate a weak relationship (where $b_3 = 0$ but $t_3 < t_{\alpha}$, n-k-1).

In this case to accept the null hypothesis $b_3=0$ and conclude that X_3 does not affect Y would be in direct contradiction to both our prior belief and the statistical evidence. Also, we would be reversing a prior belief even though the statistical evidence weakly confirmed it. This remains true for any positive t ratio although as t becomes smaller, our statistical results clearly contradict our prior belief.

Consequently, if we had strong prior grounds for believing X_3 and X_4 to be positively related to Y, they should not be dropped from the regression equation, since they have the right sign, instead, they should be retained, with all the relevant information of their t ratios.

Wonnacott and Wonnacott (1979)[22] have warned that classical statistical theory alone does not provide firm guidelines for accepting H_0, acceptance must be based also on an extrastatistical judgement. Thus, prior belief plays a key role, not only in the initial specification of which regressors should be in the equation, but also in the decision about which ones should be dropped in view of the statistical evidence as well as the decision on how the model eventually will be used.

To conclude, hypothesis testing should not be done mechanically. It requires:

(1) Good judgement and good prior theoretical understanding of the model being tested.

(2) An understanding of the assumptions and limitations of the statistical techniques.

1.5.2 Correlation

Whereas regression analysis shows how variables are linearly related, correlation analysis will only show the degree to which variables are linearly related. In regression analysis, a whole function is estimated, but correlation analysis gives only one number - an index that gives an immediate picture of how closely two variables relate.

More precisely correlation is intended to answer three questions about two variables or two sets of data: -

(i) is there a relationship between the two variables (or sets of data)? If the answer to this question is 'yes' then two other questions follow:

(ii) what is the direction of the relationship? and

(iii) what is the magnitude?[23].

(a) Simple Correlation

Simple correlation obtains sample correlation coefficient r, also referred to as Pearson product moment.

Relationship in this context refers to any tendency for the two variables (or sets of data) to vary consistently. Statistical values for r range from -1.0 to +1.0 and expresses this relationship in quantitative form. Relationship with +1.0 would indicate perfect positive correlation between two variables. Likewise, relationship with –1.0 would indicate perfect negative correlation between two variables.

Perfect correlation of +1.0 or -1.0 is rarely found and most coefficients of correlation in social research are around +0.50 or less. The coefficient of correlation may be seen as an indication of the predictability of one variable given the other in a simple regression equation. This relationship between two variables can be examined visually by plotting paired measurements in a graph paper with each pair of observation being represented by a point. These points form a scatter diagram.

The coefficient of correlation shows the strength of the relationship between two variables.

Where the value for r is zero it does not necessarily imply no relationship exist, but rather it means that no linear relationship exists between the two variables. This means that simple correlation is a measure of linear relation only. It does not describe non-linear relationship.

Also, correlation as a whole refers to measures of association and does not necessarily indicate causal relationship between variables[24].

(i) Analysis of Variance

Analysis of variance is the procedure of analysing or decomposing total variation components. Total variations has two components:

(1) explained variation

(2) unexplained variation

Illustration

Let Y_i = independent variable

Y_c = fitted independent variable by regression

$\bar{Y}$ = mean of independent variable

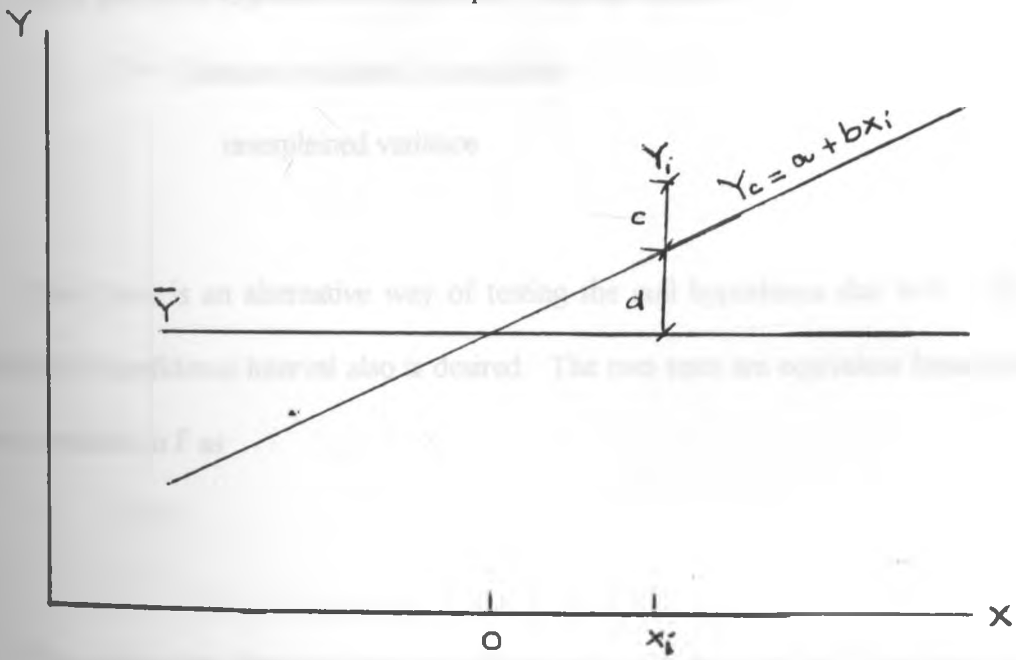

Fig. 1.2. The value of regression in reducing variable in Y

Source: Wonnacott and Wonnacott (1979)

$c \quad = Y_i - Y_c$ (deviation not explained by regression)

$d \quad = Y_c - \bar{Y}$ (deviation explained by regression)

$c + d \quad = Y_i - \bar{Y}$ (total deviation)

This means:

$$\sum(Y_i-\bar{Y})^2 \quad = \quad \sum(Y_c-\bar{Y})^2 \quad + \quad \sum(Y_i-Y_c)^2$$

total = explained + unexplained

variation variation variation

From the above equation we obtain the F-ratio as follows:-

$$F = \frac{\text{Variance explained by regression}}{\text{unexplained variance}}$$

The F test is an alternative way of testing the null hypotheses that $b=0$. The t is preferable if a confidence interval also is desired. The two tests are equivalent because the t-statistic is related to F as

$$t^2 = F$$

This means that there are three equivalent ways of testing the null hypothesis that the regression has no effect on Y, the F test and the t test of $b=0$, and the test of $p=0$.

(ii) Coefficient of Determination

This is the proportion of the total variation in Y explained by fitting the regression in a linear relationship. Expressing it in a mathematical form.

$$r^2 = \frac{\Sigma(Y_c - \bar{Y})^2}{\Sigma(Y_i - \bar{Y})^2} = \frac{\text{explained variation of } Y^{25}}{\text{total variation of } Y}$$

(b) Multiple correlation R

Multiple correlation measures indicate the degree of association between three or more variables simultaneously, whereas the partial correlation measures how Y is related to all the regressors at once. R is defined by first calculating the fitted values Y_c using all the regressors.

$Y_c = a + bX + yZ.$

The multiple R is defined as the ordinary (simple) correlation between the fitted Y_c and the observed Y.

$$R = {}^{r}Y_{c}Y$$

Similarly R^2 is defined as

$$R^2 = \frac{\Sigma(Y_c - \bar{Y})^2}{\Sigma(Y_i - \bar{Y})^2}$$

$$= \frac{\text{variation of Y explained by all regressors}}{\text{total variation of Y}}$$

Thus R^2 provides an overall index of how well Y can be explained by all the regressors, that is how well a multiple regression fits the data.

(c) Stepwise Regression

Stepwise regression refers to the inclusion of regressors one by one to the regression model. Where a large number of regressors need to be introduced, a computer is programmed to introduce regressors one at a time. After each inclusion the computer prints the regression equation. Then at the end, the computer prints a summary consisting of the list of regressors in the order they were introduced and the corresponding value of R^2 at each step. Where the computer cannot print the summary, one can easily do the summary since all values are printed[26].

It is from stepwise regression where one can tell how many regressors should be retained in the regression model. Again prior knowledge should be considered before a decision can be made.

(d) Regressors to be Retained in the Model.

The criterion normally used is to keep bias and variance low, that is the mean squared error (MSE) of the response predicted by the regression equation. When this criterion is used, it can be stated that:

"If the data determines the order that the regressors are being included, add regressors until:

$\frac{(1 - R^2)}{(n-k-1)^2}$ is a minimum".

This means when a regressor is added, K is increased, thereby decreasing the denominator, while R^2 is increased thus decrease the numerator only if this increase in R^2 is sufficient will the ratio itself fall, and justify adding the regressor[27].

1.6 Scope and Limitations of the Study

This research will analyse building projects undertaken by the Ministry of Public Works on behalf of client ministries. The Ministry of Public Works can also be a client to itself. Thus this research will limit its scope to projects handled by the Ministry of Public Works. Also, since cost control starts from inception of a project to completion of the project, this research intends to study cost control during design stages prior to tender stage. The Ministry of Public Works keeps records of previously completed buildings. These records are available at the contracts department for analysis of this research.

The period of study chosen covers twelve years between 1979 - 1990.

1.7 Significance of the Study

Progress in scientific research should not go without mention. The invention of silicon chip and desktop microcomputers and more recently personal computers has enabled all spheres of enterprise to process and obtain reliable information within a short time possible. Processing of data is faster than ever before. The modern client has become more concerned with value for money. Cost control has therefore been his major concern. In an effort to keep abreast with client's requirements for stricter cost control the design teams have devised ways of realising the needs of the client. Several techniques have been developed and to-date researchers are still developing cost forecasting models.

Whereas regression models have been reviewed as 'black-boxes' for analysing recorded historical data, the accuracy that can be achieved by using these models is much more precise than what human estimators (traditional models) can achieve[28].

With this view in mind, it has become apparent that the field of cost control should seek to establish other methods of expressing building cost other than what traditional methods currently provide.

FOOTNOTES

1 The New English Bible: St. Luke Chapter 14.

2 Ferry D. J. and Brandon P.S. Cost Planning of Buildings 5th Edition. Collins - London, 1986. pp101.

3 Raftery, J. (1984) "Models in Building Economics: A Conceptual Framework for Assessment of Performance" CIB Working Commission W55 Third International Symposium Building Economics' (Proceedings) Ottawa, Vol.3, pp.103 - 111.

4. Republic of Kenya, Development Plan. 1989-1993. Government Printer Nairobi, 1989.

5. Sidwell A.C. An Evaluation of Construction Management and Economics, Vol.1.No.1 E & F.N. Spon - London, Spring 1983. pp47-55.

6. Bathurst P.E. Building Cost Control Techniques and Economics, 2nd edition, Heinemann London 1980 pp8.

7. Republic of Kenya, Statistical Abstract, Central Bureau of Statistics, Nairobi, 1995 pp 59

8. Ibid 1995 pp175.

9. HMSO : Cost Control in Building Design: R & D Building Management handbook 4, McCorquodale and Co. 1968. pp8.

10. Mbatha C.M. Building Contract Performance in Kenya : A Case Study of Public Sector Projects, M.A. Thesis University of Nairobi 1986. pp118.

11. HMSO : Op. cit. pp7.

12. Nesbit, J. The Role of the Quantity Survey During the Design Stage. The Chartered Surveyor. July 1959.

13 Seeley. I.H. Building Economics : 2nd Ed. Macmillian London, 1978.

14. HMSO: Op. Cit. pp46.

15. Ibid pp50.

16. Finbarr S. Design Cost Control for Building Work U.N. (E.C.A.) Course Bouwecentrum, Holland September 1972. pp2.

17 Ibid pp4.

18 Ferry D. J. and Brandon P.S. Op. Cit.

19. Brandon P.S. Building Cost Modelling and Computers, (Edited), E & F.N. Spon - London, 1987. p52.

20. Mbatha C.M. Op. Cit.

21. Daily Nation, 20th January 1990. Nairobi

22. Wonnacott and Wonnacott, Econometrics 2nd Edition, John Wiley and Sons, New York, 1979 pp.89.

23. Cohen, L. & Manion, L. Op. Cit. pp94 - 101.

24. Ibid pp.153-156

25. Wonnacott & Wonnacott, Op. Cit. p9 - 45.

26. Ibid. pp89.

27. Ibid. pp71-89.

28. Brandon, P.S. Op. Cit. pp53.

CHAPTER TWO

LITERATURE REVIEW

2:1 Implementation of Government Building Contracts

The government allocates a large proportion of its development expenditure to the Building Sector for the provision of public buildings - hospitals, schools, roads, residential houses and offices.

The Ministry of Public Works handles most of government building projects. The ministry of Lands and Housing oversees projects that fall directly under its ministry and liases with the ministry of Public Works only where it is necessary on professional advise. This means, all other ministries in need of building development seek the services of the ministry of Public Works for the provision of those building developments. The buildings department of the ministry of Public Works, which was set up in 1970, is in charge of executing all client ministries' building requirements. Over time the buildings department has undergone several changes and now groups together various professions under different branches with a specific function to perform in the development of design and also offer post - design services. These branches are briefly discussed below: -

(1) Architectural

The main function of this branch is to design and administer the construction of development projects. Drawings and specification of proposed buildings are prepared in this branch to suit client ministries' requirements.

(2) Quantities and Contracts

This branch prepares cost estimates and tender documents. Then, with the tender documents, invites and approves a successful tenderer. The branch also administers the acceptance of development work contracts as well as provides the client ministries with services pertaining to quantity surveying practice.

(3) Building Services

This branch specialises in the design of building services such as mechanical, electrical and fire prevention services. It also administers the construction and maintenance of all building services.

(4) Structural

The main function of this branch is to provide structural drawings, and specifications including drainage and sewerage disposal facilities, marine and bridge works, which fall within the responsibility of the Ministry of Public Works.

(5) Building Maintenance

This branch co-ordinates and implements the maintenance of all permanent government buildings.

(6) Forward Planning

This branch deals with the planning, maintaining and implementing of the annual works programme. It does so by checking the physical and financial progress of all jobs carried out in the branch and providing feedback information to the other branches and also to client ministries for purposes of management.

(7) Research and Development

This branch is responsible for reviewing builder-user feedback with the intention of continuously improving the design and construction methods. It does so with particular reference to the utilisation of local materials and the minimisation of construction costs. However, the contribution of this department is hardly felt in the industry. It requires to be resuscitated, as it is a vital department, which can revolutionise building cost and technology appropriately.

(8) General Administration

Under this branch, overall control and organisation of the departments, both within the headquarters and at all provincial offices throughout the republic is undertaken.

(9) Kenya Building Centre

This branch is regarded as the 'public relations arm' of the ministry of Public Works. It provides information to the public on all matters pertaining to the construction industry maintains a library of technical publications and also provides graphic arts and report printing services[1].

All these branches make up the buildings department and have specific functions to perform as briefly outlined above. In total there are about nine branches, each providing a professional service different from the other branches. This diversity of professional services within the buildings department needs integration at the early design stage and construction stages so that strict control of construction costs can be realised. This requirement has been hindered by the amount of work that the ministry of Public Works is faced with when the building works programme is overstretched. There is lack of adequate staff to handle the works programme, which means that some work has to be sublet to consultants. The consultants are commissioned by the permanent secretary on the advise of the various branch heads participating in the building works. Having commissioned the consultant, the respective branch liases with the respective consultant with the sole aim of controlling expenditure.

In theory therefore the branches are supposed to perform as discussed above. In practice however, cost control has not been effective.

2:2 Design Method and Cost Advice

Design can be regarded "as a fundamental human activity requiring both consciousness and thought to imagine changed states of the environment in anticipation, and skill to bring intentions and plans to concrete realisation"[2]. This means design activity can be defined as action aimed at finding solution to perceived problems within a resource envelope.

Building design has been recognised as a complex interaction of skills, judgement, knowledge, information and time which has as its objective the satisfaction of the client's demands for shelter within the overall needs of society.

In itself satisfaction is a subjective phenomena. This follows from the fact that no two people can perceive ideas in the same way. They will attach different value judgements in arriving at a decision following the client's requirements. This implies that different designers will arrive at different design solutions given the same problem. For this reason Ferry (1986)[3] argues that ultimate satisfaction is obtained only when the 'best' solution has been discovered within the constraints imposed by factors such as statutory obligations, technical matters, feasibility, environmental standards, site conditions and cost.

During the development of the design, the architect finds himself with several options from which to choose. His major problem then becomes how to select the optimising option. The major task the architect faces at this point is to establish which of the alternative options available is the 'best' as some factors such as visual delight are difficult to measure. While the architect is pondering on what design decision to adopt, he must obtain information with regard to initial and future costs so that the design team can make decisions knowing the cost implications of those decisions.

