DEVELOPING A MODEL FOR ESTIMATING CONSTRUCTION PERIOD

A SURVEY OF BUILDING PROJECTS IN NAIROBI

by:

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DECLARATION

I, Titus Kivaa Peter, 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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DEDICATION

This study is dedicated to my wife Jemmimah, for her encouragement and for providing me with a motivating social environment throughout the study. And, to the Lord God Almighty is glory, for He made this work possible.

ABSTRACT

In Kenya, the time required to complete a construction project is estimated using the estimator's personal intuition which is based on his skill and past experience. There are no hard and fast rules for such estimating (Mbatha 1986).

This method of predicting construction period is very likely to produce unrealistic time estimates because the method does not consider, objectively and accurately, all the factors that influence the construction time of a project. Underestimating construction time is a major factor that leads to time overruns in construction projects (Bromilow 1969, Mbatha 1986, Mbeche 1996).

The aim of this study is to develop a mathematical model for predicting the construction period. The prediction model is developed by regressing actual construction period on the variables that normally influence construction time in any building project. The variables are: project scope, complexity and environment.

Each of the variables has been measured in terms of three different surrogates and each surrogate treated as an independent variable by itself. Out of the nine surrogates, five of them are found to have a significant correlation with the construction period. The period is therefore regressed on the five significant surrogates. All the five surrogates are entered into the regression equation at first and then by the backward elimination method of regression, the least significant of the surrogates are removed from the equation.

The multiple regression analysis produces a prediction model that is formulated as follows:

$$\mathbf{T = 18.064 + 0.858C - 0.001C^2 + 1.871H}$$

Where:

- T is construction period in weeks (date of site possession to the date of practical completion);

- C is construction cost measured in millions of Kshs, adjusted to December 1997 construction cost index;
- H is building height measured in number of storeys;

In this expression the independent variables account for 73.96 % of the variability in the construction period.

The study recommends that the model above be employed in the Kenyan building industry, by consultants and contractors, to estimate the construction period of building projects.

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Chapter I

THE PROBLEM AND ITS SETTING

1.1 Introduction

The goal of the parties in a given construction project is to obtain a constructed facility within the specified time, budget and specifications.

While the priced bills of quantities show in detail the cost and quality standards expected they simply state the contract period that a contractor normally quotes during tendering. In practice, there is no specific requirement in the building contract that contractors submit their detailed computations of plant and labour times and contents used in the project scheduling.

Mbatha (1986) and Wachira (1996) observe that adherence to the contract period estimated at the tendering stage of a project has been rather elusive in the construction industry in Kenya. Others like Baradyana (1996), Bromilow (1969), Hughes (1989) and Mbeche (1996), have made a similar observation about the Kenyan construction industry and other construction industries abroad. The difference between actual and planned construction periods is termed as a delay or time overrun.

The researchers mentioned above have generally observed ten major causes of project delays:

1. Material shortages;

2. Unexpected subsoil conditions - underground water, rock etc;
3. Variations in design;
4. Financial problems – unrealistic project budgets, delayed payments, poor contractors' cash flow etc;
5. Poor organizational/ managerial forms – ineffective communication and control, bureaucracy etc;
6. Shortage of plant and equipment;
7. Unrealistic (too optimistic) estimates of construction period;
8. Inclement weather;
9. Industrial disputes – mainly wages, workers not paid as per agreement, leading to strikes or go slows;
10. Others e.g. contractual claims, shortage of skilled/unskilled labour etc.

They conclude that project delays are a persistent problem in the construction industry today, and suggest five possible measures that could be taken to solve the problem:

1. Training all construction industry participants on the most appropriate managerial skills, e.g. planning, scheduling and control;
2. Employing better (highly skilled and more experienced) construction project managers;
3. Improving on the realism of construction period estimating;
4. Drawing realistic project budgets that consider, *interalia*, inflation and availability of funds before indulging into a project.

Abu-Hijleh and Ibbs (1989) and Stukhart (1984) add that inclusion of schedule based incentives (preferably bonus and bonus/penalty schemes) in a construction contract would highly motivate contractors to complete works on or before the target date. Project delays cause significant cost overruns either in terms of revenue lost for not being able to use the facility for productive work in time, or by way of price escalations and contractual claims (Baradyana 1996). A study of delays on projects executed between 1988 and 1995 in Tanzania shows that the coefficient of correlation between the delays and cost overruns is 0.5256, indicating existence of a relatively strong positive relationship between time and cost overruns (Baradyana 1988). The coefficient of determination is 0.2762 showing that 27.62% of the variations in cost overruns could be explained by project delays. The study also shows that project delays average 184.7 % while the corresponding cost overruns average 152.3 %. In Kenya, project time performance is also worse than project cost performance. Mbatha's (1986) study of government projects executed between 1966 and 1984 reveals that 73 % of the projects are normally delayed while only 38 % of them have a cost overrun. These observations imply that either cost estimates are more realistic than contract period estimates or project participants manage costs more carefully than they manage the contract period

In spite of the strong correlation between time and cost overruns, time estimating and evaluation are given less importance in the construction contract administration. Predicting the contract period is usually based on contractors' or consultants' past experiences and therefore the reliability of their prediction is difficult to assess (Mbatha 1986). Preparing bills of quantities and estimating cost are given a more specific and clearer approach.

The realities of time performance are usually well removed from expectation mainly because the estimated contract periods tend to be too optimistic (Baradyana 1996, Bromilow 1967, Mbatha 1986, Mbeche 1996). The implication in this observation is that factors that disturb the regular progress of construction works resulting in delay can be realistically considered in estimating construction period, their likely interference on the project schedule be incorporated in the period estimate and the necessary precautionary measures be taken well in advance to avoid the expected interference.

Wachira (1996) gives the main reason for the 'too optimistic' contract periods as being lack of sufficient data on productivity of labour for accurate analytical estimation of activity times in the project schedule whose 'sum' gives the construction period. Muli (1996) attributes the 'optimism' and poor time performance to the attitudes of project participants towards the project schedule. He observes that clients and consultants, more often than not, fail to appreciate the full importance of the schedule. He observes that in the traditional approach to project implementation, there are no stringent requirements for scheduling specifying important things like the level of detail required, the method to be used and the frequency of schedule updates. He also observes that most contractors view the requirement for the schedule as an unnecessary expense and waste of time and fail to invest sufficient resources in preparing the schedule. He argues that these poor attitudes highly reduce the chances of achieving the targeted completion time.

Atkinson (1991) observes that in Britain, for a variety of reasons, pressure is now on to reduce the design and construction period for most projects. A very likely reason for this may be that construction finance is getting more expensive; the longer a project takes the higher the cost of financing it. Before a developer commits himself to the terms of a loan agreement, he really needs to be quite certain that the proposed project could be completed within the stipulated time to avoid cost escalations (Halperin 1974). Atkinson (1991) also warns that it is becoming more difficult to hide design mistakes in the contract period. Contractors are more claim conscious and hence likely to pursue claims arising from design mistakes. Similarly, in situations where the performance of the design team adversely affects the quality, cost and timing of a project, it is now more likely for the client to seek redress through the courts.

Accurate pre-contract determination of the construction period is very essential because of the following reasons: -

(a) It facilitates proper cash flow forecasting for both the contractor and the client (Chan and Kumaraswamy 1995).

(b) It provides a sound basis on which detailed project scheduling using methods like bar charts, Programme Evaluation and Review Technique (PERT)/Critical Path Method (CPM) etc can be done.

(c) It helps the client and consultants structure effective incentive schemes to encourage contractors to complete the construction works in a shorter time than the stipulated contract period (Abu-Hijleh and Ibbs 1989, Stukhart 1984)

(d) It makes a sound basis for evaluating the success of a project and the efficiency of the project organization. (Ahuja and Nandakumar 1984, Chan and Kumaraswamy 1995).

Unless a realistic estimate of the contract period has been made at the start of the project, it becomes rather impractical for the project team to establish an effective time management approach for proper project execution.

The aim of this study is to develop a model for predicting the construction period of construction projects. It is expected that the model will give a realistic estimate of the period (at or before the tendering stage of the construction project) because it sufficiently takes into account key factors that influence construction time. This approach could form a reasonable basis for establishing a time check system that could evaluate construction time.

1.2 Problem Statement

The estimation of construction period in construction projects in Kenya still remains rudimentary. In practice, the contract completion time is often estimated using the estimators' past experiences. There have been no hard and fast rules for such estimating (Chan and Kumaraswamy 1995, Mbatha 1986). This approach does not sufficiently consider the key factors that influence contract periods.

The unscientific approach to construction period estimation has resulted in the following consequences:

(1) Difficulties in estimating time-related project costs such as cost of finance,

insurance, water, electricity and telephone.

(2) Difficulties in assessing and justifying extension of time.

(3)Difficulties in managing the estimated contract period efficiently to ensure that a construction project is completed on time (Baradyana 1988, Mbatha 1986, Wachira 1996).

At the time of tendering, a contractor is normally required to state *the construction period*, which becomes the *contract period* after the tender is accepted. After the tender accepted, the contractor then submits a project schedule. This requirement for the construction schedule does not specify any obligation for contractors to show how they calculate activity times. There is nothing that shows in detail computations of times for the various operations. More often than not, the programme submitted by the contractor is approved *albeit* with a few alterations where necessary. The schedule is then used for monitoring the progress on site and is updated from time to time as necessary. However, lead consultants are not able to pinpoint accurately critical activities that may deter the regular progress of the works. Consequently, efficient coordination of the project team to meet the time target satisfactorily may be very elusive. Thus, this system of managing project time has proved inefficient as already noted.

An efficient time management system would be one that starts with an accurate estimate of the construction period followed by a detailed schedule of the construction activities most preferably a network programme (e.g. CPM, PERT etc). A realistic incentive scheme can then be introduced in the contract to motivate the contractor to work most diligently to complete the works earlier than scheduled.

1.3 Objectives

The objectives of this study are to:

1. compare the pre-contract estimate of contract period with the actual completion period;
2. establish the correlation between construction period and the surrogates of project scope, complexity and environment;
3. develop a mathematical model for estimating construction period.

The model is developed by regressing the construction time actually taken in completed projects, on three variables - project scope, complexity and environment- that normally influence construction period in any building project.

1.4 Hypotheses

The hypotheses of this study are:

1. The actual construction period is significantly greater than the construction period estimated at the tendering stage.

If realistic planning, design and scheduling of a project are done, the difference between the actual and the estimated construction periods should be insignificant. Ideally, a time estimator should foresee all the factors that influence the contract period and factor in their likely influences in order to get a realistic estimate of the construction period.

The construction period is usually estimated and fixed before commencement of construction works and therefore underestimating the period is very likely to render time management in the project rather ineffective. The effect of other factors such as delay occasioned by shortage of materials, plant etc leading to non- completion on time, sets in after the works have started. This effect is significantly influenced by managerial control (Sidwell 1984). All the same, underestimating the construction period may be the initial error in most construction projects that is likely to affect time management during construction.

2. The larger the scope of a project the longer the construction period.

Project scope refers the physical size of a project. A big project is likely to require relatively more time to execute than a small one. Scope can be measured in terms of the following surrogates:

- cost value (Kshs)
- floor area of the building (square metres)
- height of the building (number of storeys)

Construction period has a statistically significant correlation with the cost value, floor area and height of a building.

3. The more complex a project is the longer the construction period.

Project complexity is the state of being difficult to handle. A difficult project is likely to require more time to execute than a simple one. Complexity is highly related to the type (functional use) of the building as explained in section 2.4. The following surrogates can be used to measure complexity irrespective of the building type:

- irregularity of the building plan shape (total area of walls, windows and doors per unit of floor area)

- quality of finishes and services (cost of internal finishes and mechanical & electrical installations per unit of floor area).
- potential for conflicts among teams in the project (number of the interactions among the teams).

Construction period has a statistically significant correlation with the irregularity of the building plan shape, quality of finishes and services in the building and the potential for conflicts amongst the teams in the project.

4. The more a project environment interferes with the planned progress, the longer the construction period.

Project environment is defined as the circumstances under which a project is executed. The circumstances normally interfere with the planned schedule tending to increase the construction period. The environmental interference can be measured in terms of the following surrogates:

- risks in the project (cost of insurance and contingencies per unit of floor area).
- ambiguity of works at tendering time (cost of provisional sums per unit of floor area)
- managerial efficiency in handling factors that may disturb the regular progress of the works.

Construction period has a statistically significant correlation with the risks in a project, ambiguity of the works at tendering time and the efficiency of the management function in the project.

Construction period is directly proportional to all the six surrogates of scope and complexity and the first two surrogates of environmental interference above. It is however, inversely proportional to the third surrogate of environmental interference - managerial efficiency.

1.5 Significance

The results of this study have practical implications in the construction business. The time prediction model developed here is more objective than the non-mathematical method mainly used in the Kenyan construction industry today and is likely to give a more accurate contract period estimate. Using the prediction model, project participants (client, consultants and contractors) can easily but realistically estimate the contract period as early as the proposal and sketch design stages of the project before detailed project scheduling. This is important because there is usually insufficient time, data and money available at these stages to allow for a detailed schedule (Lock 1973).

Based on a realistic contract period estimate, a detailed and practical project schedule (most preferably a network - PERT/CPM – programme) can be prepared. The scheduler considers the productivity of the resources (labour, equipment etc) available to get the units of each resource required to complete the works within the contract period. Time related costs e.g. cost of finance, water, insurance etc can also be accurately estimated.

The realistic contract period (and schedule) will enable the client (and consultants) introduce an efficient schedule-based incentive scheme in the contact to motivate the contractor to produce a system that will complete the works on or before the target date. Incentive schemes are designed to reward contractors for early completion and, possibly, penalize them for late completion. If the planned project is one for which early completion produces a sizable and early return on investment, the client can afford to share a portion of the expected benefit and create an incentive for the contractor (Abu-Hijleh and Ibbs 1989, Stukhart 1984).