Bathurst (1980)[4] points out that the architect has the major problem of designing a building to relate to his client's brief to the constraints posed such as size of the site, available forms of construction, statutory planning requirements etc. He considers each constraint in the light of his experience and his personal inspiration. His decisions may be controlled by a cost limit imposed by the brief and he should be conscious of the cost implications involved. Nesbit (1959)[5] then asserts that the cost limit set by the client's brief plays an important role throughout the design process. At first it influences the size of the project and its general form, referred to as the morphology of the project and then indicates the type of the structure and subsequently affects the choice of services and finishes. For this reason cost is seen to be a contributing influence during the design process and two distinct phases of estimating cost have been identified to comprise: -

Firstly, the determination of total cost usually referred to as approximate estimating stage.

Secondly, the costing of the design within the total sum usually referred to as cost planning stage.

Approximate estimating and cost planning stages are mutually supporting, although they are not synonymous since they carry different meanings and apply to separate aspects or phases of the costing process.

The two phases of costing are reviewed in the RIBA plan of work as shown in appendix 5; Ferry (1986)[6].

The RIBA plan of work represents a model of procedures to be followed during the design process. The design team is expected to pool their combined knowledge for the benefit of the client, whose representative should whenever possible be a member of the design team and apply his own part in the corporate decision - making process.

Hardly will two designers approach a problem in the same manner; thus there exists different approaches in solving the same problem. However, some common techniques are often incorporated in a typical approach to the task of achieving good designs. What this implies is that the design team can select the form of cost advice most appropriate to a particular problem.

In a study entitled 'Time, Cost and Architecture' George (1975)[7] points out that the team approach to design which he referred to as the systems approach to design, when properly applied and understood means combining sophisticated methods of decision making (often computer assisted) in the planning and design process with a philosophy of setting design and development in motion based on criterion and performance requirements. How much this perception of design is exercised in the realisation of public projects is questionable. But one can arguably conclude that since satisfaction is closely related to performance the level of dissatisfaction in the performance of government building projects is a clear indication of poor cost performance. While conducting a research on Building Contract Performance Mbatha (1984)[8] found that most government projects had poor performance, in that, cost overruns and time overruns for the projects he studied were acute, parameters of which he used to study performance. He blamed cost and time overruns on lack of adequate cost control mechanisms of the projects right from initiation to completion.

A successful design is one perceived to fulfil the client's requirements to the minutest detail. To achieve a successful design, George (1975)[9] is of the opinion that it must be as a result of creative minds solving the given problems of function and environment. But design should not be looked at in isolation. All factors that may affect design must be considered in relation to one another. Thus, Stone (1983)[10] asserts that a building design is a compromise between the best solution for the many functions it needs to serve. If the final solution is to provide the best results the various problems must be considered together since the solution for the various functions tend to react one upon another. For instance, the arrangement of space within the building shape, the form of construction, heating, lighting, and other services, and the initial and running costs are all closely related. Therefore the design process should be looked at as being made up of the 'whole' comprising of three parts - design, production and organisation. It is apparent given the available knowledge and the range of materials and forms of construction, it is difficult for architects to know not only the form of building and the layout and equipment but also the way in which the frame and services, the environment and the costs all react together especially if he does not specialise in the type of building. To conclude, Stone (1983)[11] suggests that the architect in an effort to cope with the problem needing solutions to his design efforts have a knowledge of principles and experience in the application of the various factors of design, and information on the materials and components available for use in building construction. Since it is not possible for the architect to know every information he requires in developing the design, he should rely on specialist knowledge. This follows from the fact that, being the leader of the design team, the architect receives the commission to design and supervise the erection of the building. The volume of specialised knowledge necessary for the design of a modern building is so great that the architect will need the assistance of specialists to handle some of the design problems.

One of the crucial piece of information the architect needs while designing is cost information. This must be compatible with the design method adopted. Since cost is one of the variables that influences the manner in which the architect simulates his design solutions, it is argued that unless cost is of paramount importance then it should not dictate the approach the designer takes. Thus striving to achieve optimisation in cost is only but a part of the total objective. This argument holds water since one project may involve so many consultants who working out on their own form subsystems of activity as is in the case of the many branches in the Buildings Department of the Ministry of Public Works whose sole aim is to satisfy client ministries' requirements. These subsystems of activity have different areas of interest to which they seek optimisation. Unless then all the subsystems of activity work together will there be optimisation of performance. It is performance of all subsystems acting together that leads to realisation of client's satisfaction[12].

Before commencing design work the architect should therefore understand the client's brief. Studies done on design suggest that frequently the client is vague as to the exact purposes for which he requires the building, the performance parameters, the way these are likely to change in the future and what he can afford by way of initial and running costs. For a design to be satisfactory, the designer needs to stimulate the client to work out his requirements in clear terms. With the brief clearly formulated and understood by both the designer and the client, design of the building takes place. During the early stages of design, the architect will formulate his ideas and decide upon the disposition of the accommodation, the shape of the building and the general form of the shape of the building, and the general form of construction and specification. This process presents a complex activity, interplay of one factor with another and interaction of design and specifications render it impracticable to consider separately the various factors affecting building costs.

It is therefore convenient to consider basic problems initially, at least under two headings as suggested by Bathurst (1980)[13].

Firstly is the design or quantity decisions which govern general and detailed planning and ultimate appearance of the building.

Secondly, is the decisions which concern the quality of materials used in the building and standard of workmanship required.

Under both headings, distinction between 'key' decisions and 'incidental' decisions must be made. 'Key' decisions being those which have irreversible effect on a building project, such as its basic plan shape or height while 'incidental' decisions are those which can be changed upto the time of construction without any fundamental effect on the building design as a whole such as the specifications of tiling in bathrooms.

During the early design stages, advise will usually focus on 'key' decisions. One of the earliest parameters the architect will require to resolve is shape of the building, since this decision alone may as well influence more than any other the final cost of the building.

Apparently the importance of the client and therefore the role he plays in the construction industry is gaining much recognition among researchers. A recent report entitled 'The Public Client and the Construction Industries' known as the 'Wood report' devoted a whole section to the role of the client in a construction project. It identifies the client's primary responsibilities as:-

(i) The nomination of an individual to co-ordinate his requirements.

(ii) The provision of a clear project brief to the design team.

(iii) Monitoring the progress of the designs and construction teams and involvement of the client representation in any major strategic decisions that may be required during the course of the design and construction phases.

Dialogue between the client and the design team in the formulation and development of the brief is crucial to the optimisation of the client's requirements within the budgetary constraints imposed upon him. The effectiveness of the design team determines whether or not the project will give value for money[14].

Many approaches to the understanding of the clients brief and therefore the development of the brief throughout the design process have been advanced. The Building Performance Research Unit of Strathclyde University[15] views the design process as consisting of three main stages namely:- analysis, synthesis and appraisal stages.

2:2:1 Analysis stage

This stage is commonly referred to as the understanding of the problem. Relevant information is gathered, relationships established, constraints and objectives identified so that the problem is fully understood and therefore seek good and imaginative solutions.

2:2:2 Synthesis stage

This is the stage where a design solution is produced. The problem structure may suggest part or whole solutions. The solution(s) may result to a single design or a variety of different designs or a cluster of similar designs.

Markus (1972)[16] further argues that in the search for a solution, the designer appears to select from amongst, or combine three stages.

(i) He predicts, on the basis of a body of knowledge, the results of decisions. This knowledge includes his own and others experience, the results of research, the whole corpus of professional skill.

(ii) He tries out an idea and tests it largely unaware of its consequences until after the test. The test may be as simple as obtaining the reaction the client.

(iii) If his knowledge is inadequate and he cannot try the idea out in its full complexity, he designs and builds a solution that embodies all, or several other possible solutions in the hope that even if one or more fail(s) one at least will work at all times. Markus termed these three stages as the predicative, the simulation and the multi-modal routes respectively.

2:2:3 Appraisal Stage

At this stage performance of the solution is established. This is a retrospective act by which the designer establishes the quality of his solution. There are three steps in appraisal. The steps involve representation of the results, measurements of the results and evaluation.

In traditional estimating, quantity surveyors have been involved almost exclusively in the appraisal stage literally ignoring the first two stages and yet the real decision - making lies within these two former stages. This is the stage where cost advice is applied in the Ministry of Public Works largely ignoring the most critical stages of synthesis and appraisal. More vital cost information is required by the Architectural branch of the Buildings Department during the two stages in order to evolve a design which does not only provide optimum satisfaction but also cost effectiveness which is normally a limiting factor in government development projects.

No doubt therefore new techniques are required to enable the architect to contribute to understanding and solving the design problem.

It is assumed by the Strathclyde team that decision making becomes more detailed and refined as time goes on and that in each stage different methods of problem solving techniques are adopted.

Any cost technique must therefore follow a similar pattern which may involve 'coarse' measurement and evaluation in the very early stages and a more reliable measurement and cost application when more information becomes available. It is with these thoughts in mind that cost models have been constructed to provide information at each level of refinement of the design[17].

2:3 Cost Planning and Cost Control During Design Stages

Cost planning process is viewed as a deductive process because it relates to the deductive procedure followed in the early design stages of a project. It deals with the art of estimating design solutions on the basis of cost data organised to suit important design criteria. The deductive process moves from general to more specific criteria i.e. from cost relations to functional requirements[18].

A more comprehensive and apt definition was devised at RICS Postgraduate Cost Planning Course at Brixton, as "A systematic application of cost criteria to the design process, so as to maintain in the first place a sensible and economic relation between cost, quality, utility and appearance, and, in the second place, such overall control of proposed expenditure as circumstances might dictate"[19].

Cost planning is therefore a technique that involves the preparation of a cost plan, and the carrying out of cost checks to ensure that subsequent design process keeps to the cost limit set. A cost plan on the other hand is defined as a statement of the proposed expenditure on each section or element of a new building related to a definite standard of quality. Each item of cost is generally regarded as a 'cost target' and is usually expressed in terms of cost per square metre of floor area of the building as well as total cost of the element. And a cost check is the process of checking the estimated cost of each section or element of the building as the detailed designs are developed against the cost target set against it in the cost plan[20].

Cost planning is a relatively new discipline having its roots in the 1960's after the RICS sitting at that time passed a resolution at a conference of quantity surveyors, that the profession should devise methods of examining analytically the costs of buildings. Two methods of cost planning evolved - elemental and comparative cost planning. Both methods have their advantages and disadvantages but today the majority of professional offices use a combination of them to suit their own requirements[21].

2:3:1 Elemental Cost Planning

In elemental cost planning sketch plans are prepared on the one hand and total cost of the work obtained by some approximate method on the other hand. The building is then broken down into various elements of construction or functional parts such as walls, floors, roofs, etc. Each element is then allocated a cost limit based on cost analysis of previously erected buildings of similar type. The sum of the total targets set against each element must not exceed the total estimated cost. This is done by applying cost checks throughout the design stage. Finally, a last cost check is done on the whole scheme after tenders have been received. This means that the system incorporates a progressive costing technique with the establishment of cost targets and the use of constant checks to ensure that the design is kept within the cost targets.

2:3:2 Comparative Cost Planning

This system stems from sketch plans but does not use a fixed budget as does the elemental system. Instead a cost study is made showing the various ways in which the design may be performed and the cost of each alternative approach.

The purpose of the cost study is to indicate whether the project can be carried out within the cost limit laid down by the building client. The study is usually based on approximate quantities and constitutes an analysed estimate.

The advantage of the cost study is such that it provides the architect with a ready guide to design decisions. It therefore enables the architect to select a combination of the alternatives which will satisfy the financial, functional and aesthetic considerations.

The essential difference between these two methods of cost planning is that whereas in the elemental system, the design is evolved over a period of time within the agreed cost limit, in the comparative system the design is fairly established at the sketch plan stage after the choice of various alternatives have been made. The decisions made are not generally altered after this stage. The elemental system is commonly referred to as 'designing to a cost' while the comparative system is referred to as costing a design[22].

There is no universally accepted method of cost planning which can readily be applied to all types of projects. This situation has been brought about by the fact that the type and size of a project have become increasingly large in magnitude and complex in execution. This causes administration and contractual management to be complex, resulting to a wide range of cost planning techniques aimed at meeting the needs of varied situations.

Cost planning should therefore not be viewed only as a method of pre-tender estimating but also as a system that seeks to offer a controlling mechanism during the design stages. Apart from providing cost advice to control expenditure and also to offer the client better value for money it also attempts to keep the designer fully informed of all the cost implications of the design.

Several methods have been used for tender estimating. These estimating methods are also cost models under the traditional approach. They are -

- unit method
- superficial method
- superficial - perimeter method
- cube rules
- storey enclosure method
- approximate quantities
- cost planning
- financial methods[23].

These methods of tender estimating are reviewed in detail under cost modelling in the construction industry later.

Actual cost planning is hardly exercised in the Ministry of Public Works although cost targets set by the client ministries are used as guidelines in cost estimates. Proper cost plans and cost checks are not done in the design process. However, there exists a Cost Planning Unit within the quantities and contracts branch which prepares unit rates obtained from various tender rates over time. These unit rates are published and circulated to Quantity Surveyors who in turn may use them for estimating the sketch designs or working drawings at pretender stage. When this estimate is close to the cost target it is adopted and tenders invited. No records of similar buildings carried out in the past on elemental basis are kept nor cost plans, for reference in determining proper cost estimates for projects at hand. This partly explains the high variance between cost estimates prior to tender and tender sums received. It is therefore imperative that an elaborative cost planning technique be practised if cost control is to be effective.

2:3:3 Cost Control

Seeley (1978)[24] defines cost control as all methods of controlling the cost of building projects within the limits of a predetermined sum throughout the design and construction stages. Properly applied cost control ensures that resources are used to the best advantage. Considering that buildings have become more complex and building clients more assertive in their requirements, an improvement and refinement of existing cost control tools is necessary. Most cost control techniques so far, have attempted to ensure that the client receives value for money in building work. This means advise may be given on the strategic planning of a project which will affect the decision whether or not to build, where to build, how quickly to build and the effect of time on costs or prices and on profitability. During the design stage, advise is needed on the relationship of capital cost, to maintenance costs and on the cost implication of design variables and also on different construction techniques.

The cost control process should not only stop at design stage but should continue throughout the construction period to ensure that the cost of the building is kept within the agreed cost limits. Haddock (1969)[25] asserts that building cost can be considered as a medium relating purpose and design and that it forms an important aspect of design.

2:3:4 Procedure at Design Stages for Cost Control

Several stages that are observed in cost control during design process, have been summarized by Finbarr (1972)[26] in a diagrammatic form as follows:-

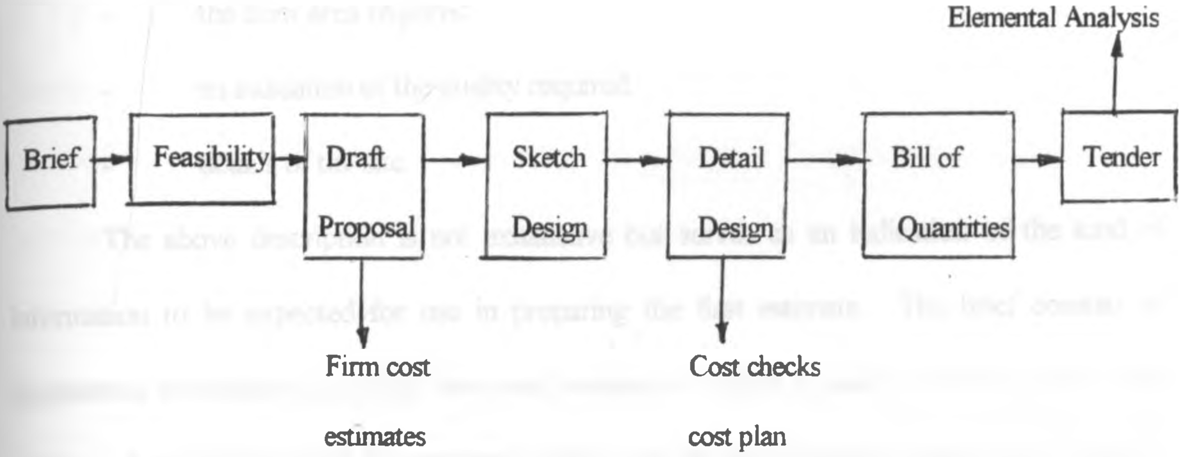

Fig. 2.1. Design stages for cost control

Source: Finbarr (1972)pp.9

Theoretically, the stages are tangible and do not overlap. However, practice has shown that they overlap. In order that cost control is achieved, all the stages must be fulfilled.

Stages 1 and 2 : Brief and Feasibility

This is the stage where the client requirements are specified. The design team then considers them in general and preliminary studies are undertaken to examine possible design solutions in relation to site, town planning considerations and broad cost implication. The design team then produces a first estimate from the brief and information available. This first estimate is normally based on the initial brief, which contains description of:-

- the use by which the building is to be put .
- the floor area required.
- an indication of the quality required.
- details of the site.

The above description is not exhaustive but serves as an indication of the kind of information to be expected for use in preparing the first estimate. The brief consists of fragmented information such that the initial estimate is simply a guiding figure to the design process. Also of importance to note here is that given the brief, various designers will interpret it into drawings and specifications differently. This follows from the fact that a subjective concept has different value judgements placed on it by various people.

With the first estimate complete, the design team communicates this information to the client. Once the client accepts the first estimate, it becomes a cost limit. However, given technical difficulties that may face the project, a firm estimate is not always forthcoming, such that the client is normally provided with the cost bracket within which design can be produced[27].

Stage 3: Draft Proposals

On completion of stages 1 and 2, the brief is developed further. Outline design solutions on shape and size of buildings are prepared and towards the end of stage 3 firm cost estimates are given to the client.

A cost estimate is then built up from the elemental cost data bank by determining the probable cost for the building by adding the element costs. Very little design information exists at this stage such that the estimate obtained cannot be considered for inclusion in the final design but rather provides a guiding figure to the designer in evolving the design. The estimate therefore provides a reliable cost target at an early stage in the design process to which an allowance for both price and design risks are included by assessing the cost of unforeseen design difficulties and possible price rises between the preparation of the outline cost plan and the receipt of tender[28].

When the client accepts the outline cost plan, the design team is expected to produce a scheme design within the cost shown on the outline cost plan.

Stage 4: Sketch Plans

During this stage the design is further developed. Many issues are resolved. The type of structure, appearance, outline specifications and type of services are decided upon. Towards the end of this stage a cost plan is prepared whose purpose is to:-

- ensure the cost of the building is allocated in a balanced way to the different parts of the building
- set detailed cost targets, which will act as guidelines for cost control during the detail design.

The preparation of the cost plan abstracts from the general total cost target then, to the specific individual cost targets on the basis of elements. Cost is then allocated to each element after examining the elemental cost data bank and by applying judgement and experience in selecting and adjusting elemental costs from the data bank. With careful judgement, firm targets for each part of the building are set, preceeding detail design[29].

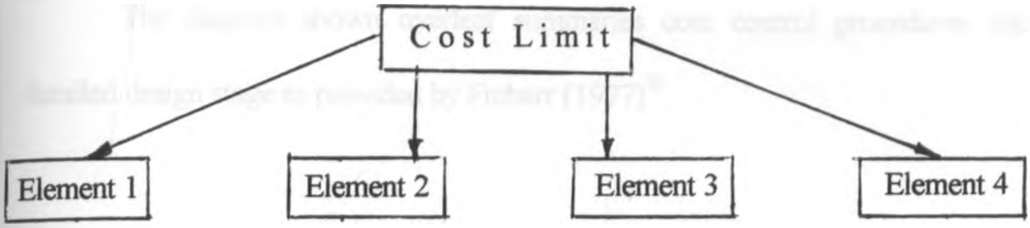

Fig. 2.2 Cost limits

Source: HMSO 1972. pp42.

The figure shows how cost limits are broken down into cost targets corresponding to the elements that form the building. The cost limit is first arrived at by agreeing with the client to the expenditure he is prepared to undertake in the project. The cost allocated to elements are referred to as cost targets.

Stage 5: Detail Design

This is the stage where full design details are produced and final decisions on specifications reached. The most important task during this stage is to check that the elemental cost targets set in stage 4 are not exceeded. If the elemental cost targets is exceeded, the architect is informed so that he can re-design the element or else reduce the allocations of the succeeding elements.

Cost checking is very important in this stage since it imparts corrective action, which attempts to ensure that the total cost-target will not be exceeded.

The diagram shown overleaf summaries cost control procedures adopted at the detailed design stage as provided by Finbarr (1977)[30].

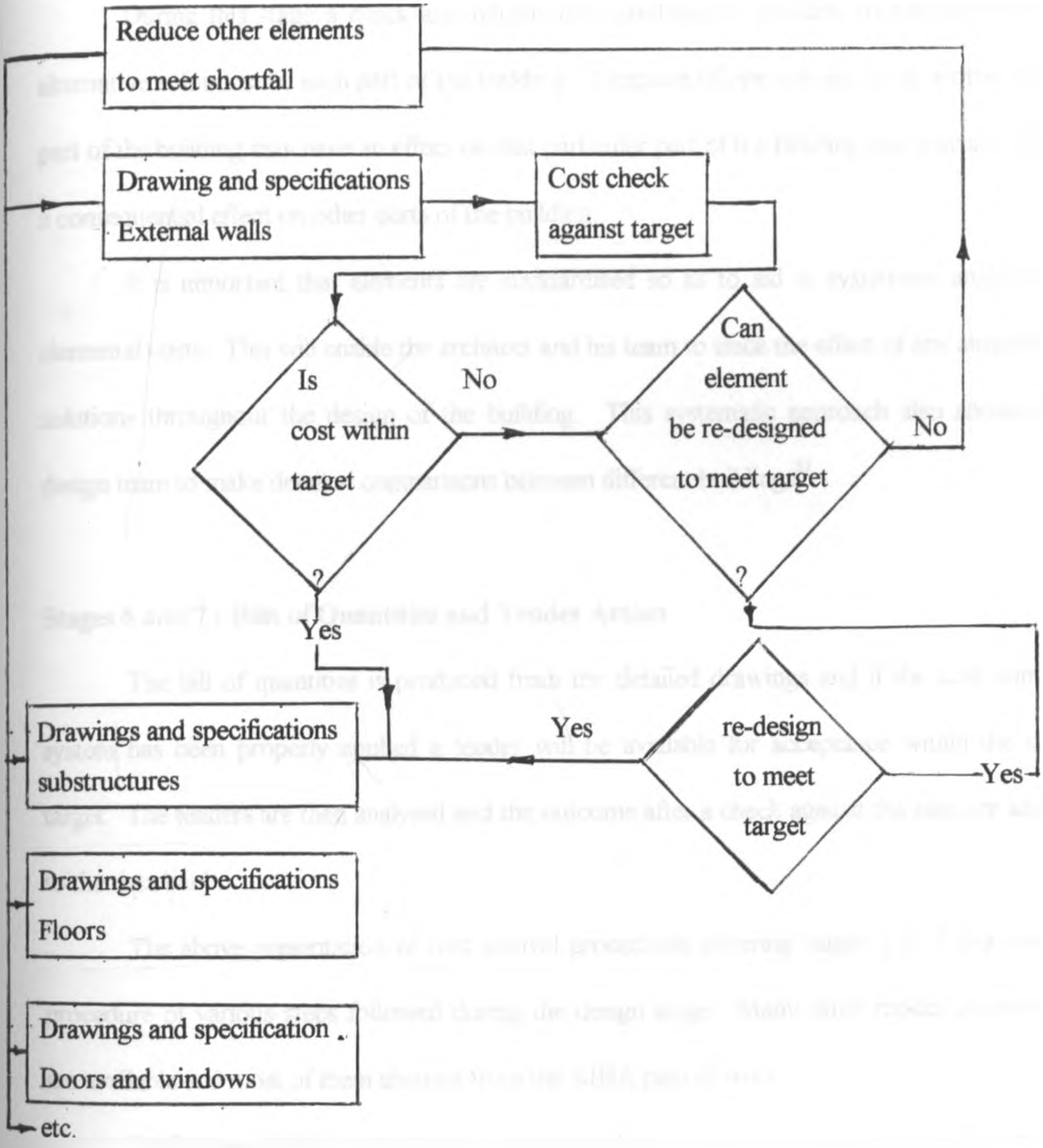

Fig. 2.3 Cost Control at detailed design stage

Source: Finbarr (1972).

During this stage a quick and reliable cost guidance is available to the architect on alternative solutions for each part of the building. Adoption of one solution over another for a part of the building may have an effect on that particular part of the building and may also have a consequential effect on other parts of the building.

It is important that elements are standardised so as to aid in systematic analysis of elemental costs. This will enable the architect and his team to trace the effect of any alternative solutions throughout the design of the building. This systematic approach also allows the design team to make detailed comparisons between different buildings[31].

Stages 6 and 7 : Bills of Quantities and Tender Action

The bill of quantities is produced from the detailed drawings and if the cost control system has been properly applied a tender will be available for acceptance within the cost target. The tenders are then analysed and the outcome after a check against the plan are added to the data bank.

The above presentation of cost control procedures covering stages 1 to 7 is a model procedure of various steps followed during the design stage. Many other model procedures are available and most of them abstract from the RIBA plan of work.

During each design stage, the relationship between the information available at the beginning of the stage and the design and cost decision made during the stage is as shown below.

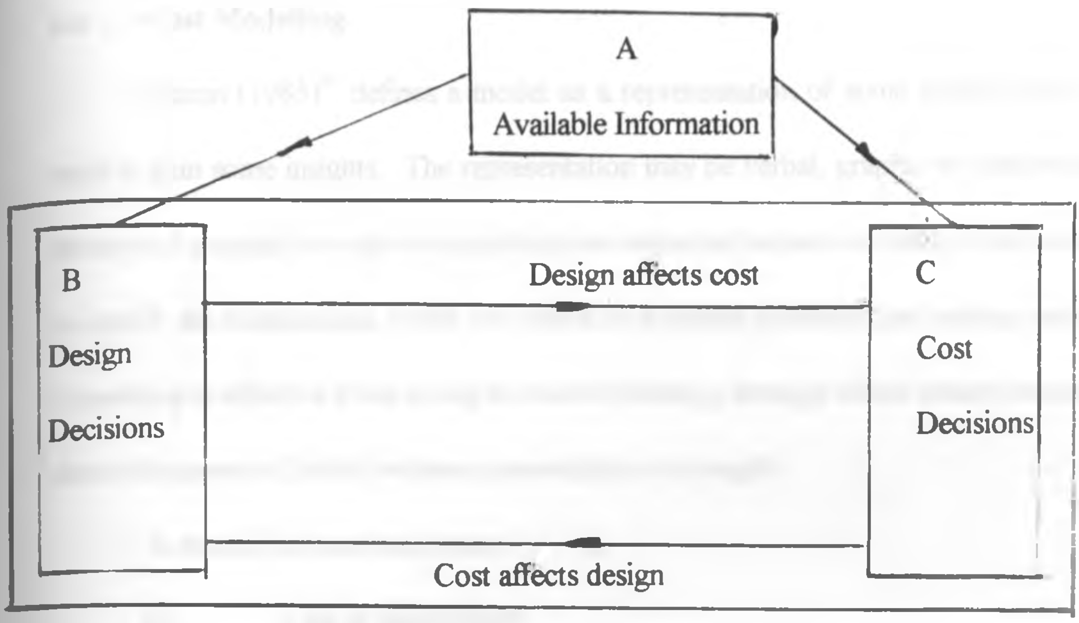

Fig. 2.4 Relationship between design and cost decisions

Source: HMSO (1972) pp179

Items A, B and C correspond to design stages shown in the figure shown above. It shows that for design decisions or cost decisions to be arrived at available information for each is necessary. Between design decisions and cost decisions, two important results are obtained. First is that design affect cost and secondly is that cost affects design. This means cost is a function of design and design is a function of cost such that in any design process cost and design cannot be separated from each another.

2.4 Cost Modelling

Mixon (1985)[32] defines a model as a representation of some reality about which we need to gain some insights. The representation may be verbal, graphic or mathematical. The purpose of a model is to allow some focus on important aspects of reality to be made and also to specify the relationships, which are central in analysing problems and making decisions. For a model to be effective it has to aid in channel thinking, through which deductions can be made about the aspects of reality whose representation we sought.

A model has three main parts:-

(i) a set of assumptions

(ii) logical statements

(iii) conclusions

Assumptions state the descriptive aspects of reality we are maintaining for the problem; while logical relationships state carefully those relationships that are construed to be of immediate importance ignoring other relationships. And conclusions stem from the model's assumptions and the relationship arrived at. From conclusions, deductions for probable events in the future can be made.

It is not possible for models to contain all the complexities that explain reality due to time involved and cost incurred[33].

Models have been used in the construction industry for a long time. The building is represented in a form understood by the various parties involved in the project. In particular quantity surveyors have represented the building in form of Bills of Quantities which breaks down the building in terms which when priced, the total of the sum indicates the total building cost. Douglas (1987)[33] defines cost modelling "as the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost".

Chapter one of this research work mentioned briefly the cost models developed and used in the construction industry. Three types of cost models are recognised. That is first generation models, second generation models and third generation models. In this chapter we discuss each one of these models to some detail, highlighting the shortcomings and strengths of each as a cost control tool.

2:4:1 First Generation Models

As the name suggests these models were the first to be used with the dawn of quantity surveying practice. Occasionally, the models have undergone changes in order to make them effective and more reliable as forecasting tools. Due to their widespread use and more so for being the first set of models to be used in the quantity surveying profession some writers have preferred to name them as traditional models. Under traditional models there are several cost models that have been used in preparation of bills of quantities.

The bills of quantities represent a building in a form suitable for the contractor's estimator. When prices are then applied to the measured quantities, the bill becomes a representation (or model) of the cost of building. The quantity of the measured items or the price can be changed according to variation in specification such that evaluation of the effect on cost of manipulating certain design variables can be simulated. The bill itself however suffers one major drawback. It is prepared at a very late stage of the design process such that any information available as a result of changing the quantities or price rates would come too late to avoid any abortive design effort. This means also that an estimate obtained from a bill would be too late to give the client an indication of his likely cost commitment at the beginning of the project. It is this drawback which is responsible for all innovations that the construction industry has seen itself in, thus the various sets of the cost models in use to-date.

Ferry (1987)[34] has presented traditional cost models in pyramidal form in an attempt to show the level of detail retained as one descends the list. It shows the level at which the bills of quantities is placed in relation to the other traditional models. In this case it is grouped under S.M.M. items (Level 5).

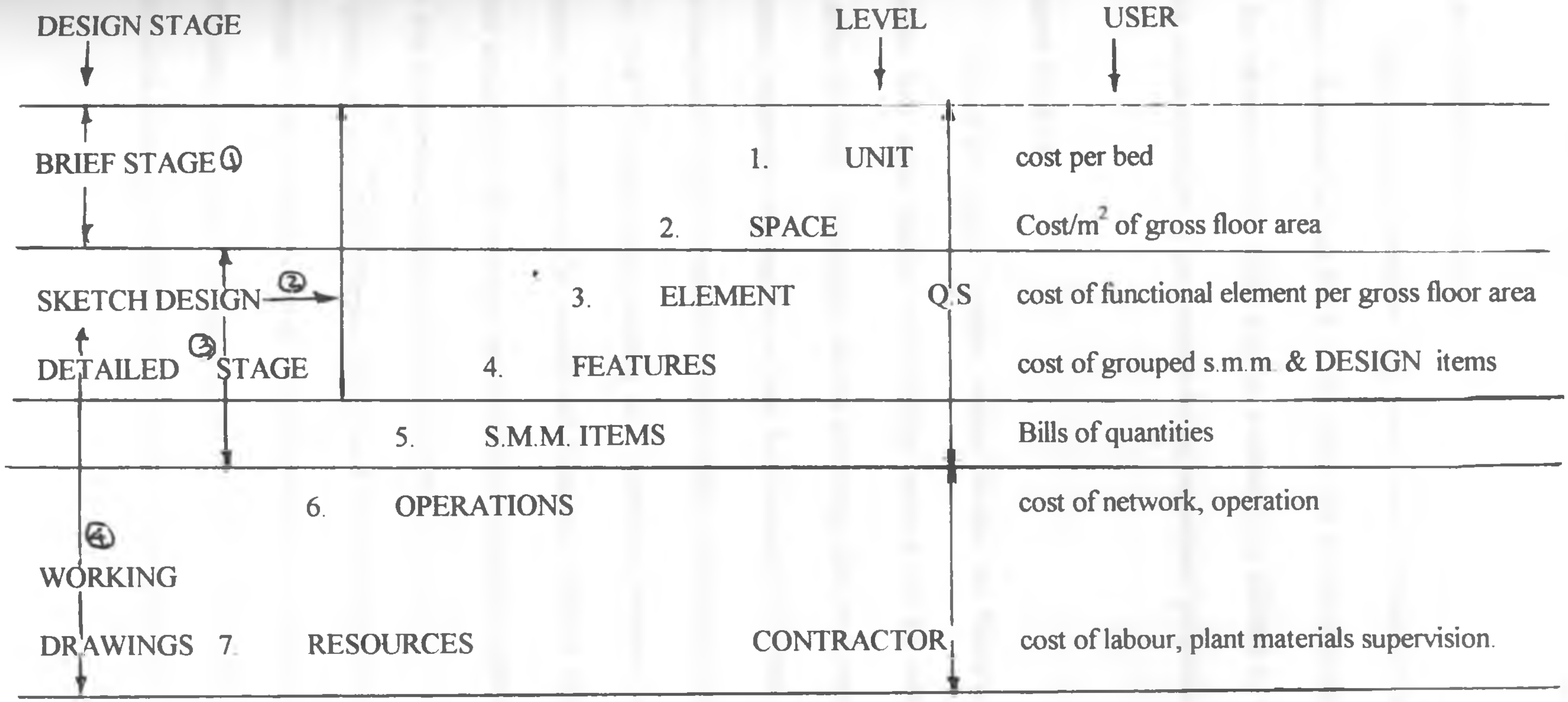

Fig 2.5: Traditional Cost Models

Source: Ferry (1987)

The diagram as presented by Ferry is reviewed below as follows:-

Unit and Space (Level 1 and 2)

These types are basically "unit price - rate" methods of estimating cost. The size of building is measured in one form or the other and the result multiplied by a unit price-rate to give the estimated cost. With such an estimate it is difficult to relate the cost of the work shown on the drawings to the estimate during subsequent progress of the design.