1.6 Scope of the study

The scope of this study was limited to the following categories of construction projects:

1. Residential buildings- bungalows, maisonnetes and flats;
2. Commercial buildings- shops, offices and warehouses;
3. Institutional buildings- schools, colleges and hostels;
4. Industrial buildings- factories etc;
5. Others- archives, hospitals, hotels etc.

In addition, only private construction projects were considered. The rationale for this decision was that there is a general economic trend towards privatization of industries in Kenya including the construction industry. Hence, findings of this study have theoretical and practical implications in a more liberalized construction market.

Another consideration that defined the scope of the study is the geographical location. In this regard, only projects in Nairobi were included in the sample. The justification for this decision is that construction work in Nairobi accounts for up to 62% of the cost value of the private buildings completed between 1991 and 1995 in the main towns of Kenya (Republic of Kenya 1991-95). This allows generalizations to a reasonably large population of construction projects.

Only buildings started and completed in the last seven years (1991 to 1997) were included in the sample. This period was considered long yet recent enough for generalizations to be made to the majority of building projects in Kenya.

A total of nine explanatory variables i.e. three surrogates for each of the three major constructs - project scope, complexity and environment - that influence construction time. This number of explanatory variables nine was considered large enough to provide a significant explanation of the variation in the dependent variable- construction period. The surrogates chosen for measurement of project scope were those factors in a building project, which had been considered by past researchers to have influence on construction period. The surrogates chosen for measurement of project complexity and environment were those factors in a building project, which the researcher had conceptualized as possible determinants of construction period, from his experience in the construction industry and from review of literature related to time management in building projects. The surrogates selected were those that are normally *easy to measure with reasonable accuracy* at the tendering stage of a project.

Finally, the scope of the study was limited to statistical analysis of the data collected. The analysis was applied to the data to create a model for predicting construction period and to compare the model created with two other models developed in the past, using the coefficients of determination (R^2 values) obtained in the models.

1.7 Definition of Terms

1. *Construction Period* - time between the date a contractor takes possession of site to the date he completes the construction work i.e. date of practical completion.

2. *Contract Period* - Construction period which has been agreed on between the contractor and the client as the time within which the construction work should be completed. Contract period is legally binding and is normally based on the estimate of construction period.

3. *Project Period* - construction period *plus* the design period. The design period starts from the time a building client conceives the idea to develop up to the time the contractor takes possession of site.

4. *Construction Cost* - Cost of putting up the building - normally associated with the materials, transport, labour, equipment and plant. It is the cost incurred in respect of contractors and sub-contractors.

5. *Project Cost* - All the costs involved in a building project, including cost of acquiring land, cost of finance professional fees.

1.8 Outline of the Study

The study is organized in five chapters. Chapter 1 discusses the problems of construction delays and the inefficiency of the time management system in the construction industry, particularly in the prediction of the construction period at the pre-contract stage. The need to establish a defined method of estimating the construction period is discussed, and the objectives and hypotheses stated.

Chapter II discusses the different methods of estimating the contract period and the works previously done in the field of estimating the period as well as factors related to project delays in Kenya and abroad. In this chapter, factors that influence construction time performance of projects are discussed. The intuitive and mathematical approaches to time prediction are explained and a critique is made of previous work done in the area of mathematical time prediction models.
Chapter III discusses the methodology employed in conducting the study. The target population, sampling technique applied, data collection procedures, measurement criteria for the variables and data analysis procedures are discussed.

Chapter IV presents the analysis of the data and chapter V covers conclusions, recommendations based on the study findings and areas for further research.

Chapter II

LITERATURE REVIEW

2.1 Methods of estimating the construction period.

There are two methods of estimating the construction period: non-mathematical method and mathematical method. The non-mathematical method has no hard and fast rules applied in the estimating process. The mathematical method on the other hand uses mathematical models in the process of estimating. Once the period has been estimated (mathematically or not) and the contract is awarded, the project schedule is done in detail using scheduling techniques such as Bar charts, Critical Path Method, Programme Evaluation and Review Technique etc.

2.1.1. Non-mathematical Method

In the non-mathematical method, estimators use their own intuition, based on skill and past experience, to estimate the time it would take to execute proposed projects. The task of estimating the construction period is take mostly by people with quantity surveying background or experienced contractors. The contractor relates the project scope to the expected expenditure per week to come up with the number of weeks required to complete the works (Mbatha 1986).

The Ministry of Public Works has some guidelines of estimating contract periods based on experience in past public projects. The guidelines attempt to match the contract period with the contract value (Republic of Kenya, 1986.) The guidelines may not help to produce a reasonable estimate of construction time because most of the public projects tend to have both cost and time overruns (Kaka and Price 1991, Mbatha 1986, Mbaya 1984, Talukhaba 1988). Experience with past public projects may therefore not give a sound basis of estimating the construction period.

The private sector does not have any such guidelines. In this sector, the contract period is a component of tendering. Contractors are therefore expected to somehow estimate the construction period and include it in the tender documents. Private clients tend to use the construction period estimate as a factor of competition between tenderers.

Bromilow (1969) and Mbatha (1986) observe that using the non-mathematical method more often than not produces unreasonably optimistic estimates and gives time targets that are hardly ever met in executing the works. The method is unrealistic not necessarily because it relies on rules of thumb and experience based knowledge. The importance of experience is not disputable. Expert systems[†] which employ both quantitative analytical data and heuristic experience based knowledge have proved realistic and applicable in, *interalia*, analyzing and evaluating construction schedules (Chin 1991, De La Gaza and Ibbs 1991).

[†] *An expert system can be defined as a computer program in which the knowledge and experience of one or more experts are captured and stored in a computer and are incorporated in solving problems that typically require human judgement. Expert systems rely on rules of thumb and other heuristic methods. They are not yet widely used in industry though serious research is going on in the field. (Frenzel 1987, Ortolano & Perman 1987). The application of expert systems in scheduling has mainly been researched on in the developed countries but has a lot of application in the developing countries (Chin 1991).*

It seems that the factors that influence construction time are too numerous and interrelated for time estimators to consider intuitively and accurately, their influence on a proposed project at the tendering stage. For realistic time prediction, experience should be combined with quantitative analytical data (De La Gaza & Ibbs 1991).

2.1.2. Mathematical method

In the mathematical method the estimator uses mathematical formulae, in predicting the construction period, in which there are hard and fast rules for the use of the formulae in estimating. Researchers have previously developed mathematical formulae. Three of the researchers who have used the mathematical approach to modeling the construction period are Bromilow (1969), De Leeuw (1988) and Walker (1995).

These researchers have developed formulae that express the construction period as a function of both scope and non-scope factors. This approach yields more accurate estimates than the intuitive method (Chan and Kumaraswamy 1995, Kaka and Price 1991). On average the factors considered in the three formulae explain construction time up to 73.87%. Practical application of these models has not been attempted in Kenya. Therefore, one can not assess the success or otherwise of using the models in Kenya.

From 1967, when Bromilow (1969) produced his time prediction model, researchers worldwide have been considering more and more variables and approaches in formulating their time prediction models, and in effect improving their models.

2.2 Variables affecting time performance

Bennett (1985) and Walker (1995) identified scope, complexity and managerial effectiveness as the key factors affecting the construction time performance. Ireland (1983) and Sidwell (1982) investigated the impact of managerial action and client decision making upon time performance, and both of them identified influences of these factors on time performance from inception to completion. The performance of a construction management team has been found to be influenced by internal and external factors that could be classified as project environment factors and management related factors (Chauhan and Chiang 1989).

These researchers seem to suggest that construction time performance is determined by numerous factors which can be grouped into two main categories: Project related and environment related. Of the three key factors identified by Bennett (1985) and Walker (1995) two of them, project scope and project complexity, can be termed as project related factors. On the other hand, factors like weather, money market, shortage of materials, skills of workers, etc which impact on the construction time and tend to increase it, can be termed as environment related factors.

Managerial effectiveness can also be categorized as an environment related factor and seems to depend on the client's decision making process and the appropriateness of the project organization structure adopted. Ireland's (1993) work indicated that non-traditional procurement methods e.g. design and build and project management are likely to lead to better managerial performance than traditional ones. For this reason a construction time prediction model can be reasonably formulated in terms of three key variables: Scope, Complexity and environment.

2.3 Project Scope

Project scope (size) has been found to be a useful predictor of construction time (Bennett 1985, Bromilow *et al* 1980). There are several ways of measuring the size of a building. These include: cost value, floor area, number of floors, volume above and below ground, etc (Bromilow 1969). Unfortunately, no single one of these provides a perfect indicator of scope; the best so far is the cost value (Bromilow 1969, Chan and Kumaraswamy 1995, De Leeuw 1988, Kaka and Price 1991, Walker 1995)

The cost value, as a measure of scope, has the following advantages: -

1. It reflects the design complexity and target quality as well as physical size (Bromilow 1969). The value includes the cost to be incurred due to the intricacy of the work, which is usually implied by the difficulty variables expressed in the item descriptions in the bills of quantities. The contractor's prices are expected to vary with these difficult variables.
2. The effect of the environmental variables that can be reasonably defined during the feasibility and design stages of a project is usually included in the cost value e.g. costs associated with access to site, security for the works, underpinning, water, power, telephone, insurance and contingencies.

Project scope seems to be the most important factor influencing construction time. Results of a study of factors affecting construction time performance in Australia by Walker (1995) suggest that other than the project cost, many project characteristic factors have no significant impact upon construction time performance. He reasons that these factors are subject to management planning and control. He argues that many environmental factors can be planned for and the risks that are beyond the control of the contractor e.g. weather, national industrial disputes or political events be considered by the client or construction management team which should be adequately compensated for any risks accepted.

It is due to this reasoning that most time prediction models have considered scope as a significant predictor of construction time. Bromilow (1969), Chan and Kumaraswamy (1995), De Leeuw (1988) and Kaka and Price (1991) considered construction period as a function of scope only. Bromilow (1969) established a mathematical relationship:

$$T = KC^B$$

Where:

> T = construction period in days from site possession to practical completion
>
> C= final project value in millions of Australian dollars, adjusted to a cost index
>
> K = a constant describing the general level of duration performance for one million Australian dollar
>
> B = Constant describing how the duration performance is affected by project size as measured by value.
>
> K was found to have a value of 350 working days
>
> While B had a value of 0.30

He established this model in a research study done in Australia in 1967. The model was later tested in Britain and in Hong Kong and was found valid (Kaka and Price 1991, Chan and Kumaraswamy 1995).

This model however, only partially explained the variability in construction time because the impact of many non-scope factors that impinge on time could not be reasonably represented by the cost value. The coefficient of determination (R^2) in the model (for both private and public buildings) was found to be 0.5233 in Hong Kong (Chan and Kumaraswamy 1995), indicating that only 52.33% of the variability in construction time could be explained by the project scope. This implies that non-scope factors not incorporated in this model e.g. environmental interference, complexity of the project organization structure, type of project etc, need to be incorporated in the model to make it more valid and reliable.

Mbatha (1986) and Talukhaba (1988) also attempted to derive a time prediction model postulating a linear relationship between construction period and construction cost. Mbatha (1986) observed that the relationship between the construction period and the construction cost was not actually linear, confirming Bromilow's (1969) observations. He concluded that a construction period estimate that is based solely on a linear relationship between these variables was bound to be erroneous. Talukhaba (1988) had a similar observation to Mbatha's (1986) and concluded that in estimating construction period, the effect of other factors - unforeseen circumstances, which normally influence construction period - need to be considered alongside the construction cost, in estimating the construction period.

De Leeuw (1988), a South African researcher, derived a formula for determining the building period which shows that there are identifiable differences among building periods of different building groups. Though the key factor in his model was the building cost, the formula also contains parameters, which the researcher generated on the basis of the building groups he defined using five different criteria as shown in Table 2.1. The group code digit was used to make a code for each building group for use on Table 2.2. For example, a private office development, mainly built of reinforced concrete, with minimal mass excavation and no precast concrete external facades, would be in a certain group of building whose code would be 22100. Atotal of 32 different building groups was generated using these criteria.

Table 2.1 Grouping criteria for buildings

Criteria	Group code digit	Category
(a) Sector	1. 2.	Public sector Private sector
(b) Building Type	1. 2.	Housing schemes with individual Houses, factories, hospitals, Warehouses, halls, shops, and other. Offices, churches, hostels, schools and flats.
(c) Structure	1. 2.	Concrete, brickwork and other Steel
(d) Precast concrete external facades	1. 0.	With Without
(e) Mass excavation	1. 0.	With substantial mass excavation Without substantial mass excavation

Source: De Leeuw (1988), page G16-5

The building period formula derived was as follows: -

$$T = 0.9\ (10^{X})$$

$X = \alpha(\log b_a)^{\beta}$

Where:

T= Building period in calendar days from handing over the site to the contractor to the practical completion of the building work (excluding builders holidays)

- $b_a = B_a/3.3309065$
- B_a = Building cost as adjusted to the Pretoria region costs (Gauteng) and to the third quarter of 1995. The regional tender price index for Gauteng for the third quarter of 1995 was 100, and was taken to be the base, for the purpose of this model.
- $B_a = (100/I_s) \times (I_{ba}/I_b) \times B$

B = actual building cost in SA Rand on a given date

I_{ba} = average tender price index for all regions in the third quarter of 1995 (estimated at 876.9).

I_b = average tender price index for all regions at the date applicable to B.

I_s =regional tender price index for the third quarter of 1995, which ranged from 94.799 in Free State to 114.495 in Western Cape.

De Leeuw 's (1988) formula was derived using data from 333 building projects erected in the period 1977 to 1986. The model that actually resulted from the analysis of this data was: -

$T = (10^{X})$ $\qquad X = \alpha(\log b_a)^{\beta}$

The researcher notes that construction techniques are continuously improving. This increases the likelihood that a building project would take a shorter period today than it took in the 70's and 80's. He therefore *arbitrarily* introduces a factor of 0.9 to make provision for the shorter period, altering the model to: -

$$T = 0.9\,(10^{X}) \qquad X = \alpha(\log b_a)^{\beta}$$

De Leeuw (1988) categorized buildings into 32 groups based on the five criteria described on Table 2.1 and derived the values of alpha (α) and beta (β) for each of the groups. Both Bromilow's (1969) and De Leeuw's (1988) models were based on logarithmic transformation of their data. Table 2.2 shows a comparison of the two models. While Bromilow (1969) performed a single logarithmic transformation, De Leeuw (1988) performed a double logarithmic transformation of the data.

Table 2.2 Comparing Bromilow's (1969) and De Leeuw's (1988) models

	Bromilow's (1969) Model	De Leeuw's (1988) model
Model	$T = KC^{B}$	$T = 10^{\alpha(\log b_a)^{\beta}}$
Logarithmic notations	$\text{Log } T = \log K + B\log C$	$\log T = \alpha(\log b_a)^{\beta}$ $\log(\log T) = \log\alpha + \beta(\log b_a)$

Note: 1. The B, α and β are the regression coefficients of the logarithmic models
2. The variables C and b_a refer to the final cost value of the project.

Source: Own Survey 1999

The average coefficient of determination (R^2) was observed to be 0.69415 for all the 32 building groups, which is higher than Bromilow's (1969) R^2 value (0.5233). In

De Leeuw's (1988) Model, 69.415% of the variability in the building period could therefore be explained by the two factors (cost and building group) considered. De Leeuw's (1988) model gives a better prediction of construction time than Bromilow's (1969) model. This is probably because De Leeuw (1988) not only did more transformations of the data - *in order to ensure that the basic assumptions of regression were met by his model (see section 3.5)* - but he also grouped the buildings into various types, giving the coefficients α and β separately for each of the groups.

Logarithmic transformation of construction time and cost was also employed in Walker's (1995) model. However, Walker (1995) considered more non-scope based factors and established a more elaborate model. The model could estimate construction time in workdays from the following variables: -

1. ***End value (V)*** - Construction cost in $000s indexed to January 1990, taken at the midpoint of construction period.
2. ***EXT/ACT*** - ratio of extensions of time granted to actual construction period.
3. ***Work Type (F)*** - (applicable if the project is a fit out)
4. ***Objective quality (Q)*** - the data for the client's representative's objective for high quality of workmanship, on a 7 point scale, where 1 = very low and 7= very high.
5. ***People Orientation (PO)*** - the data for the client's representative's people oriented management style measured on a 1 to 7 point scale where 1= very low and 7= very high.
6. ***Communication management for decision making (CD)***- the data for the communications management for decision making between the construction and design team measured on a 1 to 7 point scale where 1 = very low and 7= very high.

7. ***Information technology (IT) use*** - the data for the effective use of information technologies by the construction management team measured on a 1 to 7 point scale where 1 = very low and 7 = very high.

The model established is as follows:

Log T= 0.481logV + 1.188EXT/ACT - 0.489F + 0.105Q - 0.125PO + 0.080CD +0.104IT

where:

T = Workdays (actual days worked).

The formulae can be transformed from the log form as follows: -

$T=V^{0.481}EXP\ (1.188\ EXT/ACT - 0.489F + 0.105Q - 0.125PO + 0.080\ CD + 0.104IT)$

The model had a very high R^2 value of 0.9987, meaning that the coefficient of alienation ($1-R^2$) was 0.0013. This indicates that the model could be used with confidence since only a negligible percentage 0.13% of the variability in construction time was not explained by the independent variables in the model. Walkers (1995) model was therefore a better model in predicting construction period than Bromlow's (1969, 1980) or De Leeuw's (1988) models. This suggests that inclusion of a reasonable number of non-scope variables in a model results in a more plausible prediction model.

However, some of the measurement criteria for the non-scope factor influences in Walker's (1995) model can only be identified in a completed project but not in a proposed one e.g. EXT/ACT. This is because Walker's (1995) research was aimed at explaining the variance - between actual time performance and the performance represented by the model he formulated – in terms of the managerial effectiveness of the project team in responding to challenges posed by factors outside the control of the construction management team: if the response was highly efficient the variance was very low, and vice versa. This model can therefore not be considered usable for prediction at the pre-contract stage of a project.

Bromilow (1969,1980), Chan and Kumaraswamy (1995), De Leeuw (1988), and Walker (1995) considered the complexity of projects in their prediction models though each of them approached project complexity from a different perspective. Bromilow (1969,1980), Chan and Kumaraswamy (1995) and De Leeuw (1988) seem to have mainly considered the physical complexity inherent in the design and the execution of the works, while Walker (1995) mainly considered the managerial effectiveness of the client's representative in the execution of the works. However, none of the researchers seems to have considered the influence of people and group (team) interactions on the construction schedule. Unresolved conflicts between teams, which are likely to increase as the number of teams increases, are likely to prolong the construction period. The greater the number of teams, in a project the higher the possibility of conflict amongst the teams and therefore the greater the managerial burden of the client's representative. This conflict potential may be termed as the managerial complexity of a project, and seems easier to define during the feasibility and design stages, for use in time prediction, than managerial effectiveness.

Bromilow's (1969), De Leeuw's (1988), Mbatha's (1986) and Talukhaba's (1988) prediction models do not consider the influence of project environment, which Bennett (1985) observes to be a very important factor influencing construction period as explained in Section 2.5. Environmental effects are likely to be more marked in a developing country, like Kenya than in a developed one. A study by Farzad (1984) suggests that coarse economic indicators - gross national product per capita, proportion of employment in services and the proportion of exports comprising machinery - provide a good guide to the extent to which the environment will allow projects to relatively proceed as expected.

2.4 Project Complexity

Project complexity (difficulty in handling a project) is best understood by analyzing the various factors within the construction process and their interactions (Bennett 1985). In a construction project two aspects of complexity can be identified: physical complexity and managerial complexity. Physical complexity refers to the complication arising from design parameters (plan shapes, storey heights, partitions etc) while managerial complexity refers to the difficulties of co-ordination and efficiency within the project.

2.4.1 Physical complexity

Bromilow (1969, 1980), Chan and Kumaraswamy (1995), De Leeuw (1988) and Kaka and Price (1991) incorporated physical complexity in their time prediction models by considering project types. They categorized projects using several criteria: civil engineering or building works, commercial or housing projects, factories or offices, etc. This is probably because the functional use usually determines, *interalia,* the quality specifications and the intricacy of various items of work in the construction process. They established that the type of buildings, defined in terms of functional use, had a significant impact on the construction period.

Grouping building projects into different types seems a reasonable way of representing the physical complexity of projects. The more complex a project is the longer it is likely to take (Bennett 1985). Of the three time prediction models previously described, De Leeuw's (1988) model is perhaps the only one that most clearly shows the effect of building types, in predicting construction period. He groups public or private building projects into two types: type I and type II as explained in section 2.2, each type comprising buildings which he considers to be of the same level of physical complexity regardless of whether they are commercial or residential.

Type I category comprises buildings which usually involve more complicated shapes, a greater extent of internal walling and a greater variety of finishes and fittings than type II. It is shown on Table 2.3 that type I buildings generally take longer than tvpe II and should therefore be considered to be of a higher physical complexity. Using De Leeuw's (1988) model, a building costing SA Rand 10,000,000 (Kshs. 130,000,000 approx.) would take 505 days (84 weeks) to complete, if it is type I, and 420 days (70 weeks) if it is type II.

Table 2.3 Building periods for type I and type II building costing SAR 10,000,000 (Kshs. 130,000,000 approx.)

TYPE	(I) Housing scheme with individual houses, hospitals, warehouses, halls, shops and others.	(II) Offices, churches, hostels, schools and flats.
Building cost (B_a)	SAR 10,000,000	SAR 10,000,000
$b_a = B_a/3.330965$	SAR 3,002,185.70	SAR 3,002,185.70
Log b_a	6.4774376	6.4774376
Alpha (average from De Leeuw's model)	0. 5526325	0.6362625
Beta (average from De Leeuw's model))	0.8587025	0.7673775
$X = \alpha (\log b_a)^{\beta}$	2.7490992	2.6686334
$T = 0.9 (10)^{X}$	505.05853	419.63906
Building period	505 workdays (84 weeks)	420 workdays (70 weeks)

NB: 1.00 Rand = Kshs 13.00

Source: Own Survey 1999

2.4.2 Managerial complexity

Bromilow's (1969) and De Leeuw's (1988) prediction models did not consider project managerial complexity but Walker's (1995) model considered it. He considered a 'people factor' by incorporating the clients' representative's 'people orientation' in the representative's management style. This factor was measured on a 7-point scale to reflect the client's representative's objective and ability to establish and maintain a high people orientation in his project management style. It was found that a high people-orientation reduced the construction time. Perhaps a highly people-oriented management style motivates the people, establishes effective communication and facilitates prompt resolution of conflicts that may arise within the project team.

Walker's (1995) approach seems to concentrate more on measuring client's representatives' effectiveness in managing the people in a project than on measuring the difficulties involved in managing them. The representatives' managerial effectiveness is very likely to be influenced by the degree of difficulty inherent in co-ordinating different teams of people in the project organization structure.

A team can be defined as a formal group of people performing a separate role that requires a particular kind of knowledge, skill and/or experience (Bennett 1985). Some of the teams involved in a building project include: client, architect, quantity surveyor, engineer(s), general contractor, specialist subcontractors and nominated suppliers. These teams interact in various ways and are interdependent in their work in a given project organization.

The greater the difficulty in co-ordinating different teams in a construction project, the lower should be the expected managerial effectiveness of the client's representative. The difficulty is likely to increase as the number of teams increases because the greater the number of teams, the more the number of team interactions which need to be co-ordinated to facilitate the execution of the works. Every interaction has a potential of producing conflict that could slow down the work progress. The interactions should therefore be well managed to prevent and overcome inter-group conflict.

Project managerial complexity could be conveniently measured in terms of the teams in a project organization structure (Bennett 1985). Bennett (1985) argues that this complexity increases linearly with the number of teams in a project. However, this may not be the case in real life, perhaps because complexity is more likely to be directly proportional to the number of team interactions than to the number of teams.

In a project organization, there are bound to be more team interactions than teams, since all the teams are interdependent in their work. Every two teams will pose an interaction that has a conflict potential. Table 2.4 shows how the number of interactions increases as the number of teams increases.

It can be seen that the relationship between the number of interactions and the number of teams is not actually linear. The number of separate team interactions is a measure of the conflict potential in a project or the difficulty in preventing and overcoming inter-group conflicts that may arise from differences between people and groups.

Table 2.4 Separate interactions between teams in a project

Number of Teams (n)	2	3	4	5	6	7
Number of Interactions $I = nC_2$	2	3	6	10	15	21

Source: Own Survey 1999

It is almost impossible to have a project without differences between people: differences of opinion, values, objectives etc. These differences can lead to discussion, argument, competition and conflict. Discussion and argument are constructive whereas competition can be both constructive and destructive, but conflict is always destructive (Harrison 1985). The client's representative must therefore constructively prevent and overcome this destructive inter-group conflict to maintain an effective mixed project team.

2.5 Project Environment

Project environment refers to anything outside the boundaries of the project organization system. In practice only things likely to influence the system need to be regarded as making up environment. These things constitute the *circumstances* in which the project is executed. The construction project environment comprises many variables which are dynamic, uncertain but predictable: cultural, economical, political, social, physical, aesthetic, financial, legal, institutional and technological factors (Ahuja and Nandakumar 1985, Bennett 1985, Hughes 1989, Walker 1995).

Project environments interfere with the planned progress and the causes of interference in a project change as the project moves through its separate phases. In the early stages, political, bureaucratic and special interest groups (e.g. archaeologists, environmentalists etc) are important while in the construction stages, weather, design information and material procurement problems tend to dominate the environmental influence (Bennett 1985)

Variations that tend to occur during the construction stages should be considered with environmental factors (Bennett 1985). Given that projects move through a flexible strategic phase which brings objectives, end product and organization into balance, and produces a set of clearly defined roles required to complete the project, then variations should arise from changes in the environment. The effect of variations tends to be an interruption to planned progress. This implies that variations generated entirely from within a project organization should be seen as a failure. As Bennett (1985) notes, interruption of the progress of construction is expensive and wasteful.

Interruption of the progress of work may cause work to slow down or to stop completely. Slowing down progress of work or total stoppage add time and consequently extra costs to projects. The influence of the environment can be modelled by assuming that teams make no progress in a proportion of the time units in which they are participating in a project. Results of studies in U.K. reveal that environmental interference extends construction period by about 15% during the construction phase (Bennett and Ormerod 1984). This suggests that the project environment could explain about 15% of the variability in the construction period in U.K. This figure may be higher or lower depending on the site location and the variables in the environment considered.

Though the results of Bennett's and Ormerod's (1984) study are specific to the projects, which formed the subject of the case studies, they do suggest that the influence of the environment can be modelled. In network scheduling, to forecast project duration, the impact of environmental variables is usually considered intuitively, by allowing a contingency time in the schedule (Ahuja and Nandakumar 1985).

For more reliable forecasts of project duration, it would be beneficial to develop a model that could represent the expected occurrence of uncertainty environmental variables, explicitly analyze and quantify their combined impact, and incorporate it in the project duration estimate. Environmental factors that influence construction time can be prioritized and their likely impact on the time be assessed explicitly from project information (Ahuja and Nandakumar 1985, Baldwin *et al* 1971, Hughes 1989, Nkado 1995, Ogunlana *et al* 1996).

2.6 The Literature Gap

1. The review of literature shows that the non-mathematical method of time prediction used in Kenya has been considered in past researches and found wanting. However, none of the researches has developed a reliable mathematical model for predicting construction period in the construction industry in Kenya.

2. Past studies in this area have developed prediction models in Australia, South Africa and Britain, but the approaches adopted in these models may not be suitable for the Kenyan construction industry. Before application in Kenya they should be tested and the necessary adjustments be made in the formulae to account for the difference between Kenya and the foreign countries in the construction project environments.

3. The prediction models established so far have mainly considered scope factors but given little emphasis on complexity and environmental factors that also influence construction period.

Chapter III

METHODOLOGY

3.1 The Research Design

This study is a survey that aims at establishing the relationships between:

- actual construction period and the construction period estimated at the tendering time,
- actual construction period and the factors that influence it.