Element (level 3)

This is the type of model, which divides the building into functional elements. Elements have some relation to the design process and are easily understood by all parties including the client. This model has the advantage that each major part of the design can be estimated separately and used as a basis for checking when that part of the building has just been designed. This is the model by which design cost planning can be achieved. According to Ferry (1987)[35] design cost planning is a technique whereby the original estimate can be prepared on the basis of the known and economic standard of construction and finish. He further argues that the estimate can be checked constantly against the working drawing, such that any necessary adjustments can be made prior to tender. The essence of this technique is the control of cost as the design develops and the building goes up. Thus, if a budget based on elements is set, budgetary control procedures can be adopted that allows maintaining and correction of the design. A balance in terms of cost can also be achieved between the various parts of the building and this forms a first step to providing value for the client.

Features (Level 4)

This type of model is based on approximate quantities. The model attempts to deal with problems experienced in unit and space models at a later stage in design. While this model resolves problems encountered in unit and space models it has a main disadvantage: the quantity surveyor requires extra time and a substantial additional fee for the work involved. Drawings have also to be fairly complete for these models to be effective. Another disadvantage is that where a discrepancy exists between the approximate estimate prepared and the original estimate, it is not easily traced, hence, the model is not compatible with the design process nor is it sufficiently sensitive to allow for ease of adjustment.

S.M.M. Items (level 5)

The model that features here is the bill of quantities. The pyramid shows the position of modelling of bills of quantities in terms of the detailed modelling used in traditional techniques. There have been attempts in recent revisions of the rules for measuring Bills of Quantities, (the standard method of measuring building works - S.M.M.) to orientate the building to the way costs are incurred on site. However, majority of items are still measured in place, hence, the bills of quantities is still primarily a document for management in obtaining a contractual estimate in a short space of time, rather than a document for management and cost control of construction on site[36].

Operations and Resources (Level 6 and 7)

These two models down the pyramid are closely related to construction. A contractor prepares a network, outlining the sequence of activities or operations as undertaken on site. These models help in site management and the organisation of labour, plant, and materials. These are basic resources, hence the models form the most detailed level of modelling, as they are the ingredients of the production process. All the other models discussed earlier on assume knowledge of resource requirements although in most cases the resources assessment is so distant that it is hardly recognisable.

Of importance to note here is that level 1 to 4 use data based upon an analysis of bills of quantities which essentially is somebody else's view of what he intends to charge for the resources plus profit and overheads. This fact leaves levels 5 to 7, which are more independent in the data, used for forecasting costs.

Ferry (1987)[37] concludes his summary of traditional models by asserting that,

> "the factor that allows each technique to work is the knowledge that the overall cost of the job, which has been analysed to provide data for the model is the going-rate; for that building. If adjustment is made for current market conditions affecting price levels it should be possible to build an identical building on the same site for a similar price. This is the theory behind all estimating, but of course there are usually vast numbers of differences between one job and another and this is what makes forecasting very much a matter of professional judgement".

Raftery (1984)[38] provides a form of presentation of a first generation model and is an element based floor area model. It is used as a preliminary cost plan. The model is defined as:

$$C = \sum_{E=1}^{6} (t.q.qu.R)\,E$$

Where C = Cost of the building per unit floor area

E = the main element headings (substructure, superstructure, internal finishes, fittings, services, external works)

t = The time adjustment.

q = The quality adjustment which attempts to account for differences in the level of specification of the element in the building chosen for comparison and that of the project in hand.

qu = The quantity adjustment. This is usually assumed to be linear.

R = Either the element unit rate or the cost of the element expressed per unit gross floor area.

The model illustrated above is a simple one with only six elements. The model could be detailed to contain 32 elements as follows:-

$$C = \sum_{E=1}^{32} (t.q.qu.R)\,E$$

Each of the six elements are broken down to some detail such that an element like 'superstructure' becomes frame, upper floors, roof, stairs, external walls, internal walls etc.

2:4:2 Second Generation Models

These models are commonly referred to as regression models. A regression model is a method of determining the relationship between variables by the method of least squares. Least squares method seeks to minimise the sum of the squares of the difference between the observed values and the predicted values. For instance knowing the shape, height or other variables of a particular building may through this technique is able to forecast the cost of the building more reliably than by using one of the traditional single price methods.

In first generation models, relationships between the design variable and cost are assumed fixed and that the cost factor applied to the algebraic formula is constant. This is not the case in social sciences and particularly where human intervention is involved, exact relationships are not generally observed. Instead statistical relationships prevail and only average relationships may be observed among the variables.

Kouskoulas and Koehn (1974)[39] carried out extensive research based on regression model to study the effect of various variables on pre-design cost estimation. The model was of the form.

$$C = 81.49 + 23.93V_1 + 10.97V_2 + 6.23V_3 + 0.167V_4 + 5.26V_5 + 30.9\ V_6$$

where,

C = some cost measure of buildings (in the derived model C became the dollar cost per unit floor area)

V_1 = locality index

V_2 = price index

V_3 = building index

V_4 = height index

V_5 = quality index; this attempts to measure:-

(i) the quality of workmanship and materials used in the construction process

(ii) the building use

(iii) the design effort

(iv) the material type and quantity used on the components

$$V_5 = I/K \sum_{I=1}^{K} I_i C_i$$

Where k is the number of building components and I is an integer between 1-4 (corresponding to fair, average, good and excellent) arbitrarily applied to that component.

In the derived model, the number of building components K was 8, these were the building use (multi-tenancy, single tenant, mixed etc); building design (minimum, average, high loads etc),, exterior wall, plumbing, flooring, electrical etc.

V_6 = Technology index; this attempted to take into account extra cost of special types of Buildings or the labour and materials savings resulting from the use of new techniques.

V_6 = 1 for normal situations,

V_6 > 1 for extra costs (i.e. chemistry lab=1.45, bank = 1.75) and

V_6 < 1 for savings as a result of technology.

Indices for these six independent variables were applied to the sample of buildings, a least squares analysis carried out on each of the linear equations which, when solved, simultaneously gave the function shown above[40].

Regression models as the one demonstrated above by Kouskoulas and Koehn is a method by which estimates are made of the value of a variable (e.g. cost) from a knowledge of the values of one or more other variables (e.g. height and shape of building), and the errors involved in this estimating process measured[41]. In its simplest form it describes the relationship between two variables by computing a straight line through the data obtained. This is known as two-variable linear equation. The factor whose value we wish to estimate (e.g. cost) is referred to as the dependent variable and denoted by Y. The factor from which these estimates are made is called the independent variable and denoted by X. Thus, in a two-variable linear regression the expression for the straight line is of the form:-

$$y = a+bx$$

where a is the intercept of the axis and b is the slope of the line.

Extension of simple regression model is the multiple regression model. In this case the multiple regression takes the form

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 + \dots + b_kx_k$$

Which means all the independent variables x_k are affecting the nature of y and are doing so at the same time[42].

Despite the advantages the second generation models have over first generation models, they face three major drawbacks -

(i) The models rely in most cases on historical data. When this happens, the resultant coefficients are 'locked into time'. This means that no matter how comprehensive the data is, and how good a correlation is achieved, the line of least squares (best fit) will relate to that sample of data at that point in time. The reliability of the coefficient falls with new production methods being developed, new materials being marketed, or changes in cost relationships. This means a re-analysis is necessary in order for the coefficient to be effective. The problem is best overcome by analysing resource quantities instead of relying on historical data. Still, this does not take into account the productivity of labour at a later date e.g. labour. Time factor can be adjusted using indices thus, making this model superior to traditional models.

(ii) It is unlikely that building programmes will be regular to warrant the use of historical data as and when required by the industry. This is because the construction industry like many others responds to the economy. At periods of economic depression, the construction industry will respond positively, such that no construction activity will be recorded in the industry. The method may not therefore be available to the cost adviser at times when the effect of his cost advice is probably most beneficial due to the economic constraints. A further problem is that lack of input data at times of recession may distort the index, unduly weighing it towards boom conditions.

(iii) It is possible to place a line mathematically through any set of data even though no correlation exists. This means that one must ensure that a linear relationship exists in a two variable model and other statistical tests such as correlation should be used to confirm the strength of that relationship.

2:4:3 Third Generation Models

Third generation approach to modelling begun in the early 1980's. The two previous techniques have attempted to describe the cost of buildings in algebraic or statistical terms so that the cost effect of changing one or more of the design variables can be evaluated. This method is based on the premise that a likely range of values for the unit of cost indicates the likely range of say the inflation rate over time. A repeat of the exercise for two or more alternatives, obtaining a distribution of solutions for each, gives a chance to compare the results and see which solution has the highest probability of being the most economic choice over the likely range of circumstances.

Owing to the amount of data required and analysis, the collection of data is a tedious task which will not only require adequate time and money but also computer aided analysis.

As mentioned in the previous two model techniques, concerning variability of data; Monte-Carlo technique has overcome this problem. However, it does not help us with problems such as technology change.

"Simulation can be defined as a means of creating a typical life-history of the system e.g. total building cost and activities under given conditions, working out step-by-step what happens during each unit of life of the system. In order to do this we need to know the detailed characteristics and operation of the system and its relevant measures. The effect of variability on the system as a whole is reproduced by sampling from the relevant distributions." Monte Carlo simulation can therefore be adopted for other uses such as undertaking a random search for the optimum solution to a design problem within a computer. Random numbers are used to select alternative shapes of building; structural frame types, specification etc, to build up a causal model of the building cost. Even with these aids and a powerful computer it can take several hours to achieve a successful solution with a complex model[43].

2.4.4 Assessment of Model Performance

Raftery (1984)[44] has studied and analysed the performance of the three types of models discussed above. He considers four criteria useful for the assessment of performance, which are based on a systems view of the problem. These are: -

(i) Data

(ii) Data/model Interface

(iii) Model Technique

(iv) Interpretation of Output.

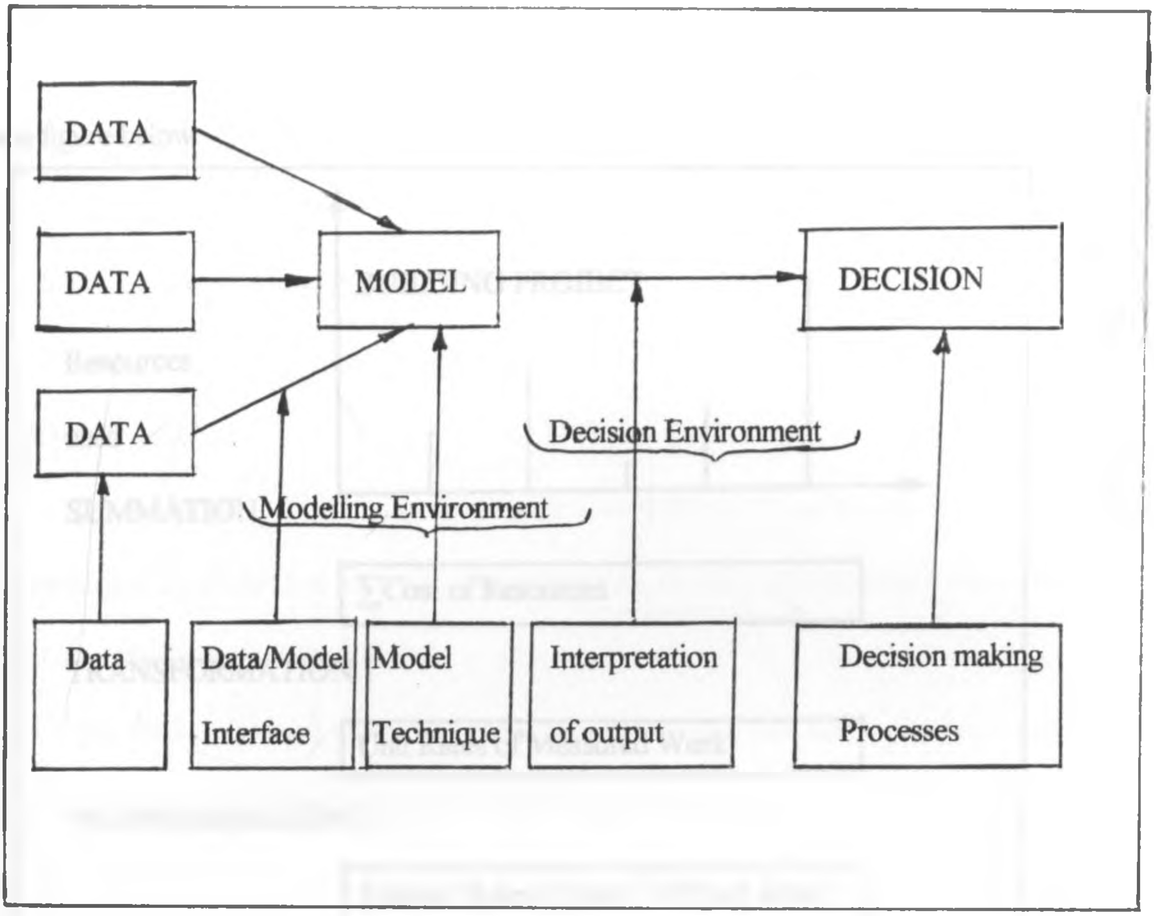

Fig. 2.6 Raftery's Conceptual Framework

Source: Raftery (1984) pp.54

(i) Data

The data used in the elemental floor area model is derived from elemental cost analyses. These cost analyses are compiled by quantity surveyors from the priced bills of quantities of the successful tenderer for a particular project. The tender price is broken down into the unit rates for particular items of measured work.

Two major transformations of data occur. The first is when the sum of the resource costs is spread over the unit rates to produce the priced bill of quantities. The second is when the unit rates are subdivided and clustered into elemental costs. These processes are illustrated in the figure below: -

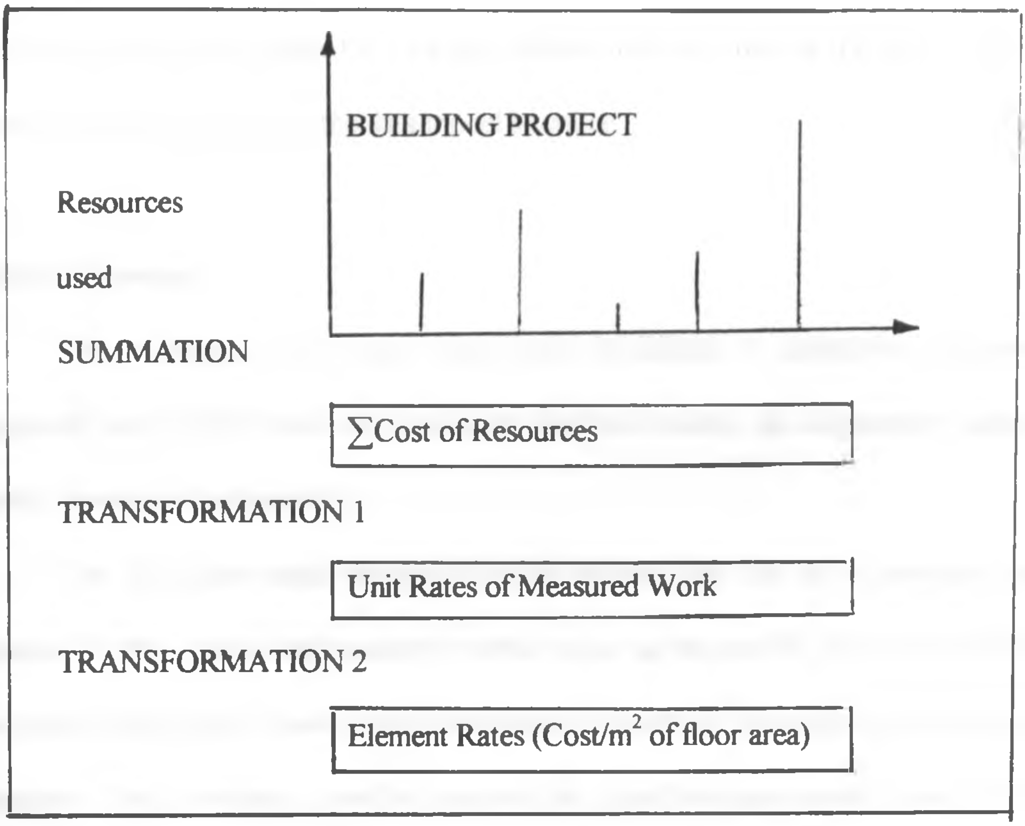

Fig 2.7 Data Transformations.