The outcome of the study is a mathematical model for predicting construction period. The model takes into account three variables (scope, complexity and environment) that influence the construction period.

3.2 Population, Sample and Sampling Technique

The target population in the study was defined as: all the professionally designed and managed private building projects executed in Nairobi, between January 1, 1991 and December 31, 1997. The study only considered new works.

A two-stage cluster sample of 75 projects was targeted. The sample was limited to this size by budget constraints. The amount of money to be spent on data collection increased drastically with increase in the sample size and therefore 75 cases was the maximum size affordable. However, it was borne in mind that ordinarily a sample size of less than about 30 cases provides too little certainty to be practical (Alreck & Settle 1985). In Talukhaba's (1996) study of delays in building projects, a response rate of about 40% had been achieved. Assuming the expected response rate in this study would be about the same -since the method of data collection was similar- a target of 75 cases would ensure at least 30 cases.

Projects handled by every quantity surveying firm listed in the sampling frame were considered to be clusters of the cases to be studied. Quantity Surveying firms were selected for the study because much of the information required involved measurements of the works, which are usually the domain of the quantity surveyor, and were likely to be in his records. The choice of quantity surveyors (but not any other participant in the construction project) as source of data was not expected to introduce any bias in the study results because the information required was found in their existing records but not in their personal opinions.

A list of 76 Nairobi-based quantity surveying firms was compiled from two existing records:

- 67 quantity surveying firms that were members of the Architectural Association of Kenya. This record was obtained from the Architectural Association of Kenya – AAK - list of members as at February 18,1998.
- 58 quantity surveying firms (some of which were not members of the AAK) published in a local construction magazine. This record was obtained from the Construction Review journal, March 1998, Vol. 9/No.3.

Every firm that occurred in either of the two records was selected. Firms that occurred in both records were counted only once to avoid overlap in the list compiled.

In the first stage of the sampling process, 25 clusters (quantity surveying firms) were selected randomly from the list of 76. In the second stage each of the 25 firms selected was requested to give a list of projects (of the nature described in the population definition) which the firm had been involved in. From this list three projects were randomly selected, giving a total of 75 projects as the target sample size.

3.3 Data Collection

The data was collected from the existing records (bills of quantities, project files, final account documents, etc) in the quantity surveying firms using a checklist (data sheet). Two research assistants were engaged to collect the data between May 28, 1998 and July 17, 1998. The research assistants had a background in construction and were also trained on how to search the information from project documents and how to enter it in the data sheets.

Information like contract sum, contract period, parties involved in the project etc was collected. Appendix B shows the format of the data sheets used and the kind of information sought.

3.4 Variables in the Study

Dependent Variable: ***Construction period***

Construction period is defined as the time from the date a contractor takes possession of a site to the practical completion of the project. It is normally measured in weeks.

In practice, the project architect certifies the date of practical completion after the construction work is complete. It is possible that an architect certifies the completion date weeks after the actual practical completion, creating a difference between the *actual* completion date and the *certified* completion date. A basic assumption in this study is that this difference is not statistically significant.

Independent Variables

The constructs - project scope, complexity and environment - that influence construction time, are rather latent in nature and can not be measured directly. However, they can be measured in terms of various measurable surrogates that indicate them. Each of the constructs was measured in terms of three surrogates.

3.4.1 Surrogates of Scope

Cost value, floor area and height of a building are the three main attributes of a construction project that are normaly used to express scope.

3.4.1.1 Actual Cost

Cost has a direct bearing on scope. For projects of the same type such as flats or maisonnetes, executed during the same time, the higher the amount of money a project consumes the greater the project is likely to be. In this survey the total cost value (final account sum) is used to represent scope. The value excludes claims for interest on delayed payments or liquidated ascertained damages (which may not be reasonably related to the extent of the works).

Though the other indicators of scope (floor area and number of storeys) are likely to be highly correlated with the cost value, cost value may give a better representation of the scope associated with some items of work e.g. foundations, demolitions and external works, which may not be easily related to the gross floor area or the number of storeys. The cost value per unit area of a building varies with time. Factors like the strength of the local currency in the international market, rate of inflation, and the level of taxation in the construction industry influence the cost per unit of floor area. To remove the influence of time (year of construction) from the cost value, project costs in this study are given in Kenya shillings adjusted to the December 1997 cost index.

The construction cost indices used are shown in Appendix C. The cost index for every project is taken to be the index in the quarter immediately preceding the date of the tender opening.

3.4.1.2 Floor Area

The total area, in square metres, occupied by a building represents the physical extent of the works to be executed in the building project. The larger the floor area, the greater the volume of work in the building project, and also the longer the project is likely to take, holding all the other factors constant.

One major assumption is that the influence of floor area on construction period is not affected by changes in the economy such as rate of inflation, level of taxation etc, unlike the influence of cost value on the period. Therefore, a prediction model based on floor area is likely to be more stable than one based on the cost value, assuming that the technique of construction (technology) does not change considerably. Innovations in the building technology, management approaches, and type of materials etc are likely to decrease the construction time per unit of floor area. For example, systems building normally takes a shorter time per unit of floor area, than the traditional insitu construction.

In this study it is assumed that the construction technologies employed in the projects studied are similar. They will have involved prefabrication of some components such as doors, windows and fittings and insitu concrete work, stonework, structural timber, or structural steel in the building fabric.

3.4.1.3 Height

The height (number of floors/storeys) of a building also indicates the physical extent of the works to be executed in a project. For example, in reinforced concrete construction, the greater the number of floors, the greater the volume of concrete likely to be required for beams, columns and slabs. The number of floors represents scope in terms of the repetitions of concreting operations and the waiting times of the carpenter (formwork fixer) and the concretor. Concrete in every floor level needs to be given enough time (normally 28 days) to set. The concreting crew has to wait for the concrete to set, so that one floor level acts as the support for the formwork for the upper floors. This process, therefore, has a bearing on scope.

As the number of floors increases, the extent of substructure works is also likely to increase because stronger foundations are required to support the building. If substructure work is extensive the uncertainty of the project execution is relatively higher because unexpected underground conditions are likely to occur. These conditions for example underground water, rocks and antiquities, normally interfere with the planned project schedule, and their extent and interference is likely to increase as the extent of the substructure works (especially excavations and earth works) increases.

In this study, the number of storeys has been used to represent scope, irrespective of the storey height. Basements, mezzanines, ground floors and suspended floors have all been taken to mean storeys.

3.4.2. Surrogates of Complexity

Project complexity can be expressed in terms of three characteristics: the technical difficulty in constructing the building, the quality standard of the building works and the difficulty in co-ordinating the members of the project team. The technical difficulty can be indicated by factors such as the: irregularity of plan shape, presence or absence of substantial mass excavations, kind of foundation systems, complication of roof system and level of prefabrication in the works. The irregularity of the plan shape was selected in this study to indicate the technical difficulty.

The quality standard of works may be indicated by the materials and workmanship specified for finishes. The specifications of the workmanship, fittings and fixtures of the building services (mechanical & electrical installations) may also indicate the quality expected. The difficulty involved in co-ordinating members of a project team can be expressed in terms of the potential for conflicts amongst the parties in the team.

3.4.2.1 Irregularity of Plan Shape

The more irregular the floor plan of a building the greater the complication in the construction of the building. Irregularity in the floor layout normally results in a relatively high quantity (per square metre of floor area) of items related to the length of the walls e.g. strip foundations, walling and plaster.

Roof construction is also likely to be more complicated for irregular building plans than for regular ones. Similarly, buildings with a large extent of partitioning, like most residential buildings, have more complicated layouts and are likely to take longer than godowns, offices etc which normally have a smaller extent of partitioning.

Floor plan usually determines the design of the vertical enclosure of a building, which comprises walling, windows and doors. The area of the vertical enclosure (walls, windows and doors) per unit of floor area therefore gives a reasonable indication of the complexity associated with the plan shape.

3.4.2.2 Quality of the Finishes and Services

Though the quality standard of a constructed facility may be indicated by other factors (such as the quality of concrete, roofing materials and joinery fittings), internal finishes and sanitary fittings are the two major elements that one would normally check in a building to tell the quality of the building.

For example, high quality finishes such as wood parquet, coloured ceramic tiles, marble tiles, granite tiles and acoustic ceilings require a high level of workmanship which is likely to require a relatively longer time to achieve. The high level precision and intricacy in these works is likely to need relatively more time and requires closer monitoring than simple cement-sand screed floor finish, plaster and paint. The quality of finishes can be indicated by the cost of the finishes per unit of floor area.

Building services comprise power, air conditioning, lighting, telecommunications, computer services, lifts and escalators, water supply and drainage. The kind of services to a building and the extent thereof depend on the building's functional use, which in turn depends on the socio-economic class of the intended users. In high-rise and/or high class residential buildings the cost per square metre of floor area allocated to building services is likely to be higher than in low-rise and /or low class buildings.

The difference in the elemental cost of services (i.e. cost per square metre of floor area) for different buildings may arise from the quality of the pipe-work, fittings and fixtures specified or the magnitude of user consumption dictated by the functions of the buildings. In industrial buildings, the elemental cost of building services (especially electrical power) is likely to be higher than in hostels and schools. In the former the electricity system is mainly meant to provide power to operate high energy consuming plant, like a steel miller, but in the later the system is mainly meant to provide lighting and power for lower energy consuming machines like computers, fridges, TVs and cookers.

The greater the requirement and use of building services, the more complex is the network of the services in the building. Combining the fabric with a complex network of services requires a careful co-ordination of the works of various teams. This is likely to increase the need for time to complete a project in which such services are required.

In this study the cost of internal finishes plus mechanical and electrical installations per unit of floor area measure the quality of the building.

3.4.2.3 Potential for Conflicts among Teams

The teams (client, consultants, and contractors) involved in a construction project interact with one another because they are interdependent in their work. Differences that may arise among these groups of people may result in conflicts, which, if unresolved, are likely to slow down the progress of the works. The greater the potential for conflicts the greater the managerial burden of establishing team spirit to facilitate fast progress of the works.

The conflict potential is measured in terms of the number of interactions between every two teams. The client, architect, quantity surveyor, engineer(s), general contractor, specialist contractor(s) and nominated supplier(s) are considered as different teams because in any given project, each of these parties has one main person in authority, through whom communication with the other parties is facilitated. In order to keep the time prediction model reasonably simple, the different gangs of tradesmen e.g. masons and painters in any one of the teams above (especially in contractors and subcontractors) are not considered as separate teams. All gangs working under supervision of one contractor on site are considered to be one team.

The total number of interactions is obtained by considering all the teams and selecting two at a time as explained in section 2.4.2.

3.4.3 Surrogates of Environmental Interference

The building environment can be viewed in terms of the:

- risks in the project
- ambiguity in the works
- effeciency of the project team in managing the project - handling physical, economic, financial, legal, technological etc factors that may disturb the regular progress of the works.

The physical environment like the weather in which the job is done may indicate the risk involved in a project. It may also be indicated by the political and economic stability of the region in which the project is located, the nature of the client and the possibility of problematic events such as wars and industrial strikes occurring during the execution of the works.

Ambiguity in the extent of works (especially at time of tendering, when construction period is normally estimated) may be indicated by the detail of the drawings used in preparing the bills of quantities, the amount of work measured provisionally (except substructure which is always measured provisionally), and the general level of detail in describing the works. Managerial efficiency in a project is highly dependent on the organizational form adopted and is indicated by the amount of time and cost overruns and the quality of the building (Sidwell 1984).

3.4.3.1 Risks in the Project

The degree of risk involved in the project as viewed by the contractor and insurance companies generally could be reflected in the cost of insurance for the works. The risk may arise from the likelihood of occurrence of factors that may cause damage of the works during the construction period. The occurrence of the factors is likely to disturb the regular progress of the works and dictate an extension of time. Such risks are normally transferred to an insurance company. The more a project is exposed to this kind of risk, the higher the contractor is likely to be charged by the insurance company in terms of premiums for insuring the works against the risk. The contractor in turn transfers the risk to the client and is therefore likely to price the preliminaries section (especially insurance) of the bills of quantities more highly.

In risky environments, for example where there is likelihood of tribal land clashes and exceptionally inclement weather, as it has recently been in some parts of Kenya, the contractor is likely to price relatively higher for insurance. He is also likely to require a relatively longer time to execute the works probably because the risky job requires a relatively more demanding co-ordination of the teams in the contractor's organization.

However, the cost of insurance only represents the risk that is transferred to other parties outside the project team. The risk absorbed in the project is reflected by the contingency sum that is allowed for by consultants in the bills of quantities. Though the contingency sum is a measure against cost risk (likelihood of additional project costs arising from variations, statutory requirements, etc), it forms a reasonable indicator of the time risk because there is a significantly high correlation between project delay and cost overrun, as explained in section 1.1. The cost of insurance plus allowance for contingencies per unit of floor area were used in this study as the measure of the risks expected in a construction project.

3.4.3.2 Ambiguity of Works at Tendering Time

This refers to the uncertainty of works at the time when the estimate of the execution time thereof is done. It may arise either from incompleteness of the design work or inadequate description of the works in the bills of quantities. The two factors of ambiguity are indicators of the potential for variations. The more the ambiguity the higher the likelihood of variations and the more the construction period because the variations occur after the contract period has been estimated and agreed on. Their occurrence provides a firm ground for extension of time. As the design becomes more complete and the work to be done becomes clearer, the likelihood of major variations occurring in the project reduces.

When the extent of works can not be established with reasonable certainty, provisional quantities are measured or provisional sums estimated and allowed in the bills of quantities. The cost of provisional sums per unit of gross floor area was used in this study to indicate how ambiguous the work in the project was at the time of tendering.

3.4.3.3 *Managerial Efficiency*

An effective managerial approach to contract administration provides an environment in which decision making, co-ordination and conflict resolution are done effectively, facilitating a relatively faster execution of the works. Time and cost overruns are normally used to gauge the performance of construction projects (Baradyana 1996, Mbatha 1986). A high percentage time or cost overrun indicates a relatively poor project performance with respect to the specified contract period or contract sum, respectively. Low percentage time and cost overruns indicate a relatively more successful project performance. Project success depends on the efficiency of the management function in a project setting.