Source: Raftery (1984)pp.61

To complete the picture of the cycle of use of data it is observed that elemental rates tend to be used by quantity surveyors for cost planning at an early stage of the design when there is little detail. While at the same time during sketch design stage, unit rates based on similar bills of quantities items of comparable projects are used in conjunction with approximate quantities to produce detailed cost plans.

Data/Model Interface

The issues of importance at interface are often dependent upon the stage of development of the design at the point at which the model is used. The first two models are used at pre-design stage while the third probabilistic method is used at the tender stage. All the three models perform well at the data/model interface.

Model Technique

The technique of the floor area model is difficult to categorise. However, it is suggested that its limitations arise from three features, namely, the comparative nature of the model, linearity and subjectivity.

The floor area model requires that the element unit rate for a previous project be adjusted for time, quality and quantity in order to act as the rate for the project at hand. Any two people using a cost model purely mechanically should get the same answer if the model is consistent. This is unlikely to be the case with the superficial area model as each of the three adjustments has limitations.

The assumptions of linearity in the model relate mainly to the adjustment for quantity. This is the first limitation since choosing just one building is of course unsound statistically.

The output of the model is entirely dependent on the building, which was chosen at the initial starting point. This may have been a subjective choice. Even if two experienced quantity surveyors made the same adjustments for time, quality and quantity the results would be different if they began with different buildings.

Turning to regression techniques, the Kouskoulos and Koehn model produced very good results despite the limitations of the sample. In total 38 buildings were analysed. The coefficient of multiple correlation was 0.998, which indicates a very high degree of correlation. This model was intended to be used at pre-design stage i.e. before introduction of drawings.

Interpretation of Output

Given a knowledge of the model technique, the data/model interface and the data, two main issues remain. These are interpretation of the model output with respect to firstly the age of the model and secondly, the uncertainty in the model data and output. As models age, there are three ways in which they may be updated.

(i) The model and data may both be left as they are and the output may be adjusted by the application of an index.

(ii) Both the input data and the output from the floor area model are updated by means of cost and price indices.

(ii) The model may be left as it stands but the data files updated.

The output is usually a deterministic figure. There is no statistical description of the result. No estimate of the possible range of building costs and no estimate of the chances of that particular cost being exceeded. For these reasons the actual output achieved is often a conservative one.

Least squares models, also give a deterministic output but with one important difference i.e. the nature of the model is such that a statistical description of the model's strengths and weaknesses are available to the decision-maker. This means that the decision-maker will not only have access to the coefficient of multiple correlation but can also rank the input variables in order of their correlation with the output and test the sensitivity of the model to changes in, or deletions of, particular variables. Given the constraints of the least square method, mainly extrapolation and causation effects, the output accompanied by appropriate statistics is an extremely important decision - making tool.

The discussion by Raftery (1984) is summarised in the evaluation matrix presented below which also shows the shortcomings each model exhibits.

CRITERION/ MODEL	FLOOR AREA 1	LEAST SQUARES 2	MONTE-CARLO 3
Data Collection	Transformations	Sample bias	Data
Data/Model Interface	Good fit in early stages, weak less later	Global data global model	Good fit
Model	Linearity	Linearity Effect of Sample	Independence
Output	Inflexible	Inflexible	Interpretation

Fig.2.8. Evaluation Matrix: Identifying key problems

Source: Raftery (1984)

Despite the shortcomings exhibited by the least squares methods; this research is going to use the technique in data analysis. Monte - Carlo simulation would have been the ideal model to adopt but owing to lack of facilities and time, least squares method is preferred.

FOOTNOTES

1. Mbogua, S.J. Building Contracts and Implementation. Republic of Kenya - Ministry of Works - a paper presented at workshop - Mombasa, 23 July - 4 August 1979. pp1-3.

2. Markus, T.A. Building Performance: Building Performance Research Unit. John Wiley and Sons, New York 1972. pp13.

3. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp81.
4. Bathurst, P.E. and David, B. Building Cost Control Techniques and Economics 2nd ed. Heinemann, London 1980.

5. Department of Education and Science Building Bulletin 4: Cost Study HMSO 1972 - edited by Ivor Seely, Building Economics. pp127-128.

6. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. PP. 83

7. George, T.H. Time, Cost and Architecture - McGraw Hill, New York (1975). pp79.

8. Mbatha, C.M. Building Contract Performance. M.A. Thesis, University of Nairobi, 1984.
9. George, T.H. Op. Cit. pp84.

10. Stone, P.A. Building Design Evaluation - E & F Spon Ltd., London, 1983. pp175-176.

11. Ibid. pp178.

12. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp81.

13. Bathurst, P.E. and David, B. Building Cost Control Techniques and Economics 2nd ed. Heinemann, London 1980. pp.63

14. Croome and Sherratt: Quality and Total Cost in Buildings and Services Design (editors) London 1977.

15. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp84-86.

16. Markus, T.A. Building Performance: Building Performance Research Unit. John Wiley and Sons, New York 1972. pp23.

17. Ferry, D.J. Op. Cit. pp84-86.

18. Brandon, P.S. Building Cost Modelling and Computers. E & F.N. Spon, London, 1987 pp165.

19. Seeley I.H. Building Economics 2nd edition. Macmillan London, 1978. pp15.

20. Ibid. pp14.

21. The Quantity Surveyor - Progress in Quantity Surveying 1960 - 1980, article by A. Ashworth. pp6, Jan, 1981.

22. Seeley, I.H. Building Economics 2nd edition. Macmillan London, 1978. pp134-135.

23. Willis, C.J. and Ashworth A. A Practice and Procedure for Quantity Surveyors - 9th ed. Collins, London 1987. pp144-146.

24. Seeley, I.H. Building Economics 2nd edition. Macmillan London, 1978. pp14

24. Haddock, M. Quantity Surveying .The Evolving Profession. Building, 14 March 1969.

26. Finbarr, S. Design Cost Control for Building Work. U.N. (E.C.A.) Course Bouwecentrum, Holland September 1972. pp9.

27. HMSO. Op. Cit. pp224.

28. Ibid. pp239-240.

29. Ibid. pp241.

30. Finbarr, S. Design Cost Control for Building Work U.N. (E.C.A.) Course, Boucentrum, Holland September 1972. (editor) pp9.

31. Ibid. pp10 - 13.

32. Mixon, W.J. Managerial Economics Macmillian, New York 1985. pp94.

33. Jackson, M.J. Computers in Construction Planning and Control Allen and Unwin - London 1986. pp45.

34. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp104.

35. Ibid. pp104.
36. Ibid. pp102-105.
37. Ibid. pp256.

38. Raftery, J. "Models in Building Economics: A Conceptual Framework for the Assessment of Model Performance". CIB Working Commission W55. The Third International Symposium on Building Economics, Ottawa, Vol.3, pp103-111.

39. Kouskoulas, V. and Koehn, E. Predesign Cost Estimation Function for Buildings ASCE Journal of the Construction Division, December 1974. Pp589-604
40. Ibid

41. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp226.

42. Wonnacott and Wonnacott Econometrics - 2nd edition. John Wiley and Sons, New York 1979. pp73.

43. Ferry, D.J. Cost Planning of Buildings 5th Edition 1984. Collins, London. pp274 - 287.

44. Raftrey, J. Op. Cit. pp5-67

CHAPTER THREE

THEORETICAL FRAME WORK

3.1 COST CONSEQUENCES OF BUILDING ELEMENTS

A building element can be defined as that part of a building that performs the same function irrespective of building type or specification.

A building element is cost-related. Stone (1983)[1] has indicated that a complex inter-relationship between the design of an element and its cost exists, while at the same time design of building elements interacts between themselves.

A bill of quantities being a document that breaks down the cost of a building into elements differs from one office to another in the manner of presentation. This arises due to the fact that several ways of listing elements exist. Whereas each office has the onus of adopting a suitable format of listing the elements, it has to observe the following factors: -

(1) That, any element chosen must be capable of being defined exactly so as to ensure uniformity between the elemental breakdown even when the breakdowns are done by different people.

(2) The element must be of cost importance.

(3) The element must be easily separated both in measuring from sketch drawings and in analysing bills of quantities.

(4) The list of elements selected should be capable of being comparable for analysis with those used by others.

Most elements are inter dependent and there is an apparent difference between a cost planning element and a bills of quantities element.

A cost planning element is more easily defined. A bill of quantities element has a more strict definition than that offered by a cost planning element. For instance, an element such as walling may combine several functions some of which it may share with other elements. If we consider external walling for instance, it may have all or some of the following: -

- keeping out the weather
- thermal insulation
- sound insulation
- self supporting (deadloads, windloads etc.)
- supporting floors and roofs
- transmitting light and ventilation (curtain walls).

Thus, if an external wall only performs a few of these functions then it is obviously unrealistic to compare its cost with that of a wall, which performs a greater number of these functions. This means that a cost planning element may consist of an element such as walling to include both external and internal walling not considering the different functions the two elements perform while a bill of quantities element would separate walling into external and internal walling to separate their different functions. Thus, when doing analysis, cost planning elements and bills of quantities elements should be handled differently if useful results are to be achieved. Bill of quantities elements were used in data analysis.

We now consider each of the four elements mentioned in chapter one in turn and find out how they influence the cost of the building and the function it plays. As stated in chapter one it is not possible to study all the elements, thus the selection of the four elements which are also the enclosing elements in a building morphology. These elements are capable of demonstrating the relationships that exist between them and the design parameters under consideration.

3.1.1 Substructure

Substructure has been defined as all the work below the underside of the lowest floor finish including damp-proof membrane, together with the necessary excavations and foundations[2].

Foundations normally distribute loads from walls, roofs, floors etc to the bearing strata. The type of foundation required being a factor of the type of structure, which they are to carry. This means that the type of building involved will mainly determine the type of foundation to be used. A structure, which imposes heavy point loads, cannot be carried on conventional strip foundation. In such a situation pads or piles may be used, although it is an expensive solution.

Before a decision of the type of foundation to be adopted is reached, adequate information on subsoil condition is necessary. Building Research Establishment Digest 67[3] shows that the type of construction and subsequent use of the building are important determinants of foundation design. Strip foundations, sometimes referred to as footing, are usually adopted for buildings where the loads are carried mainly on walls. Pad foundations or piles are more appropriate where columns carry structural loads. Where differential settlements are to be controlled within acceptable limits, raft foundations are adopted.

3.1.2 Walling

When studying walls, it is more appropriate to differentiate between external and internal walls, unless where listings of elements is such that separation is impossible.

(a) External Walls

External walls are those, which enclose space including basement walls but excluding items included with roof structure. Under external walls the following are also included: -

- chimneys forming part of external walls upto wall plate level
- curtain walling, sheeting rails and cladding
- vertical tanking
- insulation

This may be the most important structural element especially in the multi-storey building and being one in which various constructional methods and finishes may be used. It forms a suitable element for cost studies. Where the external walls comprise of a series of repeated pads, it will be sufficient to study a single panel in detail. Ferry (1984)[4] indicates that it is often difficult to consider external walls in isolation from windows, internal finishes and frames. While this argument applies especially where a bill element under external walls includes windows, internal finishes and probably frame superstructure, it may not be the case especially where the bill is prepared in such a way that each of the above elements form a separate item.

(b) Internal Walls and Partitions

Internal walls may be load bearing or non-load bearing depending on the type of divisions used. Partitions are normally non-load bearing except where an internal wall of which is load bearing is used as a partition. Partitions will be affected by changes in plan shape, although the nature of the effect is difficult to assess with any accuracy as it depends mostly upon the type of building being considered.

Where detailed cost analysis for a domestic building is undertaken, it would be observed that as the enclosing wall to floor ratio changes so also does the internal partition to floor ratio but in the opposite direction, often to the extent that the costs to all intents and purposes exactly compensate each other, thus one can conclude that differences of plan shape in the structure have little or no effect. This arises because of the very high density of internal partitioning used for a domestic building in order to provide a large number of small rooms[5].

If we consider a factory building on the other hand, with a very small amount of internal partitioning, the enclosing wall to floor ratio value will have its maximum effect and as the building perimeter deviates from the square so does the cost increase. Lee (1961)[6] while investigating municipal housing found out that internal partitioning accounted for about 24% of the total cost of brick - four storey maisonettes and about 32% of the total cost of brick two-storey houses.

3.1.3 Roofing

Roofs may be pitched or flat. It is the element that protects the building mostly from the elements of weather. In a cost study of low flats it was found that cost of flat roofs are consistently higher than comparative cost of pitched roofs, the extra cost amounting on average to about 30%[7].

Lee (1961)[8] further found out that roofing costs of traditional brick two-storey houses ranged from 14-18% of total costs (the minimum being for a low pitched roof with low high quality covering and the maximum for a high pitched roof with quality covering. With brick flats and maisonettes the proportion of roofing costs to total costs ranged from 6-10% (the minimum was for pitched roofs on low bricks) with total concrete framed flats and maisonettes, the proportion dropped to about 5% for blocks up to six storeys high and as low as 2% for blocks of over ten storeys.

3.1.4 Finishes

For most building types, finishes contribute upto 22% of the total cost. It may contribute the highest percentage of the total cost.

The range of choices available for wall and ceiling finishes is probably greater than for any other component of a building and the choice is influenced considerably by the class and use of the building.

Lee (1961)[9] when investigating municipal housing costs found that finishes to walls and ceilings accounted for 6-15% of total building costs in varying situations.

He also found that if full advantage of cost studies in finishes is to be achieved, the implications of their use must be fully considered at the design stage and when planning the work on site.

In the bills of quantities analysed, finishes were treated as an element with wall, floor and roof finishes included together.

3.2 Design Parameters

Design parameters affect the cost of a building in many ways. The design parameters are: size of the building, storey height, total height, shape of the building, specification among others as can be seen in the discussion below.

3.2.1 Size of Building

Researchers have expressed the size of a building as the ratio of wall area to floor area. Observations indicate that the larger the plan area for a given shape of a building, the lower is the wall area to floor area ratio. The wall area to floor area ratio as an indicator of the size of building has been used to illustrate several interesting results. Seely (1978)[10] points out that, as we increase the size of a building a reduction in unit cost is achieved such as the cost per square metre of floor area. This can be attributed to the fact that on-costs are likely to account for a small proportion of total costs with a larger project or, expressed in another way, they do not rise proportionally with increase in the plan size of a building. Certain fixed costs such as the transportation, erection and dismantling of site buildings and sheds for storage of materials and components, temporary water supply arrangements and the provision of temporary roads, may not vary appreciably with an extension of the size of a project and will accordingly constitute a reduced proportion of total costs on a large project.

It has been found that a larger project is often less costly to build as the wall area to floor area ratio reduces. Rooms tend to be larger with a proportional reduction in the quantity of internal partitions, decorations, skirting etc. and there may also be a proportional reduction in the extra cost of windows and doors over walls. With high rise buildings a cost advantage may come due to lifts serving a larger floor area and greater number of occupants with an increased plan area.

Savings that result from a larger building make the groupings of building cost effective. Ferry (1984)[11] asserts that external walls and their finishes need to have a high performance as they are exposed to weather and therefore tend to be expensive, such that reducing the area for external walls, a considerable saving is realised.

While analysing tender prices for a sample of buildings, thereafter expressing these prices per square metre of net floor area, Reiners (1958)[12] observed that tender prices tend to fall as the area increases. For the sample he studied an increase of 10% in the floor area of flats resulted to a 4.7% decrease in the price per square metre. He concluded that in general an increase in the area of flats of x% might be expected to reduce the price per square metre by x/2%. Similarly, a decrease in the area of x% resulted to a corresponding increase of x/2% in the price per square metre. He however cautioned that, such a relationship is limited to differences in area of upto about 15% as over this limit other complex relationships operate.

3.2.2 Storey Height

Storey height is the difference in height between two alternating floors or the difference in height from the finished floor level to the lowest ceiling level.

Storey height is in most cases determined by the needs of the user of the building. A greater height than is necessary to provide comfortable conditions may be required for acoustics, ventilation, accommodate large machinery or equipment, overhead cranes etc. Just like the plan shape, the storey height affects the vertical elements of the building both internally and externally. It will also have some effect on the costs of services particularly heating, due to the increased volume of the building.

A high storey building will cost more per square metre of floor area than one with a lower storey height, other factors being equal, and will also have a higher external cladding to floor area ratio. The cost of the vertical elements will be affected in direct proportion to the change in storey height.