Time and cost overruns may therefore be used to indicate the efficiency of the management function in handling factors that normally occur in the project and tend to disturb the regular progress of the works. The disturbance factors comprise variations, shortage of materials, delayed payments, contractual claims, accidents on site etc. Sidwell's (1984) study shows that non-traditional contract procurement methods such as design & build, management contracting and project management normally lead to a relatively higher project success than the traditional (design-then-build) one. The expected time and cost overruns are likely to be lower (and the expected managerial efficiency higher) in the non-traditional organizational forms because the forms provide an environment in which project communication, co-ordination and control can be done more efficiently than in the traditional one.

In this study, each of the efficiencies of the management function *in controlling cost* and *in managing time* was measured separately on a 10-point scale, where 10 represented very high efficiency while 1 represented very low efficiency. The scale is shown on Table 3.1. A semantic scale is also included to give a verbal description of the scaling. The measures of the two efficiencies were added up for each project to give an index that measures the overall managerial efficiency. According to Neuman (1994), adding the two measures to get a combined measure would enhance the reliability of the overall measure. Therefore, the index for measuring managerial efficiency would have a maximum value of 20 units and a minimum value of 2 units.

Table 3.1 Hypothetical scale for measuring managerial efficiency in controlling cost and managing time.

X = Percentage cost overrun or time overrun	Level of efficiency-Numerical Scale	Level of efficiency-Semantic scale
$X \leq 10$	10	Very high
$10 < x \leq 20$	9	
$20 < x \leq 30$	8	High
$30 < x \leq 40$	7	
$40 < x \leq 50$	6	Average
$50 < x \leq 60$	5	
$60 < x \leq 70$	4	Low
$70 < x \leq 80$	3	
$80 < x \leq 90$	2	Very low
$90 < x$	1	

Source: Own Concept 1999

This scale was hypothetically developed out of the researchers personal experience in the building industry. It was the best in the circumstances in absence of any other reference that could have been done as a measure of managerial efficiency. However, the scale needs to be tested and developed further with the input of the industry's stakeholders.

The higher the managerial efficiency in a project, the shorter the time it is likely to take to complete the project. This is because the efficiency determines the total productivity of all the parties in the project. A relatively higher efficiency implies that the project team was relatively more vigilant in avoiding the occurrence of the disturbing factors and mitigating their impact on the project schedule if the factors were inevitable.

Where the level of managerial efficiency is to be considered in predicting construction period at the pre-contract time, the efficiency cannot be estimated on the basis of time and cost overruns the way it has been done in this study. However, the expected level of managerial efficiency in this case can be estimated using the skill and experience of the estimator in construction projects.

The following are perhaps the key factors that the estimator would consider to help him estimate the expected managerial efficiency in a future project with reasonable accuracy:

1. the nature of the client (private or public, individual or co-oporate etc)
2. the clarity of the client's brief
3. the project organizational form to be adopted
4. the degree of completion of design at the tendering time
5. the availability of the materials required

Construction period can therefore be expressed in terms of the nine surrogates described in Section 3.4.1.1 to 3.4..3.3, as follows: -

$$T = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\dots + \beta_n X_n + \in$$

Where:

T is the Construction period (weeks)

β_0 , β_1 , β_2, ... and β_n are parameters; $\beta_j \neq 0$

X_1, X_2 , ...and X_n are the measures of the surrogates of project scope, complexity and environment (n = 9).

$\in$ is the random error term, whose characteristics are described in Section 3.5.

3.5 Data Analysis

The data is analyzed using the Statistical Package for Social Sciences - SPSS for windows version 6.1. Frequency tables have been used to present the types of projects studied and the types of contracts employed in the projects. The nine surrogates of the independent variables have all been treated as variables themselves.

Descriptive statistics (mean, median, mode, minimum, maximum, standard deviation, kurtosis and skewness) of each numerical variable are computed to show the most typical observation, the amount of deviation from the observation and the form of the distribution of the variable. Histograms have also been drawn to show the shapes of the distributions diagrammatically.

The mean, median and mode are the statistics used to show the most typical observation. In a distribution, the most appropriate of the three statistics depends on the shape of the distribution. While the mean is the most commonly used average, it is rather inappropriate in distributions which are very 'asymmetrical' or where there are a few outliers on the far extreme. The shape of a distribution is indicated by its skewness and kurtosis. The skewness and the kurtosis of the bell-shaped normal distribution are both equal to zero. The greater the amount of skewness the lower is the appropriateness of the mean as a measure of the most typical case. The mode is the best indicator of the most typical case when the distribution is skewed and has a high peak, indicated by a positive kurtosis. This is because a large portion of the cases is very close to the mode in such a distribution. When the distribution is slightly skewed and relatively flat so that the kurtosis is negative, or when it is near normal with only a few extreme values far to one side, the median is the most appropriate average to indicate the most typical case (Alreck and Settle 1985).

The minimum, maximum and standard deviation are the statistics used to indicate the spread of the data around the 'most typical' observation. The minimum value indicates how far the spread extends towards the lower direction while the maximum value shows the extent of the spread towards the upper direction from the average. The maximum and minimum values are very important in regression models. They define the range of the values of an independent variable within which the use of a regression model (developed using the data) is most valid and reliable. The standard deviation measures the spread of the data away from the mean (Alreck and Settle 1985).

Bivariate correlations among all the variables have been computed to show the degree, direction and significance of the relationship between every two variables. Five variables that show a statistically significant correlation with the actual construction time are selected for regression analysis. A t-test is used to evaluate the relationship between actual construction period and estimated construction period. Scatter plots of actual construction period against the selected variables and the correlation coefficients are inspected in order to find out the best model to define the relationship between the period and each of the variables. The actual construction period is then regressed on actual cost and floor area separately in order to show the degree to which each of them could explain variability in the period because the two variables have been considered to be most readily obtainable for time prediction in a proposed project.

Initially, the relationship between the construction period (y) and the independent variables area (x's) - cost or floor - is formulated as a linear model:

$$Y = \alpha + \beta x + \epsilon$$

where, α and β are the regression coefficients and ϵ is the error factor.

The significance of the regression coefficients is tested at an alpha level of 0.05.

Linear regression analysis assumes that y is approximately a linear function of x and that ϵ measures the discrepancy in this relationship. The ϵ's are normally distributed with a mean of zero and a variance of σ^2, and are independent of the x's and independent of each other (Dowdy 1991). If these basic assumptions are violated in a regression model, the model is considered to unreliable. Violations of the basic assumptions of regression are tested by examining plots of the standardized residuals of the regression against the independent variable. Where the violation of any of the basic assumptions is evident, the data is normally *transformed* as appropriate, in order to ensure that the relationship is formulated as precisely as possible. The kind of transformation - logarithmic, square root, quadratic etc - necessary is indicated by behaviour of the plots of the standardized residuals of the regression (Chatterjee 1977).

The range of the standardized regression residuals (Z residuals) is used to test whether the data has any outliers or not. If the Z residuals range between –2 and +2 (approximately), this indicates that none of the observations in the data can be considered to be an outlier (Chatterjee 1977, Neter *et al* 1996).

Finally, the actual construction period is regressed on all the five independent variables that have been observed to have a significant correlation with the period, at the same time in order to see how a combination of all of them can explain the variability in construction period. A multiple regression model is formulated as follows:

$$Y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \in$$

Usually, the interpretation of a multiple regression equation depends on the assumption that the independent variables are not very strongly related to each other. If they are very strongly related, this condition is referred to as multicollinearity and makes the regression results ambiguous. The presence of multicollinearity in data is indicated by the instability of the regression coefficients. The coefficients exhibit large changes when a variable is added or deleted or when a data point is altered or dropped. Once residual plots indicate that the regression model has been satisfactorily specified, multicollinearity may be present if:

a) the algebraic signs of the regression coefficients do not conform to prior expectation;

b) coefficients of the variables that are expected to be important have large standard errors (Chatterjee 1977).

In this study, multicollinearity is therefore detected by examining the regression coefficients and the correlations of the independent variables in the multiple regression equation. Where two independent variables are found to be so strongly related that the regression coefficients is distorted as explained above, this problem is solved by deleting one of the two variables.

Chapter IV

ANALYSIS OF DATA AND RESULTS

4.1 The Projects Investigated

Out of the 75 projects initially targeted for this study, only 31 projects were obtained. This represents a response rate of 41.33 %. This sample size is sufficient because it is larger than the minimum - 30 cases - recommended by Alreck and Settle (1985). Also, in a similar research study by Walker (1995), a sample size of about this size (i.e 33 cases) was used.

A larger sample could not be obtained from the cluster of the 25 quantity surveying firms selected, of which only 11 responded positively. Most of the others could not give relevant information because the jobs they had handled between 1991 and 1997 had been mainly refurbishments that fell outside the definition of the population in the study. Others would not give information because the projects (relevant to the study) which they had been involved in had been started but not completed. Three of the firms selected had closed down. Table 4.1 shows the numbers of various types of building projects studied.

Residential buildings featured as the most common project type followed by institutional buildings accounting for 35.48% and 29.03% respectively. No industrial building was observed.

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Residential buildings featured as the most common project type followed by institutional buildings accounting for 35.48% and 29.03% respectively. No industrial building was observed.

Table 4.1 Building project types studied

Project type	Numbers	Percentage
1. Residential (bungalows, maissonetes & flats)	11	35.48
2. Commercial (shops, offices & warehouses)	8	25.81
3. Institutional (schools, colleges & hostels)	9	29.03
4. Industrial (factories)	0	0
5. Others – hotel, hospital and archives	3	9.68
TOTAL	31	100.00

These observations imply that residential building was a most common development in Kenya between 1991 and 1997 and that commercial building projects were almost as common as institutional ones. The observations also imply that residential, commercial and institutional building development accounts for about 90% of the building projects in Kenya.

The total cost value (at December 1997 overall construction cost index) of the 31 projects is about Kshs 2.21 billion, which is 28 % of the Kshs 7.81 billion (approx.) worth of the private building projects completed in Nairobi between 1991 and 1997 (Republic of Kenya 1991- 97).

Lumpsum fixed price contracts were 74.19% of the projects in the sample while lumpsum fluctuating price contracts were 22.58%. Only 3.23% were based on a schedule of rates. This shows that the lumpsum fixed price contract is the contract type most frequently used in Kenya. This is perhaps because clients are normally quite keen to avoid cost overruns that may arise from fluctuations in the material prices and labour costs during the contract period. They transfer the price risk associated with fluctuations to the contractor. The traditional approach to contract procurement (i.e. architect being both designer and project manager) was the one adopted in all the projects in the sample.

Where a surrogate was defined in terms of cost, the cost was adjusted to the December 1997 overall construction cost index and was given in Kenya shillings. Appendix C shows the overall construction cost indices from 1991 to 1997. Appendix D shows the dates of tender opening for each project and the cost indices used to adjust the costs. The adjusted data is shown in Appendix E. All the variables were measured as explained in section 3.4 before.

4.2 Descriptives

This section presents the main characteristics of each variable: the most typical value, the amount of deviation from it and the form of the distribution. The most typical value is indicated by the mean, mode or median depending on the form of the distribution as explained in section 3.5. The amount of deviation from the most typical value is indicated by the standard deviation while the form (shape) of the distribution is indicated by the kurtosis and skewness of the variable. The minimum and maximum values are also given to show the spread in the data. Histograms (with the normal curve imposed on them) are also presented to show the distributions diagrammatically. Most of the variables are skewed and leptokurtic (more peaked than the normal bell-shaped distribution).

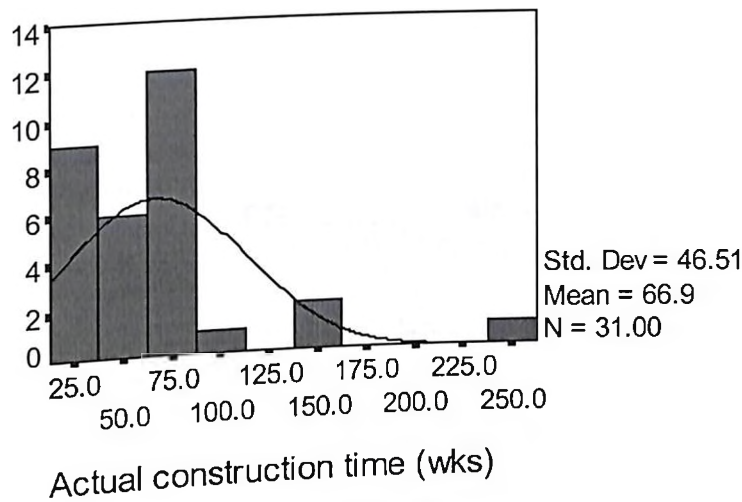
4.2.1 Actual construction period (weeks)

The distribution is positively skewed and leptokurtic as shown on figure 4.1.

Table 4.2 Descriptives of Actual Construction Time

Mean	66.903	Median	64.000	Mode	32.000
Std Dev	66.90	Kurtosis	7.930	Skewness	2.465
Minimum	18.000	Maximum	252.000		

Figure 4.1 Histogram of Actual Construction Time



This shows that in the population from which the sample was obtained, most projects took a shorter period than the mean of the periods. The mode is therefore the best indicator of the most typical construction period observed.

4.2.2 Actual cost (millions of Kshs)

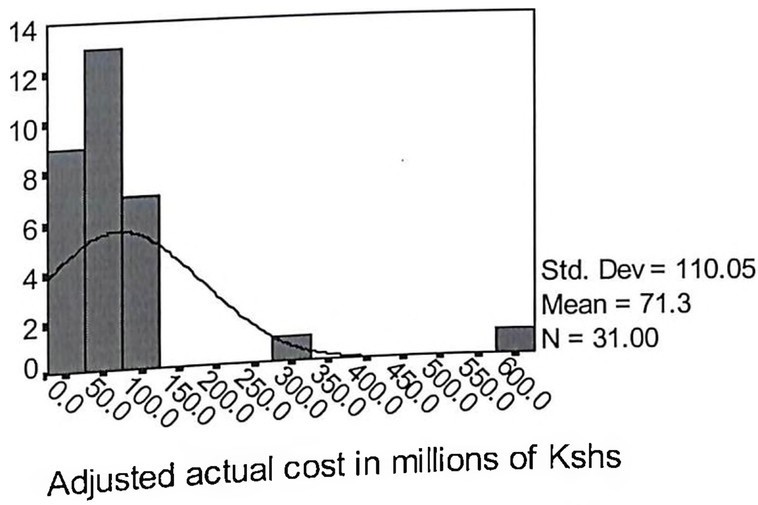
The distribution is also positively skewed and leptokurtic showing that most of the projects observed were smaller in cost value than the mean. This is perhaps a

Table 4.3 Descriptives of Actual Cost

Mean	71.338	Median	46.281	Mode	2.643
Std dev	110.051	Kurtosis	15.640	Skewness	3.746
Minimum	2.643	Maximum	575.676		

* Multiple modes exist. The smallest value is shown.

Figure 4.2 Histogram of Actual Cost



confirmation of the nature of demand for construction service in the Kenyan construction industry. The demand is characterized by most of the building projects being small in nature. The cost range of the projects studied (Kshs 2.64 – 575.68 million) is therefore a good representative of all the construction projects executed in Kenya.

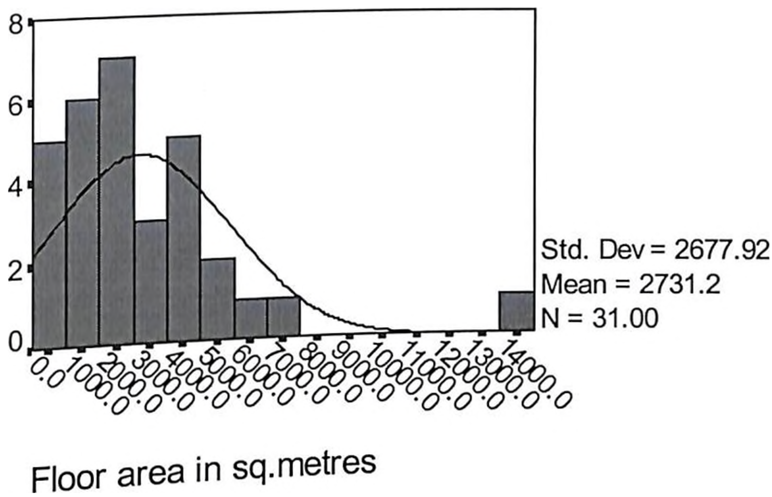
4.2.3 *Floor Area (square metres)*

The distribution is also positively skewed and leptokurtic and can be interpreted in the same way as the distribution of the actual cost because the two variables are indicators of scope and are very highly correlated as is shown in the next section.

Table 4.4 Descriptives of Floor Area

Mean	2731.226	Median	2133.000	Mode	160.000
Std dev	2677.925	Kurtosis	8.468	Skewness	2.442
Minimum	160.000	Maximum	13645.000		

Figure 4.3 Histogram of Floor Area



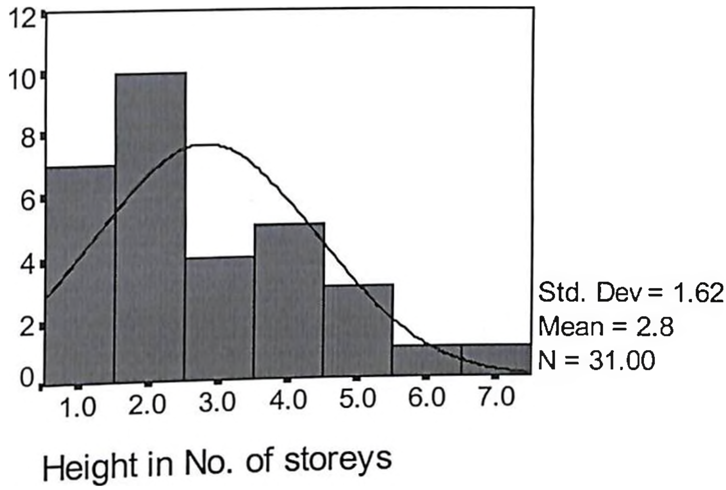
4.2.4 Height (number of storeys)

The distribution is closer to the normal distribution than the distributions of the other two surrogates of scope described before though it is slightly positively skewed. Most of the projects were two-storeyed but the sample comprises both low-rise and high rise buildings (four storeys and above).

Table 4.5 Descriptives of Height

Mean	2.806	Median	2.000	Mode	2.000
Std dev	1.621	Kurtosis	.046	Skewness	.836
Minimum	1.000	Maximum	7.00		

Figure 4.4 Histogram of Height



4.2.5 Area of walls + windows + doors per unit of floor area – WWDPA

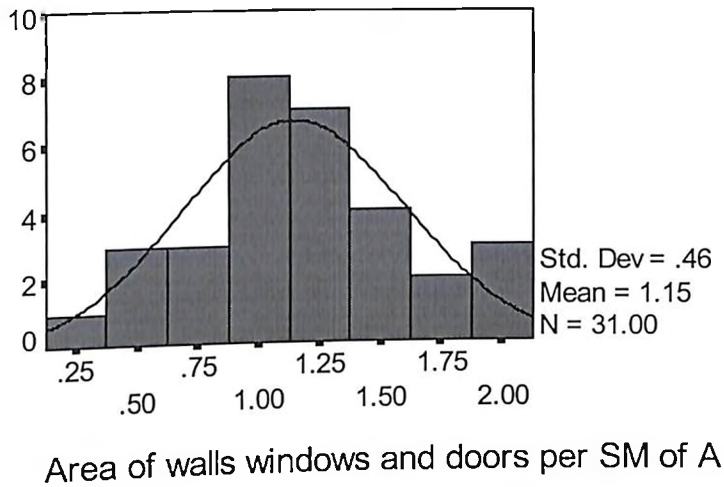
This is a measure of the irregularity of the plan shape and indicates the physical complexity as explained in section 3.4.2.1. Note that the measure is unitless because it is a ratio of two areas.

Table 4.6 Descriptives of Area of walls + windows + doors per unit of floor area

Mean	1.145	Median	1.150	Mode	1.150
Std dev	.461	Kurtosis	-.144	Skewness	.113
Minimum	.170	Maximum	2.080		

This is almost a normal distribution because its kurtosis and skewness are approximately zero. Also, the mean, mode and median are almost equal. This suggests that the vertical enclosure (external & internal walls, windows & doors) of a building is normally about 15% more than its floor area.

Figure 4.5 Histogram of Area of walls + windows + doors per unit of floor area



4.2.6 Cost of finishes + mechanical & electrical installations per unit of floor area (Kshs/squaremetre)

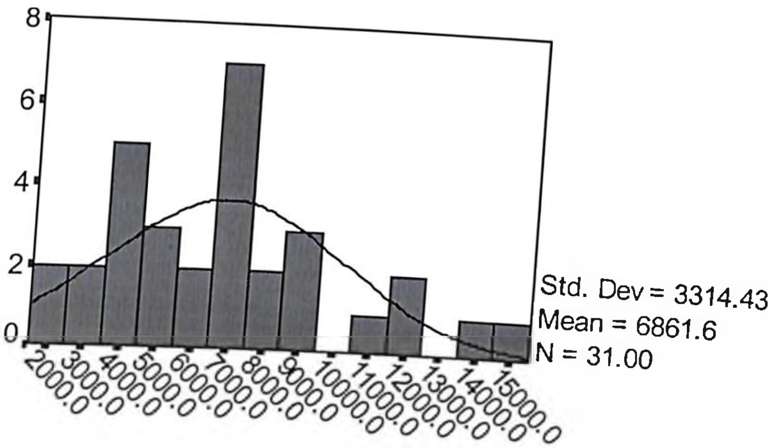
his is a measure of the complexity of a building associated with the quality of the materials and workmanship specified as explained in section 3.4.2.2.

Table 4.7 Descriptives of Cost of finishes + mechanical & electrical installations per unit of floor area

Mean	6861.613	Median	6860.000	Mode	6860.000
Std dev	3314.431	Kurtosis	.253	Skewness	.759
Minimum	1850.000	Maximum	14930.000		

It is a positively skewed distribution meaning that most of the values of the measure were less than the mean. The mode (Kshs 6860.00) is therefore the best indicator of the most typical value observed.

Figure 4.6 Histogram of Cost of finishes + mechanical & electrical installations per unit of floor area



4.2.7 Interactions among teams (number of interactions)

This is a measure of the potential for conflicts among teams in a project.

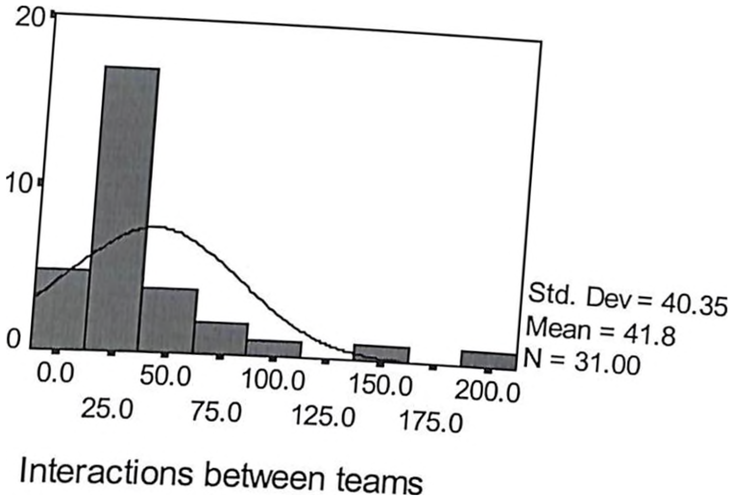
Table 4.8 Descriptives of Interactions among teams

Mean	41.839	Median	28.000	Mode	28.000
Std dev	40.346	Kurtosis	6.790	Skewness	2.531
Minimum	10.000	Maximum	190.000		

- Multiple modes exist. The smallest value is shown.

This distribution is also positively skewed and leptokurtic showing that most of the observations are less than the mean. Because the measure was computed by counting all the teams and selecting two at a time the mode (28 interactions) indicates that most of the projects had 8 separate teams ($8C_2 = 28$).

Figure 4.7 **Histogram of Interactions among teams**



4.2.8 Cost of insurance & contigencies per unit of floor area (Kshs/sq. metre)

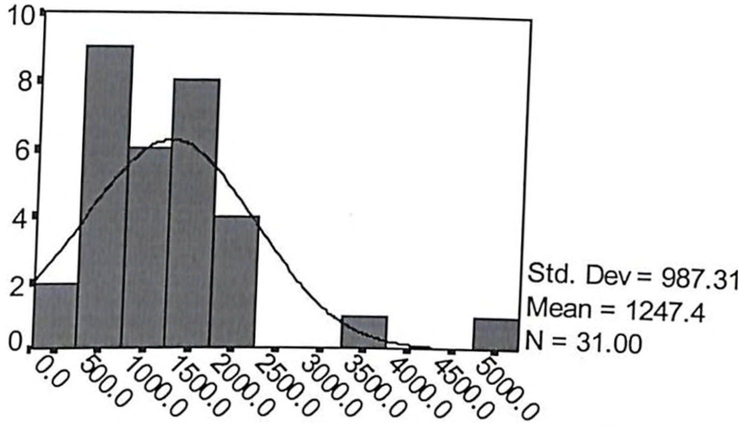
This variable measures risks in a building project and its distribution is also highly skewed and peaked as shown on Figure 4.8.

Table 4.9 **Descriptives of Cost of insurance & contigencies per unit of floor area**

Mean	1247.419	Median	1040.000	Mode	220.000
Std dev	987.313	Kurtosis	5.764	Skewness	2.090
Minimum	220.000	Maximum	4900.000		

* Multiple modes exist. The smallest value is shown.

Figure 4.8 Histogram of Cost of insurance & contigencies per unit of floor area



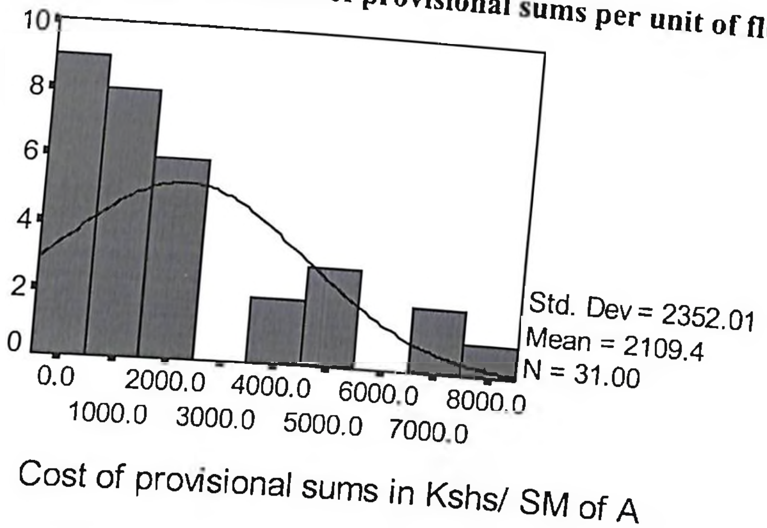
4.2.9 Cost of provisional sums per unit of floor area (Kshs/sq.metre)

This is a measure of the level of uncertainty in the definition of the works at the time of tendering as explained in section 3.4.3.2. The results show that most of the projects had their provisional sums less than their mean. Only three of the projects did not have any provisional sums at all. This shows that provisional sums are almost always allowed for in building projects and suggests that projects are rarely fully defined at the time of tendering.