For instance, if the vertical elements totalled Kshs.80.00 per square metre of floor area on a building with a storey height of 3 metres, the total analysed cost of which was say Ksh.280.00 per square metre of gross floor area, it could be expected that a similar building planned to a 4 meters height would cost

280.00 - 80.00 + (4/3 M X 80.00)

= Ksh.200.00 + 106.66

= Ksh.306.66

This calculation will apply only if the change is confined to storey height, the building being similar in all other aspects[13]. This is not normally the case.

Seeley (1978)[14] adds that the main constructional items which would be affected by a variation in storey height are walls and partitions together with their associated finishings and decorations. There will also be a number of subsidiary items which could be affected by an increase in storey height as indicated below:-

(1) Increased volume to be heated which could necessitate a large heat source and longer lengths of pipes or cables. However this point may not be the case in the tropics such as East Africa.

(2) Longer service and waste pipes to supply sanitary appliances.

(3) Possibility of higher roof costs due to increased hoisting.

(4) Increased cost of constructing staircases, and lifts if provided.

(5) Possibility of additional costs in applying finishings and decorations to ceilings.

(6) If the impact of the increase in storey height and the number of storeys was considerable, it could result in the need for more costly foundations to support the increased load.

One method that has been used to make a rough assessment of the additional cost resulting from an increase in the storey height of a building is to work on the basis that the vertical components of a building in the form of walls, partitions and stanchions accounts for about 30% of the total costs.

For instance,

- estimated cost of building = Kshs.200,000.00

- estimated cost of vertical components 30% of Kshs.200,000.00
- = Kshs.60,000.00
- proposal to increase storey

  height from 2.60M to 2.80M means

  increased cost would be $\frac{0.20}{2.60} \times 100\% \times 60{,}000.00$

  = Kshs.4,615.00

It is however necessary to consider the possible effect of some or all the subsidiary items previously listed if the increase in storey height was substantial.

3.2.3 Total Height

Total height of buildings is a major design factor that should be considered seriously during design stage. Total height is the height between finished ground floor level and the lowest ceiling level of the last floor.

Compared to two or three storey buildings offering the same accommodations tall buildings are more expensive to build. An exception to this rule applies when an addition of one or two storeys to the design of a tall building is for the purpose of making the best use of the lifts or other expensive services which may slightly decrease the cost per storey. This is however a limited exception hence, it does not invalidate the general rule[15].

Seeley (1978)[16] has presented a set of principles relating to increases in the number of storeys to a building which ought to be taken into account when high rise buildings are under considerations.

They are: -

(1) The desire to erect a tall building on a particular site so as to obtain a large floor area with good day lighting and possibly improved composition of buildings.

(2) The effect of the number of storeys on cost varies with the type, form and construction of the building.

(3) Where the addition of an extra storey will not affect the structural form of the building, then depending upon the relationship between the cost of wall, floor and roof, construction costs may fall per unit of floor area.

(4) Beyond a certain number of storeys, the form of construction changes and unit costs usually rise. The change from load bearing walls to framed construction is often introduced when buildings exceed four storeys in height.

(5) Foundations cost per floor area will fall with increases in the number of storeys provided the forms of the foundations remains unchanged. This will be largely dependent upon the soil conditions and the building loads. A large rise in costs will occur where pile foundations have to be substituted for a strip or pad foundations, beyond this point it is likely that the same foundation would serve a building with an increased number of storeys and subsequently lifts become necessary thus a rise in costs.

(6) As the number of storeys increases, both the structural components and circulation areas tend to occupy more space and the net floor area assumes a
(7) smaller proportion of the gross floor area, thus resulting in a higher cost per

usable floor area.

All these principles explain in one way or the other the effect of cost on a building, as storey height is added one after the other.

3.2.4 Shape of the Building

Most often, the perimeter to floor area ratio has been used as an indicator of shape, and the influence it has on cost. Bathurst (1980)[17] has pointed out that shape will have its major influence on areas and sizes of vertical components - walls, windows, partitions etc. He further argues that the circle presents the shape with the smallest perimeter to floor area ratio. However, the circle does not necessarily provide the cheapest solution due to some reasons he points out as: -

(1) That, the building is more difficult to set out for the contractor, thus the contractor prices such work expensively.

(2) Curved surfaces, particularly those incorporating timber or metalwork are very expensive to achieve.

(3) Circular buildings hardly produce an efficient use of internal space as inconvenient odd corners between partitions and external walls are generated.

(4) Standard joinery, which normally envisages right angles, will not fit against curved surfaces or into acute angled corners.

(5) The circle does not usually allow efficient use of site space. This means that the right angled building with the lowest perimeter will provide the best solution - that is the square shape.

However, the square may not fulfil this requirement due to the following reasons: -

(1) The square plan produces a very deep building that may require artificial

ventilation, air conditioning and lighting making it uneconomical although single storey building with its opportunities for natural top lighting and ventilation which may render this case an exception to the general rule.

(2) Where a high density of rooms exists, the use of the external walls as a boundary to the room may compensate for the amount of partitioning required. It becomes necessary in such a case to elongate the building in some way so that rooms can be serviced from either side of a spinal corridor rather than have a deep building resulting in a complex network of corridors to service all rooms plus the possibility of artificial ventilation to those that are internal.

(3) A given amount of accommodation housed in a square, in multi-storey block, may be much more expensive than the same accommodation housed in a less compact two storey block.

(4) Given a sloping site where cut and fill is a must, it becomes cheaper to provide a rectangular building with the longer side running along the contours than a square building which could cut more extensively into the slope. However, the slope may be dictated by factors beyond the scope of the design team such as boundaries, topography and orientation. In such circumstances, the design team may advise the client to acquire additional land. If this is not possible it may be advisable to under-utilise an awkwardly shaped site in order to secure a regularly shaped and more economical building.

The shape of a building may also be influenced by the manner in which it is going to be utilised. For a factory building, the determining factors may be co-ordination of manufacturing processes and the form of the machines and finished products. In schools, residential houses and hospitals and to some extent offices, shape is influenced by the need to obtain natural lighting. This means that where the rooms are to rely on natural lighting in daylight hours, the depth of the building is thereby restricted. Otherwise, it is necessary to compensate for the increase in depth of building by installing taller windows, which may compel increased storey heights. The aim in these circumstances would be to secure an ideal balanced solution, which would take into account both the lighting factor and the constructional costs. Deeper rooms result in reduced perimeter to floor area ratios with a subsequent reduction in construction, maintenance and heating costs, but these savings may be offset by increased lighting costs[18].

A survey conducted by the Building Research Station (1962)[19] found that most factory buildings were simple rectangles with an average length to breadth ratio of about two to one, although there were a few which were almost square in plan. Buildings with a high length to breadth ratio were used for engineering; the ratios in these cases sometimes being as much as five or six to one. On average single storey factory buildings were found to be around 38M in breadth, whereas the multi-storey blocks averaged about 23M.

3.2.5 Specification

The Collins English Dictionary defines specification as a "detailed description of the criteria for the constituents, construction, appearance, performance etc. or of the standard of workmanship required in its manufacture[20].

It is apparent that specification according to Collins dictionary embraces a number of factors all aimed at fully describing the subject matter under consideration. In this regard specification cannot be viewed in isolation from the design. In construction terms specification has to be viewed with the design of the building. Ferry (1984)[21] has presented design method as interacting forces of cost, size form and specification, where design method is a technique that tries to obtain optimal design solutions. The constraints that the design team encounters during the cost planning process being the interacting forces mentioned above. Below is a diagrammatic presentation of how these constraints relate to one another.

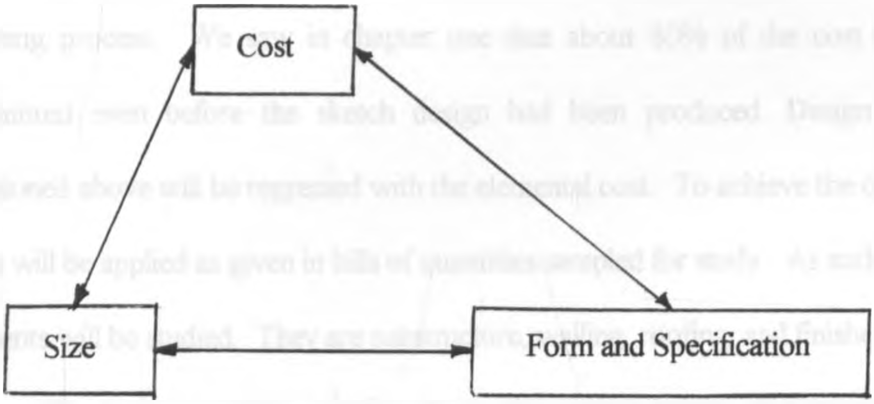

Fig. 3.1 Specification, cost and size

Source: Ferry (1984)

Each constraint can be viewed as a function of the remaining two constraints as shown in fig. 3.1 above. For instance, we may hold size of a building and form and specification implying that a certain cost has to be generated. In a like manner, if the cost of the building is established together with size, then the form and specification are the constraints. Also, if the shape and quality standard of the specification is determined together with cost, then the amount of accommodation is the design variable which is limited. This means that since one factor must be resultant, it is never possible to declare all three in an initial brief.

The above example of design method is an oversimplistic view of the cost system, but is a starting point in the understanding of the complex relationship which exists between design and cost. It is the skill of the design team in achieving the right balance between these factors that makes a project a success or a failure[22].

3.3 The Study Model

The study model intends to introduce the concept of cost modelling during the cost planning process. We saw in chapter one that about 80% of the cost of construction is committed even before the sketch design had been produced. Design variables already mentioned above will be regressed with the elemental cost. To achieve the objective, elemental costs will be applied as given in bills of quantities sampled for study. As earlier stated only four elements will be studied. They are substructure, walling, roofing, and finishes.

The design variables are plan shape, size, storey height, total height and specification which will be regressed with the elemental costs. Since projects analysed covered different periods of time, cost indices from statistical abstracts were used for respective years in order to reduce the costs to a common base.

Having established the variables, the model will assume a mathematical form of linear relationship, whose general presentation is as follows: -

$$C = a + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + \dots + e$$

Where C = Cost of element expressed per unit floor area
(units =KSh/M^2)

a = Element cost intercept i.e.
elemental cost per unit floor area that is independent of X_i'S

X_i'S = Design variables i.e. plan shape, size of building, storey height and total height of building.

B_i'S = Coefficients for X_i's

e = Error term value.

Definitions:

Plan shape = $$\frac{\text{perimeter}}{\text{floor area}} \quad (M/M^2)$$

Size of building = $$\frac{\text{wall area}}{\text{floor area}} \quad (M/M^2)$$

Storey height = $$\frac{\sum_{i=1}^{n} H_I}{n} \quad \left(\frac{nM}{n}\right)$$

Where H_i = storey at each floor

Where i = 1,2 .... n

n = number of floors

$$\text{Total height of building} = \sum_{i=1}^{n} (H_i + h_i)\ (M)$$

Where h = slab thickness between two consequent storey heights.

The model presented here is of a general form. The actual model will be considered in chapter four. The model can also be compared with the regression model derived by Kouskoulas and Koehn (1974)[23] reviewed in chapter two of this research.

FOOTNOTES

1. Stone, P.A. Building design evaluation - E and F Spon Ltd. London, 1983. pp18.

2. Ferry, D.J. Cost planning of Buildings: 5th Edition, 1984, Collins, London. pp338.

3. Building Research Establishment: Digest 67 (second series) Soils and Foundations, 1966.

4. Ferry, D.J. Op. Cit. pp300.

5. Bathurst, P.E. and David, B. Building Cost Control Techniques and Economics 2nd edition. Heinemann London, 1980. pp69.

6. Lee, M. Comparative cost evaluation - municipal housing. The Chartered Surveyor, July 1961.

7. RICS : Cost Research Panel. The cost and design of low flats - a case study - The Chartered Surveyor, June 1960.

8. Lee, M. Op. Cit.

9. Ibid.

10. Seeley, I.H. Building Economics 2nd ed. Macmillan London, 1978. pp.21.

11. Ferry, D.J. Op. Cit. pp301.

12. Reiners, W.J. Studies in the cost of housing : The tender prices of local authority flats, The Chartered Surveyor August 1958.

13. Bathurst, P.E. and David, B. Op. Cit. pp65.

14. Seeley, I.H. Op. Cit. pp.28.

15. Ferry, D.J. Op. Cit. pp300.

16. Seeley, I.H. Op. Cit. pp.30.

17. Bathurst, P.E. and David, B. Op. Cit. pp63- 64.

18. Seeley, I.H. Op. Cit. pp.20-21.

19. Building Research Establishment : Factory building studies No.12. The economics of factory buildings, HMSO, 1962.

20. Patrick, H. Collins Dictionary of the English Language 2nd ed. William and Sons, Glasgow. 1989. pp1465.

21. Ferry, D.J. Op. Cit. pp82-83.

22. Ibid.

23. Kouskoulas, V. and Koehn, E. Predesign Cost Estimation Function for Buildings. ASCE Journal of the Construction Division, December 1974. pp589-604.

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION

4.1 Introduction

This chapter set out to investigate how building cost in the four elements can be explained by design variables already discussed in chapter three. The aim is to obtain a relationship between element cost and the design variables so that it can be used during the initial stages of design process.

Not all elements are considered for investigation. A criteria was used to obtain the elements which contribute more to a building as was shown in chapter three. These are substructure, walling, roofing and finishes whose total amount to about 79% of the total building cost for most building types.

As discussed earlier in this study, the design process consists of three main stages, the analysis, synthesis and appraisal. The traditional approach to estimating building cost is mainly centred at appraisal stage, while 80% of building cost is committed during the analysis and synthesis stages. Traditional estimating methods have been accused of ignoring this fact; thus necessitating investigation of other methods of estimating which can be of use during these crucial stages in the design process. Several design parameters have been considered for inclusion in the cost model and these are the parameters that are made known from the client's brief. These parameters are shape, size, plinth area, storey height, total height, specification and the effect of time on money.

4.2 Data Analysis

Raw data from the field had to undergo a series of transformation before it was ready for analyses using SPSS/PC+ package. Various stages of transformations are attached in the appendices 1 - 4.

Raw data from the field was recorded in the self completion questionnaires. Bills of quantities and drawings were used to extract the required information. The self completion questionnaires contained the four elements covered for study for each of the three cases.

A sample of the questionnaire is shown in appendix 2. Type of building, date of tender and plinth area are entered at the top since these entries apply to all the four elements. The rest of the questionnaire is divided into seven columns and four rows. The entries in these columns were used to express the design parameters since they are a product of one or two of these columns. For instance to obtain shape we get a ratio of wall area to floor area.

Data as presented in the questionnaires were filled by Forward Planning Personnel assisted by research assistants. The questionnaires needed a further transformation so that each element is considered separately. In appendix 3 "the format for analysis of data table" is shown.

The number of columns in the format for analysis of data table is seven while the rows are forty three indicating entries for all the cases studied. From these tables various codes are obtained from the computer printout to represent the parameters for the analysis. In total four sets of data were obtained to indicate the four elements since each element was considered separately from the other. However the coding of the parameters remained the same for all the elements.

Below is a run down of the parameters.

$$\text{VAR 1} = \frac{\text{Element cost}}{\text{Floor area}}$$

This variable was also code-named 'Delemcost' in the print- out.

$$\text{VAR 2} = \frac{\text{Wall area}}{\text{Floor area}}$$

This variable is also referred in the printout as 'size'.

$$\text{VAR 3} = \frac{\text{Perimeter}}{\text{Floor area}}$$

This variable expresses the shape of the building as shown in the printout.

VAR 4 = storey height.

This variable shows the storey height. It is code-named 'Sheight' in the printout.

VAR 5 = Total height.

This variable expresses the total height and is code-named 'Theight' in the printout.

VAR 6 = Building Cost Index

This variable takes care of the effect of tender date on building cost and the year 1972 was taken to be the base year (1972 was taken to be 100). In the printout it is referred to as 'Bcostin'.

Some assumptions are made concerning specifications and building type.

Assumptions:

1. Specification

There are four elements considered: - substructure, walling, roofing and finishes. The buildings considered for study are public buildings and had similar specifications for all the four elements. Where a difference in specification was encountered, adjustment in both cost and area of that element was done in order to maintain similar specification for ease of analyses. For instance, if in the roof we had a flat concrete slab and over it a timber trussed roof covered with concrete tiles for ease of comparison, the cost of flat concrete slab was adjusted accordingly to allow for comparison of like elements of similar specification.

2. Type of building

An element has been defined as a functional unit, which fulfils a specific function irrespective of its material or specification. From the definition we find that apart from fulfilling the same function, it may have different materials or specification. Since we maintained the same material and specification the type of building becomes constant in our analyses of building elements. This assumes the fact that a tenderer in arriving at his tender sum will price an item at the same rate whether it occurs in a school, hospital or office block. Other factors that may influence the total cost of one type of building from another being its space requirements and this will affect the quantity of the element thus its total cost and not merely the price of the element per unit area, volume or extent.