Table 4.10 Descriptives of Cost of provisional sums per unit of floor area

Mean	2109.355	Median	1160.000	Mode	.000
Std dev	2352.013	Kurtosis	.680	Skewness	1.270
Minimum	.000	Maximum	8320.000		

Figure 4.9 Histogram of Cost of provisional sums per unit of floor area



4.2.10 Managerial Efficiency

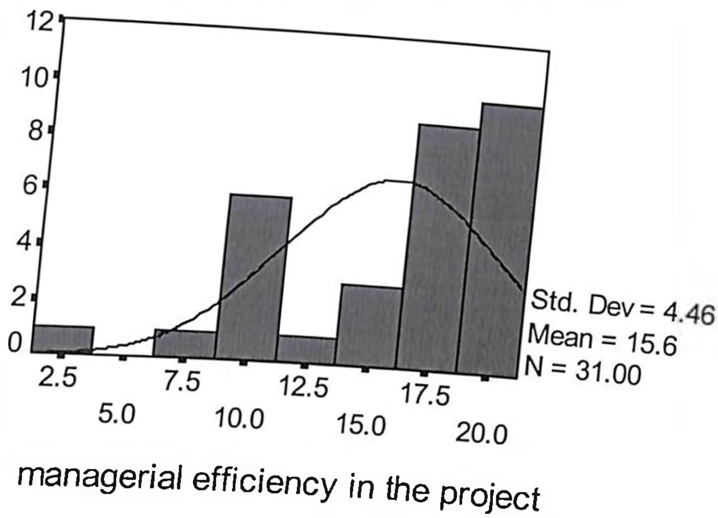
This is measured on a 20-point index computed on the basis of the project performance as explained in section 3.4.3.3.

Table 4.11 Descriptives of Managerial Efficiency

Mean	15.645	Median	17.000	Mode	20.000
Std dev	4.461	Kurtosis	1.324	Skewness	-1.242
Minimum	2.000	Maximum	20.000		

The distribution is negatively skewed unlike the others. The mean ME (15.645 out of 20.000 units) is rather high suggesting that the managerial efficiency in most of the projects was above average. The measurement of this variable was based on the performance of the projects in terms of time and cost. It was meant to indicate the overall efficiency of the managerial function in the project in responding to the influence of factors that tend to interfere with the regular progress of the works. Appendix F shows the relative frequencies of occurrence of all the factors observed.

Figure 4.10 Histogram of Managerial Efficiency



It was observed that the three most frequent factors that delayed the projects were: variations in design, delays in payments to contractors and shortage of building materials for the main contractor's work. Their relative frequencies of occurrence were 80.65%, 45.16% and 32.26 respectively. These are the factors that a time estimator should therefore consider when rating the expected managerial efficiency for a proposed project. Using his experience, he should evaluate the ability of the project team to mitigate the likely interference of these environmental factors on the proposed project. A most efficient team would be one that either avoids the occurrence of these factors or nullifies their impact on the project schedule and cost if the occurrence of the factors is inevitable, as explained in section 3.4.3.3.

For example, variations are likely to be minimal or not to occur at all in a project if the architect clearly understands the client's brief from the very start of his design and the design is practically complete at the time of tendering. Where variations are inevitable, a project team thereof can still be very efficient if the client's decision making process and the communication system in the project organization are highly efficient.

4.3 Testing Hypothesis about the Mean Actual and Estimated Construction Periods

This section compares the actual and the estimated contract period to determine whether the difference in them is significant. Table 4.12 shows the test of the equality of the means at $\alpha = 0.05$. The p-value (2-tail significance) is 0.002 which is less than α. The null hypothesis (mean actual time = mean estimated time) is rejected. The difference in the two means is statistically significant.

Table 4.12 Test of the equality of the mean times

t-tests for Paired Samples

Variable	Number of pairs	Corr	2-tail Sig	Mean	SD
T	31	0.535	0.002	66.9032	46.513
TE				41.9355	18.081

T- Actual time (weeks)
TE- Estimated time (weeks) – this variable is shown in Appendix E

This leads to the conclusion that in the population from which this data was obtained the actual construction time is significantly longer than the precontract estimate of construction time. The mean estimated time is 69.52 % of the mean actual time. The mean actual time is 59.53 % more than the mean estimated time. Also, 80.65% of the projects investigated were delayed implying that in this population, project delays are the norm rather than the exception. These two observations confirm Bromilow's (1969) and Mbatha's (1986) observations that the realities of time performance are usually well removed from expectation.

A rule of thumb, used in investment appraisal of construction projects, is to allow an extra 10 - 15 % cost to cover the risks and uncertainties associated with the cost prediction. If the same rule were to be applied in time estimating, which is equally important, the above deviation of the time estimate from the actual would not be considered acceptable.

The deviation of the actual construction period from the estimated one has been viewed in two different ways by researchers. The first view takes the estimated construction period to be realistic and considers the deviation from it to be a delay and *an indication of the inefficiency of the management function in a project* (Baradyana 1996, Mbeche 1996, Mbatha 1986, Wachira 1996). The second view takes the estimated construction period to be unrealistic and considers the deviation from it to be normal *and an indication of the degree of optimism in estimating the contract period* (Bromilow 1969). Both views seem reasonable.

The deviation can therefore be considered to be a combination and an indication of both managerial inefficiency and the time estimator's optimism. This characteristic of the deviation has two major implications: -

- In developing a prediction model, the actual construction period - but not the estimated construction period - should be used in the regression analysis because "writing in construction times known to be inadequate in hopes of spurring the cotractor to greater endeavours has little influence on the times that are actually taken in practice" (Bromilow 1969).
- A predicted construction period, whether realistic or not, requires an efficient management function for the time target to be achieved. This calls for use of non-traditional contract procurement methods - project management, management cotracting, design & build etc (Mbatha 1986, Sidwel 1984).

4.4 Testing Hypothesis about the Correlations

This section presents tests of hypotheses about the correlation between construction period and each of the surrogates of scope, complexity and environmental interference. A Correlation coefficient (r) indicates the degree and the direction of the relationship between every two variables. Table 4.13 is a matrix of the correlations among all the variables.

Table 4.13 Pearson's product moment correlations among the variables.

	TA	CA	A	H	WWD PA	FMEPA	I	INCO PA	PROV PA	ME
TA	1.0000									
CA	0.7361*	1.0000								
A	0.8350*	0.7142*	1.0000							
H	0.4263*	0.2405	0.4457*	1.0000						
WWD PA	-0.0751	0.1437	-0.0749	0.0893	1.0000					
FMEPA	0.2166	0.3081	-0.0185	0.0802	-0.1066	1.0000				
I	0.3180	0.1888	0.1818	-0.5224*	-0.2318	0.5989*	1.0000			
INCOPA	0.2449	0.2225	0.0614	-0.1811	-0.1289	0.4692*	-0.0890	1.0000		
PROV PA	0.4733*	0.3988*	0.3745*	-0.1933	-0.0903	0.2013	-0.0784	0.4501*	1.0000	
ME	-0.7900*	-0.5394*	-0.5290*	-0.1527	0.1772	0.0842	-0.1218	-0.1284	-0.4318*	1.0000

Note:-

1. * *means* that the correlation is statistically significant at 95% confidence level (see Appendix G).
2. Five of the independent variables exhibit a significant correlation with T.
3. 11 out of the 36 correlations among the independent variables are significant.
4. T- actual construction period;
   Surrogates of Project Scope: CA - actual cost; A - floor area; H- height
   Surrogates of Project Complexity: WWDPA - area of (walls + windows + doors) per unit of floor area; FMEPA- cost of finishes, mechanical & electrical installation per unit of floor area,
   Surrogates of Project Environment: INCOPA - cost of insurance and contingencies per unit of floor area; PROVPA - cost of provisional sums per unit of floor area; ME-managerial efficiency.

4.4.1 Correlation between Construction Period and Surrogates of Scope

Each of the three variables indicating project scope exhibits a positive and significant correlation with the construction period. The null hypothesis ($r = 0$) **is rejected** in respect of all the three surrogates of scope. It can be concluded that in the population from which this data was obtained, the larger the project scope, the longer the construction period.

4.4.2 Correlation between Construction Period and Surrogates of Complexity

None of the variables indicating complexity has a significant correlation with the construction period at 95 % confidence level. *Interactions among teams in a project* is the most significant complexity factor that influences construction time. Its correlation with time is statistically significant at an alpha level of 0.10.

The null hypothesis ($r = 0$) **is not rejected** in respect of all the three surrogates of complexity. This suggests that in the population from which this data was obtained, complexity *as defined and measured in this study* does not have any significant influence on the construction period. The suggestion contravenes the conceptual framework in section 1.4. Possible reasons for this result are: -

i) none of the projects investigated was complex;

ii) the complexity of all the projects investigated was almost equal and therefore complexity in this sample was more of a constant than a variable;

iii) the surrogates used in measuring complexity do not sufficiently capture the concept - complexity.

4.2.3 Correlation between Construction Period and Surrogates of Environmental Interference

Two of the surrogates have a positive correlation with construction period meaning that time is directly proportional to them. One of them, managerial efficiency, has a negative correlation with time indicating that time is inversely proportional to this variable. This is in line with the conceptualization of the relationship between the variables, explained in section 3.4.3.3.

Two of the variables indicating environmental interference -managerial efficiency & provisional sums per unit of floor area- exhibit significant correlations with the construction period. The null hypothesis ($r = 0$) **is rejected** in respect of the two surrogates of environmental interference. However, the null hypothesis ($r = 0$) **is not rejected** in respect of the third surrogate of environmental interference - cost of insurance per unit of floor area. It can be concluded that in the population from which this data was obtained, the more the environmental interference in a project, the longer the construction period.

4.2.4 The Significant Independent Variables

It can be seen from Table 4.13, that only five (Cost, Area, Height, Provisional sums per unit of floor area, & Managerial efficiency) out of the nine independent variables, have significant correlations with construction period. Therefore, each of them can explain a reasonable amount of the variation in the period. The other four variables (area of walls + windows + doors, cost of finishes & services and cost of insurance & contingencies) do not have any significant correlation with the construction period, meaning that none of them can explain a reasonable part of the variation in the period.

The coefficients of determination (r^2) between construction period and the five significant independent variables are shown on Table 4.14. This coefficient indicates the percentage of the variability in the period that can be explained by each of the variables. While plinth area alone explains 69.72% of the variability in construction period, height of building can only explain 18.17% of it.

Table 4.14 Coefficients of determination between Construction time and the five significant independent variables

Variable	Correlation coefficient (r)	Coefficient of determination (r^2)
CA	0.7361	0.5418
A	0.8350	0.6972
H	0.4263	0.1817
PROVPA	0.4733	0.2240
ME	-0.7900	0.6241

Key: -

CA actual cost
A floor area
H height
PROVPA cost of provisional sums per unit of floor area
ME managerial efficiency

These results suggest that floor area is the strongest factor in explaining construction time. It is interesting to note that managerial efficiency (an environmental variable) can explain more of the variation in construction time than cost.

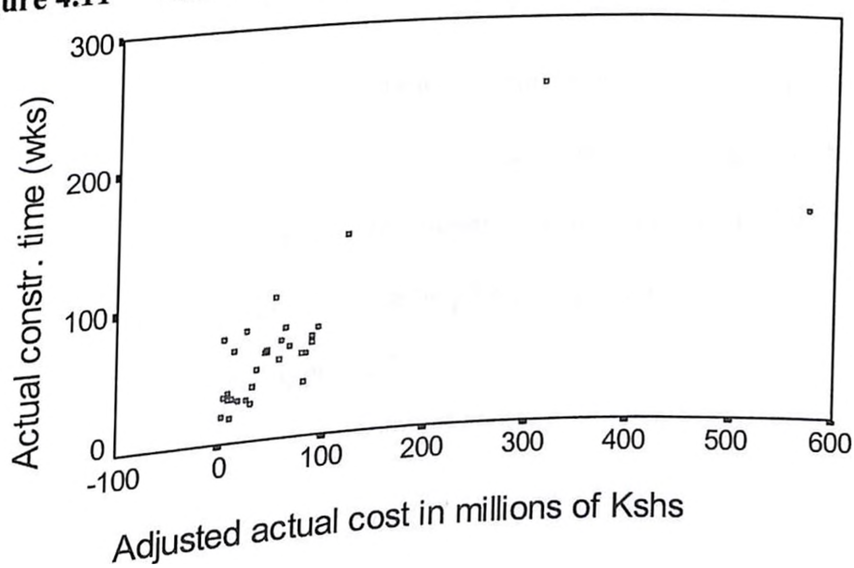
4.5 Regression Analysis

In this section, the statistical relationship between construction period and the five significant explanatory variables is presented. Floor area and cost are two major characteristics of a construction project that are normally known very early (as early as the sketch design stage) in the development of a project. For this reason, the period was regressed on each of the two significant variables separately before it was regressed on all the five significant variables simultaneously. All the regressions are shown in more detail in Appendix H.

4.5.1 Actual time and Actual cost

The scatter diagram of actual time versus actual cost suggests that the relationship between time and cost is not linear but quadratic, shown on Figure 4.11. Time seems to be increasing to a maximum and then decreasing with further increase in cost.

Figure 4.11 Time versus Cost



The relationship between the variables can therefore be expressed as follows:

$T = \alpha + \beta_1 C + \beta_2 C^2 + \in$ Where C is cost

Regressing actual time on actual cost and the square of actual cost shows that cost explains 73.65% of the variability in time in this model as shown on Table 4.15.