4. Location

Similar projects constructed on different locations will vary in their cost taking the overall cost of the projects in question. But since in our analyses of elemental cost we are dealing with how the cost of element vary with the design parameters holding other cost factors constant, the element of location will have a minimal effect on our data if any.. It is therefore assumed in this study that location will have minimum or no effect at all.

4.2.1 Correlations

A one tailed t-test was used at 0.01 level of significance. In some cases the level of significance was as high as 0.001.

(1) WALLING

VAR	Correlations
2	0.6548
3	-0.1131
4	0.3451
5	-0.0095
6	0.2167

Table 4.1 Correlations for walling

Source: Field Survey 1991.

Observation

From table 4.1 it is observed that VAR 2 satisfies 1-tailed t-test at 0.001 level of significance. This means that 42.90% of the variation shown by walling cost per gross floor area can be attributed to the tendency of size of building (VAR2) to vary linearly with cost of walling per gross floor area. This observation confirms our earlier prior knowledge that a positive linear relationship exists between size of a building and its walling cost per gross floor area.

However, our prior knowledge as observed in VAR 3 is contradicted since the negative sign in the correlation of -0.1131 shows an inverse relationship. And since the negative sign in the correlation is not zero, it implies that a weak inverse relationship exists. We can also conclude that since the linear relationship is so weak, there may be a non-linear relationship that exists, but since our model assumes a linear relationship then this parameter does not explain the tendency of walling cost per floor to vary linear with shape of a building.

The correlation of 0.3451 shown by VAR 4 is statistically significant at 0.01. This positive sign confirms our prior knowledge that a positive linear relationship exists between walling cost per gross floor area to storey height. This means, the higher the storey height, the higher the cost of walling, keeping floor area constant.

Correlation for VAR 5 is -0.0095. Again, out prior knowledge of the existence of positive linear relationship between walling cost per gross floor area with the total height of building is contradicted. It is concluded that a relationship does exist but may be non-linear thus the negative correlation coefficient of -0.0095.

As for the correlation shown by VAR 6, of 0.2167, it can be observed that our prior knowledge that building cost index has a positive relationship with walling cost per gross floor area is confirmed. However only 4.7% of the variance is common to the two measures, that is building cost index and walling cost per floor area.

(2) SUBSTRUCTURE

VAR	Correlations
2	0.7295
3	-0.0939
4	0.3039
5	0.1532
6	0.4981

Table 4.2 Correlations for substructure

Source: Field Survey 1991.

Observations

From table 4.2, it can be observed that a strong linear relationship exists between substructure cost per gross floor area and size of the building.

Thus, the correlation of 0.7295 satisfies 1-tailed t-test at 0.001 level of significance. This means that about 53.22% of the variation shown by substructure cost can be attributed to the tendency of size of building to vary linearly with substructure cost per gross floor area. Also, our prior knowledge that the more the size of a building the more loading needed to be transmitted to a firm strata by foundations which are to be designed accordingly to suit the loading is confirmed. The cost of these foundations will rise with higher loading requirements as dictated by their designs.

From the table we also observe that a weak linear relationship exists between VAR 3 (shape) and the cost of substructure. Thus the correlation of 0.0939 shows a very weak relationship between the two measures.

It can also be observed that a positive relationship exists between VAR 4 (storey height) to cost of substructure per gross floor area. Our prior knowledge is confirmed since it is expected for the cost of substructure to increase with deeper storey height. The weak relationship may explain the fact that a certain design of foundations can support loading necessitated by storey heights upto a certain limit of depth before foundation can be redesigned to accommodate heavier loads as a result of increasing the storey heights.

The correlation of VAR 5 (total height) is 0.1532. This is a weak positive relationship that our prior knowledge predicated. It is also observed that the storey height explains cost of substructure more than is the case with the total height. This is because the total height is a factor of storey height in which we found that, design of foundations can be held constant even with further increase in storey height. This means where storey height would explain more to the increase in cost of substructure than total height increasing the number of storeys total height has the effect of reducing the cost of substructure per gross floor area per total height.

The correlation of VAR 6 (Building Cost Index) is strong at 0.4981 and satisfies the 1-tailed t-test at 0.001 level of significance. It also shows that about 25% of the variation of substructure cost per gross floor area can be attributed to the tendency of building cost index to vary linearly with cost of substructure per gross floor area. The positive sign also confirms our prior knowledge of the existence of a positive linear relationship.

(3) ROOFING

VAR	Correlations
2	0.1910
3	-0.1080
4	0.2966
5	0.0359
6	0.6000

Table 4.3 Correlations for roofing

Source: Field Survey 1991.

Observations

There exists a weak positive correlation of 0.1910 between VAR 2 (size) and roofing cost per gross floor area. This means the size of building does not help much in explaining roofing cost per gross floor area.

Similarly, there is a negative correlation between VAR 3 (shape) and roofing cost per gross floor area. This means an inverse relationship between shape of a building and the roofing cost per gross floor area exists. This relationship is weak since the correlation coefficient is -0.1080. It can be observed that the shape of a building does not explain satisfactorily roofing cost per gross floor area. There is also a possibility that a non-linear relationship exists.

The correlation coefficient of 0.2966 observed between VAR 4 (storey height) and roofing cost per gross floor area is slightly significant and shows that only 8.80% of the variance is common to the two measures.

The correlation coefficient of VAR 5 is 0.0359. This means that a weak relationship exists between total height of a building to roofing cost per gross floor area. From our prior knowledge, this observation is confirmed since the cost of roof per gross floor area is not affected by total height of a building. This observation is true since the extra cost of hoisting for instance trusses to a higher level is covered as a lumpsum in the preliminaries in the case of public projects. However preliminaries are not priced separately in government projects, but rather are spread out in the rates. The effect of spreading the preliminaries in the rates is to maintain rates of identical items in the bills same throughout. Therefore regardless of the height the trusses are hoisted; the cost of the roof per gross floor area remains the same holding the floor area constant.

Finally, it is observed that the correlation coefficient of VAR 6 (Building Cost Index) is at 0.600. This correlation satisfies the 1-tailed t-test at 0.001 level of significance. It also means that 36% of the variation shown by roofing cost per gross floor area can be attributed to the tendency of building cost index to vary linearly with cost of roofing per gross floor area.

(4) FINISHES

VAR	Correlations
2	0.5318
3	-0.1513
4	0.3501
5	0.0089
6	0.2904

Table 4.4 Correlations for finishes

Source: Field Survey 1991.

Observations

There is a strong relationship that exists between size of a building VAR 7 and finishes cost per gross floor area. The correlation coefficient attained is 0.5318, which satisfies the 1-tailed t-test at 0.001 level of significance. It means that 28.3% of the variance is common to the two measures. This observation also confirms our prior knowledge; that is, the extent of finishes, and therefore the cost of finishes tend to increase as the area of walling is increased.

On the other hand a weak inverse relationship is observed between the shape of a building and the cost of finishes per gross floor area. The correlation is -0.1513. Our prior knowledge is also contradicted; thus a non-linear relationship may exist between the two measures.

The correlation coefficient of 0.3501 shown by VAR 4 (Storey height) indicates a positive satisfactory relationship. This means that as storey height is increased, the wall finishes are increased as well, thus by maintaining the floor area constant a positive relationship is observed.

However, a weak correlation of 0.0089 exists between total height and finishes cost per gross floor area. This observation is true since the relationship is positive, but the magnitude is so small and does not confirm our prior knowledge.

Finally the correlation of 0.02904 attained by VAR 6 (Building Cost Index) is satisfactory. It also shows a positive relationship, which confirms our prior knowledge. It is also a weak relationship.

4.2.2 Regressions

Chapter one of this study discussed multiple regression analysis at length. Several statistics were discussed. This section tries to put the discussions in multiple regression in practice and the notations as used here are briefly explained.

K - Number of regressors

R - Multiple correlation coefficient

N - Number of cases studied

R^2 - Overall index of how well C can be explained by all the regressors. i.e. how well a multiple regression fits the data.

Stepwise regression is also used which means a regressor is introduced at a time in the regression model. The number of regressors to be retained in the model is controlled by a criterion, which normally keeps bias and variance low, that is the mean squared error (MSE) of the response predicted by the regression equation. The criterion relies on addition of regressors until;

$$\frac{(1 - R^2)}{(n-k-1)^2} \text{ is a minimum}$$

The regressor to be retained in the model is such that the null hypothesis is rejected.

That is the observed t-value is greater than the t-value at level of significance as obtained from student t-tables.

t = t-value as observed from analysis of data

sig t = t-value at level of significance set by the test.

(1) WALLING

The regressors to be retained in the cost model are those where the observed t-value is greater than the t-value at level of significance.

Variable	t	sig t
VAR 2	5.67	0.00
VAR 4	2.61	0.013
VAR 6	0.39	0.70

Table 4.5. T-test for walling

Source: Field Survey 1991.

Observation

Only two variables VAR 2 and VAR 4 satisfy the condition for inclusion of regressors in the cost model. That is, the observed t-value is greater than the t-value at level of significance set by the test.

K	New regressor introduced	R^2 explained	$1-R^2$ residual	n-k-1	$\frac{(1-R^2)}{(n-k-1)^2}$
1	VAR 2	0.655	0.345	41	0.000205
2	VAR 4	0.716	0.284	40	0.000178

Table 4.6 Stepwise regression for walling

Source: Field Survey 1991.

Multiple correlation

Multiple R = 0.716

R^2 = 0.512

$\bar{R}^2$ = 0.488

standard error = 2542.88

Analysis of variance

F = 20.98 significant F = 0.00

Variables in the cost model

Variable	B	SE B
VAR 2	5243.79	924.14
VAR 4	5619.82	2152.55
(Constant)	-23336.01	6456.31

Therefore the cost model for walling can be expressed as: -

$E_c = -23336.01 + 5243.79 \text{ VAR } 2 + 5619.32 \text{ VAR } 4$

This model shows the relationship between cost of walling per gross floor area (E_c) and design parameters VAR 2 and VAR 4. This model can be used during the initial design process to obtain a cost estimate for walling.

(2) SUBSTRUCTURE

Variable	t	sig t
VAR 2	6.249	0.000
VAR 4	1.137	0.2626
VAR 6	3.501	0.0012

Table 4.7 T-test for substructure

Source: Field Survey 1991.

Observations

Only variables VAR 2, VAR 4 and VAR 6 are included in the cost model.

K	New regressor introduced	R^2 explained	$1-R^2$ residual	n-k-1	$\frac{(1-R^2)}{(n-k-1)^2}$
1	VAR 2	0.730	0.27	41	0.000161
2	VAR 6	0.79	0.21	40	0.000131
3	VAR 4	0.80	0.20	39	0.000131

Table 4.8 stepwise regression for substructure.

Source: Field survey 1991.

Multiple correlation

Multiple R = 0.80

R^2 = 0.64

$\bar{R}^2$ = 0.60

standard error = 1838.63

Analysis of variance

F = 22.30 significant F = 0.00

Variables in the cost model

Variable	B	SE B
VAR 6	4.36	1.83
VAR 2	1734.77	277.07
VAR 4	705.82	621.00
(Constant)	-5671.11	1731.48

Therefore the cost model for substructure can be

expressed as:-

$$E_c = -5671.11 + 1734.77\ \text{VAR } 2 + 705.82\ \text{VAR } 4 + 4.36\ \text{VAR6}$$

This cost of substructure can be explained by size, storey height, Building Cost In as shown in the model.

3. ROOFING

Variable	t	sig t
VAR 4	0.81	0.42
VAR 6	4.80	0.00

Table 4.9 T-test for roofing

Source: Field Survey 1991.

Observation

Only variables VAR 4 and VAR 6 are considered in the cost model.

K	New regressor introduced	R^2 explained	$1-R^2$ residual	n-k-1	$\frac{(1-R^2)}{(n-k-1)^2}$
1	VAR 6	0.60	0.40	41	0.000238
2	VAR 4	0.69	0.31	40	0.000194

Table 4.10 stepwise regression for roofing.

Source: Field survey 1991.

Multiple correlation

Multiple R = 0.69

R^2 = 0.48

$\bar{R}^2$ = 0.44

standard error = 721.39

Analysis of variance

F = 16.20 significant F = 0.00

Variables in the cost model

Variable	B	SE B
VAR 6	4.16	0.75
VAR 4	118.30	48.27
(Constant)	-811.31	321.00

Therefore the cost model for roofing can be expressed as:-

$E_c = -811.31 + 118.30\ \text{VAR}\ 4 + 4.16\ \text{VAR}\ 6$

This means roofing cost per gross floor area can be explained by storey height and Building Cost Index.

4. FINISHES

Variable	t	sig t
VAR 2	4.19	0.00
VAR 4	2.21	0.03
VAR 6	1.27	0.211

Table 4.11 T-test for finishes

Source: Field Survey 1991.

Observations

Only variables VAR 2, VAR 4 and VAR 6 are considered for inclusion in the cost model.

K	New regressor introduced	R^2 explained	$1-R^2$ residual	n-k-1	$\frac{(1-R^2)}{(n-k-1)^2}$
1	VAR 2	0.53	0.47	41	0.000280
2	VAR 4	0.63	0.37	40	0.000231
3	VAR 6	0.65	0.35	39	0.000230

Table 4.12 stepwise regression for finishes.
Source Field survey 1991.

Multiple correlation

Multiple R = 0.648

R^2 = 0.419

$\bar{R}^2$ = 0.375

standard error = 2146.14

Analysis of variance

F = 9.39 significant F = 0.00

Variables in the cost model

Variable	B	SE B
VAR 6	3.71	2.92
VAR 2	1616.73	386.08
VAR 4	2296.23	1039.93
(Constant)	-10210.34	3017.72

Therefore the cost model for showing the relationship between finishes cost per gross floor area is expressed as:-

$$E_c = -10210.34 + 1616.73 \text{ VAR } 2 + 2296.23 \text{ VAR } 6$$

This implies that finishes cost per gross floor area can be explained by size, storey height and building cost index.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Cost modelling of building cost by elements treats each analysis as a separate estimate. The separate element estimates from each analysis are totalled giving a number of independently estimated cost targets. In our analyses, it was assumed that a linear relationship exists between the cost of the element per gross floor area to the design parameters considered.

Several observations are noted in the analysis and treatment of our data. Both strong and weak relationships alike. Strong relationships exhibited the fact that cost modelling can be used, as a cost forecasting tool while weak relationships tended to nullify this belief. It is important to note here that, not all design parameters considered had satisfied a linear relationship with the element drawn. However, it can be said that cost modelling not withstanding the shortcomings of a linear relationship considered can be used as forecasting tools as can be seen from conclusions drawn from the study in respect of the following.

Of the four elements considered it has been shown that cost of substructure per gross floor area is more explained by design parameters followed by finishes, walling and roofing in that order.

(i) Substructure

The hypothesis tested using student t-test and a confidence level of 99% showed that cost of substructure per gross floor area can be explained by size of the building whose correlation coefficient was 0.7295. Thus the results were significant at 99% confidence level and the conclusion drawn from the results suggests that the null hypothesis be rejected in favour of the hypothesis that a linear relationship exists between the cost of substructure per gross floor area and size of the building.

The next parameter, which explains the cost of substructure per gross floor area, was building cost index whose correlation coefficient was 0.4981. Again the null hypothesis is rejected in favour of the hypothesis.

Storey height was the other parameter, which showed considerable correlation coefficient of 0.3039. The parameter satisfied the criteria for inclusion of regressors in the cost model for substructure using stepwise regression. The multiple correlation coefficient R attained by these three design parameters was 0.80 and standard error of 1838.63. The results from the study suggests that the cost of substructure can be determined at the initial stages of the design process with the knowledge of size of the building, storey height and building cost index. The cost model was also shown to be significant using analysis of variance F-test, where F = 22.30, significant F = 0.00.

(ii) Finishes

The hypothesis was tested using student t-test at 99% confidence level. The results showed that cost of finishes per gross floor area can be explained by size of the building with a correlation coefficient of 0.5318, storey height with a correlation coefficient of 0.3501 and building cost index with a correlation coefficient of 0.2904. The null hypothesis was rejected.

The three design parameters also satisfied the criterion for inclusion of regressors in the cost model for finishes using stepwise regression. The multiple correlation coefficient R attained by these parameters was 0.648 and a standard error of 2146.14. The result for the study suggests that the cost of finishes can be determined at the initial design stages, once a knowledge of size of the buildings, its storey height and building cost index at the time design is initiated is known. The cost model was also shown to be significant using Analysis of Variance, F-test where F = 9.39 while significant F = 0.00

(iii) Walling

The hypothesis was tested using student t-test at 99% confidence level. The results showed that cost of walling per gross floor area could be explained by two design parameters while maintaining a linear relationship. These parameters are size of the building with a coefficient of correlation of 0.6548 and storey height with a coefficient of correlation of 0.3451. The null hypothesis was rejected in favour of the hypothesis that a linear relationship exists between cost of walling per gross floor area and design parameters that is size and storey height.

These two design parameters also satisfied the criterion for inclusion of regressors using stepwise regression in the cost model. The multiple correlation coefficient R, attained by these parameters was 0.716 and a standard error of 2542.88. The results of this study suggest that knowledge of size of building and storey height is sufficient to obtain a first cost estimate during the initial design stages. The cost model was also shown to be significant using analysis of variance, F-test where F = 20.98 while significant F = 0.00.

(iv) Roofing

The hypothesis was tested using student, t-test at 99% confidence level. The results showed that cost of roofing per gross floor area could be explained by two design parameters while maintaining a linear relationship. These parameters are storey height with a correlation coefficient of 0.2966 and building cost index with a correlation coefficient of 0.6000. The null hypothesis was therefore rejected.

The two design parameters also satisfied the criterion for inclusion of regressors using stepwise regression in the cost model. The multiple correlation coefficient R attained by these parameters was 0.69 and standard error of 721.39. Therefore, the results from the study suggests that with a knowledge of storey height and building cost index the cost of roofing can be determined as early as at the initiation of the design.

The cost model was also shown to be significant using analysis of variance F-test where F = 16.20 while significant F = 0.000.

All the three objectives of the study have been achieved through the analysis of the data collected and observations from the various tests. The first objective of obtaining cost implications of design variables was achieved by the fact that a linear relationship was found to exist among the parameters and elements considered for study. The second objective of enabling the client realise the cost effect of his brief is achieved by use of design parameters. And lastly, expressing building cost in other method other than the ones currently in use for obtaining first estimates that is, cost targets for use in cost planning. This objective has been achieved by introducing the concept of regression cost-models for use alongside the existing methods during design and cost planning processes.

Of main concern is the fact that cost modelling as a forecasting tool is most useful during early design stages where cost can be estimated as design evolves prior to detailed design stages before traditional methods of preparation of firm estimates using Bills of Quantities can be incorporated. Cost modelling in this context is desired to assist in early design cost estimates rather than advocate for complete overhaul of the existing traditional methods.

Once again this study wants to emphasis the fact that information available during early stages of design is so scanty as to warrant estimates that can be relied upon with accuracy. This contention arises due to the fact that estimates at this time are based on a set of assumptions since traditional methods require the use of areas to the extent of forgetting important aspects of cost, that is, the implication of design parameters on building cost; thus the client's brief which expresses space requirements can easily be broken down into design parameters. These parameters on the other hand can be transformed into cost by use of cost modelling as highlighted in this study.

5.2 Recommendations

This study strongly recommends further research be done on cost modelling using detailed current cost resources such as labour, plant etc used to produce an element say walling and then adding a mark-up to cover contractor's overheads and profits for the contractor. Though this method may not entirely remove the variability of data in the sense that different rates will be submitted by different contractors for an identical building during tendering, it will tend to reduce it.

Another area of further research would be to use Monte- Carlo simulation where no assumptions need be made about the relationship be it linear or otherwise but rather the data fits on its own relationship. This study has referred to Monte Carlo simulation as third generation models. As we noted one of the weaknesses in our modelling encountered was the assumption that our relationship was linear.

It is felt that cost modelling as a tool of estimating cost is very useful especially in the initial stages of the design process. All what needs to be done is a study into the manner in which work evolves on site that is, resource based rather than the use of Bill of quantities rates which are subject to great variability even between identical buildings.

And since research findings on cost modelling are rarely put into use, it is also recommended that estimators in all fields of construction be educated on the usefulness of cost models for estimating. It is from regular use, thereby criticism pointing out the weaknesses, that cost models can be improved rather than not be used at all.

BIBLIOGRAPHY

1. Ashworth, A. Progress in Quantity Surveying 1960 - 1980. Jan. 1981.

2. Asworth, A. Cost Modelling for the Construction Industry. The Quantity Surveyor, July 1981.

3. Bathurst, P.E. and David, B. Building Cost Control Techniques and Economics. 2nd edition Heinemann, London, 1980.

4. Building Research Establishment, Factory Building Studies No.12. The economics of factory building (HMSO), London, 1962.

5. Brandon, P.S. Building Cost Modelling and Computers (edited), E & F.N. Spon, London, 1987.

6. Cohen, L. and Manion, L. Research Methods in Education 2nd edition, Groom, Helm, London, 1985.

7. Croome and Sherratt. Quality and Total Cost in Buildings and Services Design, (edited), London, 1977

8. Daily Nation, Nairobi, 20th January 1991.

9. Department of Education and Science Building Bulletin, No.4 : Cost Study. (HMSO), London 1972.

10. Ferry, D.J. Cost Planning of Buildings 5th edition, Collins, London, 1985.

11. Finbarr, S. Design Cost Control for Building Work. U.N. (E.C.A.) Course Bouwecentrum, Holland, September, 1972.

12. George, T.H. Time, Cost and Architecture McGraw Hill, New York, 1975.

13. Haddock, M. Quantity Surveying. The Evolving Profession, Building, 14th March, 1969.

14. HMSO, Cost Control in Building Design, a programmed text, London, 1985.

15. Jackson, M.J. Computers in Construction Planning and Control, Allen and Unwin, London, 1986.

16. Kouskoulas, V. and Koehn, E. Predesign Cost Estimation Function for Buildings, ESCE Journal of the Construction Division, London, December 1974.

17. Lee, M. Comparative Cost Evaluation, Municipal House. The Chartered Surveyor, London, July 1961.

18. Markus, J.A. Building Performance, Building Performance Research Unit, John Wiley and Sons, New York, 1972.

19. Mbatha, C.M. Building Contract Performance. M.A. Thesis, University of Nairobi, (Unpublished), 1984.

20. Mbogua, S.J. Building Contracts and Implementation, Republic of Kenya, Ministry of Works - a paper presented at workshop in Mombasa, 23rd July - August 1979.

21. Mixon, W.J. Managerial Economics, Macmillan, New York, 1985.

22. Nesbit, J. The Role of the Quantity Surveyor During the Design Stage, The Chartered Surveyor, London, July 1953.

23. Patrick, H. Collins Dictionary of the English Language, 2nd edition, William and Sons, Glasgow, 1989.

24. Reiners, W.J. Studies in the Cost of Housing: The tender prices of Local Authority Flats, The Chartered Surveyor of London, August 1958.

25. Republic of Kenya, Statistical Abstract, Central Bureau of Statistics, Nairobi 1995.

26. RICS: Cost Research Panel, The Cost and Design of Low Flats - a case study, The Chartered Surveyor, June 1960.

27. Seeley, I.H. Building Economics 2nd edition, Macmillan, London, 1978.

28. Sidwel, A.C. An Evaluation of Management Construction, Management and Economics, Vol.1, No.1. E and F.N. Spon, London, Spring 1983.

29. St Luke, The New English Bible, Chapter 14.

30. Stone, P.A. Building Design Evaluation. E & F.N. Spon, London, 1983.

31. Willis, C.J. and Ashworth, A. A Practice and Procedure for Quantity Surveyor, 9th edition Collins, London 1987.

32. Wonnacott and Wonnacott Econometrics 2nd edition, John Wiley and Sons, New York 1979.

APPENDICES

APPENDIX 1

List of Buildings Drawn for Study

1. Administration office Olkejuado Primary School - Kajiado.
2. Category 'D' house at Maseno.
3. B.I.A. stores - Moi Barracks, Eldoret.
4. House at State House
5. Dining hall at State House.
6. Moi Barracks Eldoret.
7. Canteen at Kibish G.S.U. Camp.
8. Camping Office at Kibish G.S.U. Camp.
9. Academic block - Moi University.
10. House at 78 battalion - Isiolo.
11. Category `E' houses at Bungoma District hospital.
12. Laboratory at Kabete.
13. Hostel bock at Moi University.
14. Category `D' house at Bungoma district hospital.
15. Category `C' house at Bugoma district hospital.
16. Generation house at Kabete.
17. Kitchen block - coast agricultural institute.
18. Dormitory block - Kenya Water Institute South 'C'.
19. Category 'D' flats at Migori.
20. Category `E' flats at Migori.

21. Laboratories at Kenya Water Institute South C.

22. Classroom at Kenya Water Institute South C.

23. Students Common Room - Coast Agricultural Institute.

24. Administration block - Coast Agricultural Institute.

25. District Commissioners house - Migori.

26. Office block - Migori District headquarters.

27. Market Centre - South Nyanza.

28. Dispensary - Ugina South Nyanza.

29. Workshop at Vehicle Inspection Centre - Kisumu.

30. Artillery block - 77 Artillery Mariakani.

31. Labour Office - Bungoma.

32. Quardroom - 77 Artillery Mariakani.

33. Divisional Office - A.P. Lines at Kalokol.

34. Multi-purpose hall - Kajiado Primary School.

35. Kitchen block - Kajiado Primary School.

36. Classroom - Kajiado Primary School.

37. Armoury store - 77 Artillery Mariakani.

38. Category `F' house - A.P. Lines at Kalokol.

39. Workshop - K.I.M.C. New Training School - Nairobi.

40. Category `F' house - Ugina Health Centre.

41. Office block - Vihiga district headquarters.

42. Students hostel - Naivasha.

43. Office block at Kabete.

APPENDIX 2

Sample Questionnaire

Field Survey, 1991

Self completion questionnaire

Type of Building ....

Date of Tender ....

Floor Area ....

Element Type	Wall Area	Perimeter height	Storey height	Total cost	Element notes	Specification

APPENDIX 3

Format for Analysis of Data Table

Type of element

Bldg No.	Element Cost/ Floor	Wall Area/Floor Area	Perimeter/Floor Area	Storey Height	Total Height	Cost Index

APPENDIX 4

DATA PRINT OUTS

1. Correlations

```
cor var1 with var2 to var6.
------------------------------------------------------------------------------
Page  8                             SPSS/PC+          WALLING

Correlations:   VAR2          VAR3         VAR4         VAR5         VAR6

  VAR1          .6548**     -.1131         .3461       -.0095        .2167

 of cases:      43          1-tailed Signif:  * - .01   ** - .001

 . " is printed if a coefficient cannot be computed
==============================================================================
Page  11                            SPSS/PC+          ROOFING

Correlations:   VAR2          VAR3         VAR4         VAR5         VAR6

  VAR1          .1910       -.1080         .2966        .0359        .6000**

 of cases:      43          1-tailed Signif:  * - .01   ** - .001

 . " is printed if a coefficient cannot be computed
==============================================================================
Page  14                            SPSS/PC+          SUBSTRUCTURE

Correlations:   VAR2          VAR3         VAR4         VAR5         VAR6

  VAR1          .7295**     -.0939         .3039        .1532        .4981**

 of cases:      43          1-tailed Signif:  * - .01   ** - .001

 . " is printed if a coefficient cannot be computed
------------------------------------------------------------------------------
Page  17                            SPSS/PC+          FINISHES

Correlations:   VAR2          VAR3         VAR4         VAR5         VAR6

  VAR1          .5318**     -.1513         .3501        .0089        .2904

 of cases:      43          1-tailed Signif:  * - .01   ** - .001

 . " is printed if a coefficient cannot be computed
     ---------------------------------------------          ----------
```

2. Regressions

(i) Walling

```
Page  44                                    SPSS/PC+

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1    DELEMCOST


Variable(s) Entered on Step Number
   2..    VAR4      SHEIGHT


Multiple R              .71551
R Square                .51195
Adjusted R Square       .48755
Standard Error    6542.88365

Analysis of Variance
                         DF       Sum of Squares       Mean Square
Regression                2     1796241107.54413   898120553.77206
Residual                 40     1712373058.45878    42809326.46147

 =       20.97955       Signif F =   :0000
------------------------------------------------------------------------
Page  45                                    SPSS/PC+

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1    DELEMCOST


 ---------------- Variables in the Equation ------------------

Variable              B         SE B        Beta            T  Sig T

VAR2         5243.78546   924.13737      .62923        5.674  .0000
VAR4         5619.82071  2152.55540      .28952        2.611  .0127
 Constant) -23336.01483  6456.31468                   -3.614  .0008


 ---------- Variables not in the Equation ------------

Variable     Beta In   Partial   Min Toler          T   Sig T

VAR3         -.12129   -.15848      .83322    -1.002   .3223
VAR6         -.05466   -.07142      .83317     -.447   .6572


 d Block Number   1   PIN =     .050 Limits reached.
 ------------------------------------
```

(ii) Substructure

```
Page  12                                SPSS/PC+

         * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1   DELEMCOST


Variable(s) Entered on Step Number
   1..     VAR6       BCOSTIN
   2..     VAR2       SIZE
   3..     VAR4       SHEIGHT
   4..     VAR5       THEIGHT
------------------------------------------------------------------------
Page  13                                SPSS/PC+

         * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1   DELEMCOST



Multiple R              .83264
R Square                .69329
Adjusted R Square       .66101
Standard Error    1699.79875

Analysis of Variance
                       DF      Sum of Squares       Mean Square
Regression              4     248182828.75131    62045707.18783
Residual               38     109794000.46581     2889315.80173

F =       21.47419      Signif F =  .0000
------------------------------------------------------------------------
Page  14                                SPSS/PC+

         * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1   DELEMCOST


------------------ Variables in the Equation ------------------

Variable               B          SE B         Beta          T  Sig T

VAR6             6.53979       1.86792       .39251      3.501  .0012
VAR2          1929.45521     265.66583       .70847      7.263  .0000
VAR4           500.59786     578.89972       .08534       .865  .3926
VAR5          -344.20521     123.51888      -.29369     -2.762  .0088
(Constant)   -5043.63648    1616.77429                  -3.120  .0034
```

(iii) Roofing

```
Page  70                                    SPSS/PC+

          * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   VAR1    DELEMCOST


Variable(s) Entered on Step Number
   2..     VAR5       THEIGHT


Multiple R              .66083
R Square                .43669
Adjusted R Square       .40853
Standard Error       752.39532

Analysis of Variance
                       DF       Sum of Squares       Mean Square
Regression              2       17554176.90918     8777088.45459
Residual               40       22643948.48166      566098.71204

  =        15.50452       Signif F =   .0000

 ---------------- Variables in the Equation ------------------

Variable                  B           SE B         Beta          T   Sig T

VAR6               4.15886         .74795       .74652      5.560   .0000
VAR5            -121.93123       52.26801      -.31320     -2.333   .0248
 Constant)      -927.41360      359.02480                  -2.583   .0136


 --- ------- Variables not in the Equation ------------

Variable     Beta In   Partial   Min Toler          T   Sig T

VAR2          .11612    .14271      .72023       .900   .3734
VAR3         -.02431   -.02957      .70756      -.185   .8544
VAR4          .09426    .11821      .70191       .743   .4617

 nd Block Number   1   PIN =     .050 Limits reached.
        ------------------------------------------------
```

(iv) Finishes

```
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        * * * *   M U L T I P L E   R E G R E S S I O N   * * *

Equation Number 1    Dependent Variable..   VAR1   DELEMCOST

------------------ Variables in the Equation ------------------

Variable                    B         SE B         Beta          T  Sig T

VAR6                  3.71205      2.92173       .16379      1.270  .2114
VAR2               1616.73118    386.07599       .51226      4.188  .0002
VAR4               2296.22975   1039.93299       .28404      2.208  .0332
(Constant) -10210.34206   3017.72172                        -3.383  .0016

End Block Number   1   All requested variables entered.
```

```
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        * * * *   M U L T I P L E   R E G R E S S I O N   * * *

Equation Number 1    Dependent Variable..   VAR1   DELEMCOST


Variable(s) Entered on Step Number
   1..     VAR6       BCOSTIN
   2..     VAR2 .     SIZE
   3..     VAR4       SHEIGHT


Multiple R               .64762
R Square                 .41941
Adjusted R Square        .37475
Standard Error   3146.13841

Analysis of Variance
                     DF       Sum of Squares       Mean Square
Regression            3      278859730.72597    92953243.57532
Residual             39      386029288.01926     9898186.87229

F =        9.39094       Signif F =  .0001
```

APPENDIX 5

RIBA PLAN OF WORK

Stage A Inception	Appointment of design team and general approach defined.
Stage B Feasibility	Testing to see whether client's requirements can be met in terms of planning, accommodation, cost etc.
Stage C Outline Proposals	General approach identified together with critical dimensions, main space locations and uses.
Stage D Scheme Design	Basic form determined and cost plan (budget) determined.
Stage E Detail Design	Design developed to the point where detailing is complete and the building "works". Cost checking against budget commences.
Stage F Production Information	Working drawings prepared for for the documents.
Stage G Bills of Quantities	

Fig 2.1 RIBA Plan of Work

Source: Ferry (1986). Pp. 83