Table 4.15 Regression of Construction Time on Cost

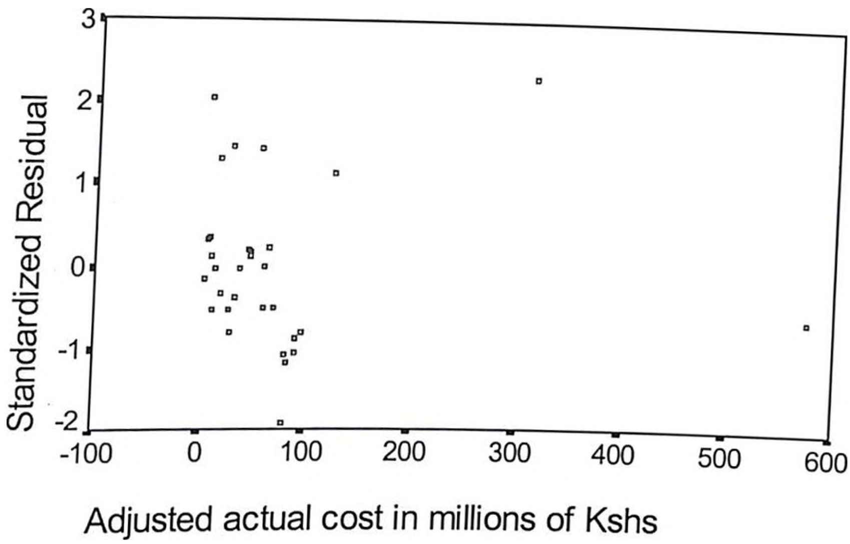
Dependent Variable - Actual construction time (wks)

Independent Variable	Regression Coefficient	p-value
Actual Cost - Kshs'000,00	0.904466	0.0000
Actual Cost squared	-0.001123	0.0001
Constant	21.259319	0.0077
R^2 = 0.73647		
Standard Error = 24.71577		
$-1.9220 \leq$ Z residuals ≥ 2.3272		

A study of the standardized regression residuals (Z residuals) does not show any violation of the basic assumptions of regression as shown on Figure 4.12. That is, the standardized residuals are randomly distributed around the zero axis, and do not show any noticeable pattern. They also range between –2 and +2 (approximately) indicating that none of the observations can be considered to be outliers. All the regression coefficients are statistically significant meaning that both C and C^2 explain a significant proportion of construction time in this model. The relationship between time and cost can therefore be given by this equation:

$T = 21.2593 + 0.9045C - 0.0011C^2$

Figure 4.12 Residuals versus Cost



This equation means that the increment in time for every increment in cost decreases as the cost increases. This is probably because the number of construction activities that can be executed simultaneously increases with project scope. Added work arising from increased scope may be executed in parallel with the other activities in the smaller-scope schedule, hence reducing the net effect of the increased scope on the overall construction period.

The R^2 value in this model is 0.7365 and is higher than in Bromilow's (1969) model. He observed the relationship between time and cost to be of the form:

$T = KC^B$ (i.e $\log T = \log K + B\log C$)

where C is cost as shown on Table 2.3.

Testing Bromilow's (1969) model on this data gives an R^2 value of 0.5532 as shown on Table 4.16, which is lower than the R^2 value in the quadratic relationship.

Table 4.16 Regression of log (Time) on log (Cost)

Dependent Variable - logarithm of construction time

Independent Variable	Regression Coefficient	p-value
Log (Actual Cost - Kshs'000,00)	0.362302	0.0000
Constant	1.183393	0.0000
R^2 = 0.55315		
Standard Error = 0.17205		
$-1.7476 \leq Z$ residuals ≥ 2.5777		

The R^2 value in the quadratic model is also higher than the average R^2 (0.6942) in De Leeuw's (1988) model. Testing De Leeuw's (1988) model on this data gives an R^2 value of 0.4697 as shown on Table 4.17.

Table 4.17 Regression of log(log Time) on log(log Cost)

Dependent Variable- log of (log of construction time)

Independent Variable	Regression Coefficient	p-value
Log{log (Actual Cost - Kshs'000,00)}	0.248329	0.0000
Constant	0.197631	0.0000
R^2 = 0.46967		
Standard Error = 0.04682		
$-2.1766 \leq Z$ residuals ≥ 2.4573		

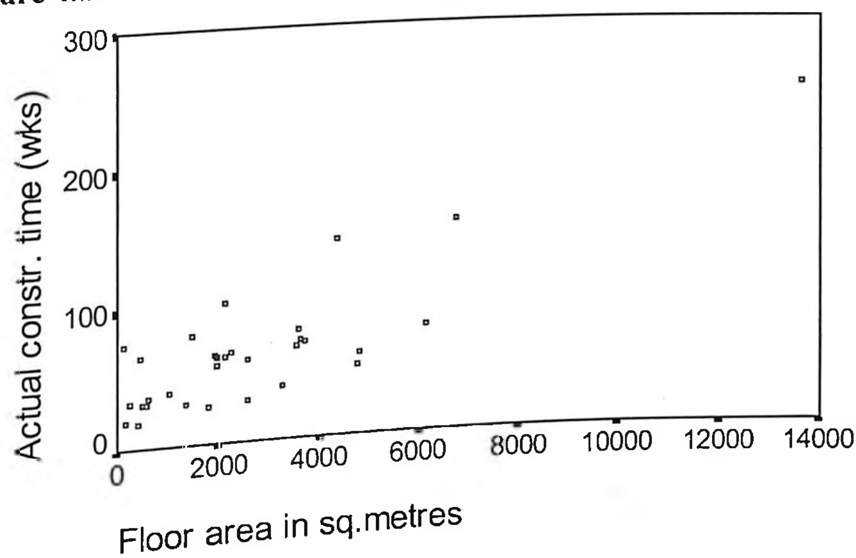
NB: It is assumed that all the projects in this study belong to one De Leeuw's (1988) group because the sample is too small to produce many sufficiently large groups.

Though this value is within De Leeuw's (1988) range (0.4269 - 0.9614) of the R^2 values for 32 building groups, it is still lower than the R^2 value in the quadratic relationship. These observations imply that CA explains more of the variability in T in the quadratic relationship than in the power relationship.

4.5.2 Actual construction time and floor area

The scatter diagram gram of time versus floor area shown on Figure 4.13 suggests that a linear model can represent the relationship between the two variables.

Figure 4.13 Time versus Floor Area



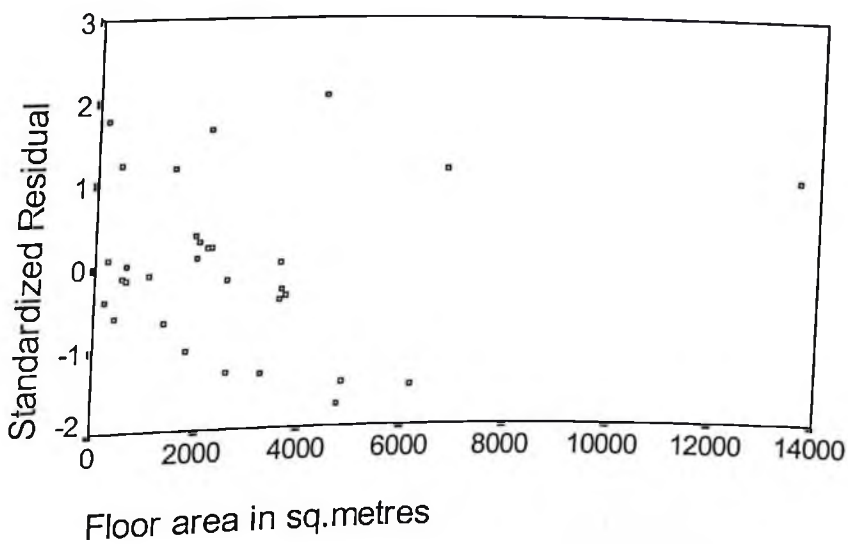
Regressing time on floor area gives an R^2 value of 0.69722 as shown on Table 4.18. A plot of the residuals against A does not reveal violation of any of the basic assumptions of regression. The R^2 value in this case is lower than in the quadratic relationship between time and cost. Also, the standard error in this linear relationship is higher than it is in the quadratic relationship between time and cost observed in section 4.5.1 before. This means that the quadratic time-cost model is better than the linear time- floor model in explaining the construction period.

Table 4.18 Regression of Time on Floor Area

Dependent Variable - Actual construction time (wks)

Independent Variable	Regression Coefficient	p-value
Floor Area - Square metres	0.014503	0.0000
Constant	27.291824	0.0003
R^2 = 0.69722		
Standard Error = 26.03191		
$-1.7028 \leq Z$ residuals ≥ 2.0598		

Figure 4.14 Residuals versus Floor Area



The linear time-floor area model has a higher R^2 value than the power time-cost model showing that floor area explains more of the variability in time than cost. The quadratic time-cost relationship is however, more precise than the linear time-floor area relationship because the standard error in the quadratic relationship is lower.

4.5.3 Multiple Regression

Regressing T on the five significant variables shows that the variables together explain 90.65% of the variability in construction time as shown on Table 4.19.

Table 4.19 Regression of Time on all the significant variables

Block Number 1. Dependent Variable - Actual construction time (wks)

Independent Variable	Regression Coefficient	p-value
Actual Cost - Kshs'000,00	0.646133	0.0054
Actual Cost squared	-7.41918E-04	0.0239
Floor Area - Square metres	-0.006179	0.0884
Height - No of storeys	6.227526	0.0154
Cost of Provisional Sums/Floor Area - Kshs/Square metre	4.75199E-04	0.7798
Reciprocal of Managerial Efficiency	367.973225	0.0000
	2.060667	0.7754
Constant		
R^2 = 0.90676		
Standard Error = 15.87935		

Block Number 2. Dependent Variable - Actual construction time (wks)

Independent Variable	Regression Coefficient	p-value
Actual Cost - Kshs'000,00	0.667657	0.0020
Actual Cost squared	-7.70468E-04	0.0122
Floor Area - Square metres	-0.006417	0.0641
Height - No of storeys	5.964712	0.0106
Reciprocal of Managerial Efficiency	375.107021	0.0000
Constant	2.821211	0.6676
R^2 = 0.90645		
Standard Error = 15.58442		
$-1.6536 \leq Z$ residuals ≥ 1.9768		

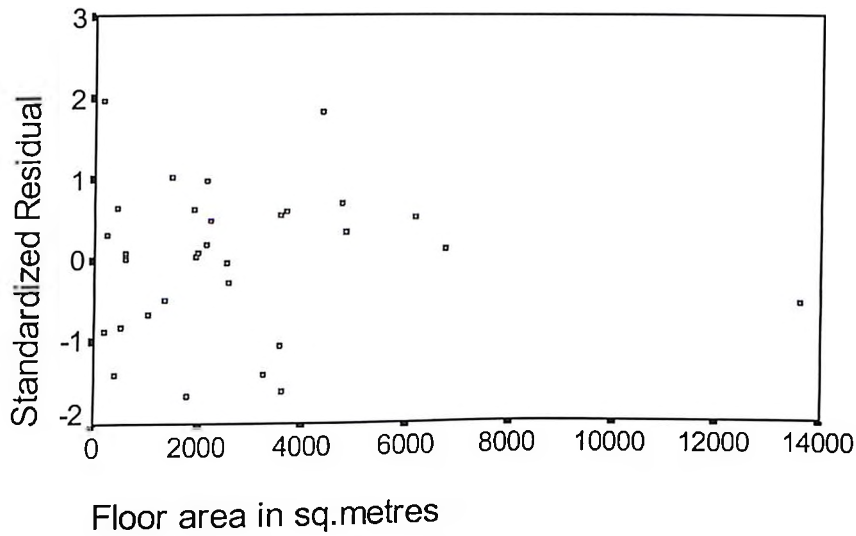
Note that the *reciprocal of managerial efficiency* is used in this regression because construction time is inversely proportional to managerial efficiency, as evident from the correlation analysis in section 4.4. Also, *Actual Cost squared* is included in the regression because of the quadratic relationship between construction time and cost, shown in section 4.5.1. *Block 1* of Table 4.19 shows all the five independent variables while *Block 2* shows only the most significant independent variables, after the insignificant ones have been removed from the regression equation in the backward regression procedure.

In the final stage of the regression process (Block 2) the variable *Cost of Provisional Sums per unit of Floor Area* has been eliminated from the equation meaning that it is the least significant in the group. It can be seen that eliminating this variable reduces the standard error from 15.87935 to 15.58442, and means that the regression equation resulting from final stage is more precise than the one resulting from the first stage (Block 1).

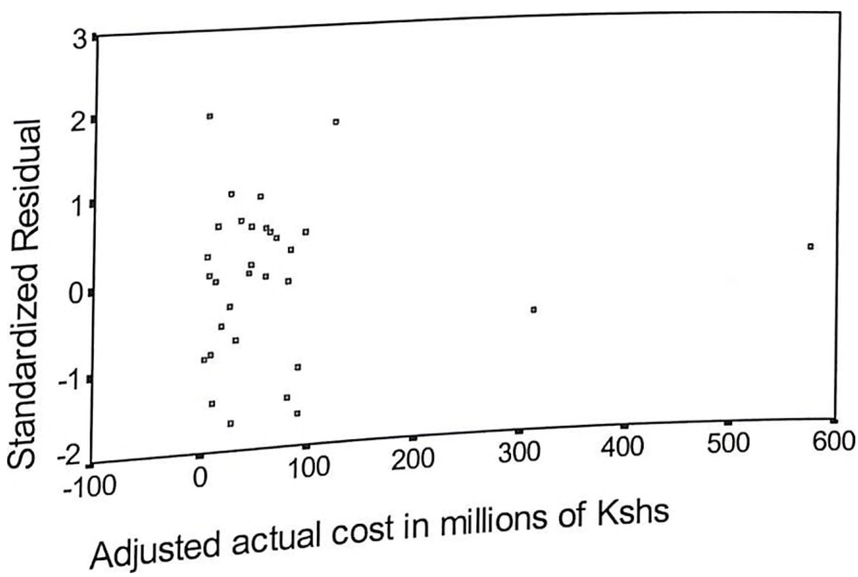
Scatter plots of the regression residuals against each of the independent variables do not reveal violation of any of the basic assumptions of regression as shown on Figure 4.15 (i)-(iv). This means that the regression model is well specified. However, the regression coefficients are somewhat distorted. The coefficient of Floor Area in particular has a negative sign suggesting that Time is inversely proportional to Floor Area. This contradicts the results of the correlation analysis in section 4.4. It is evidence that there is multicollinearity in the independent variables. Examining the correlation matrix on Table 4.13 reveals that there is a very strong correlation ($r = 0.7142$) between actual cost and floor area. This, however, cannot be unexpected in practice because floor area is normally used to estimate the cost of a building. The other correlations are relatively weaker.

Figure 4.15 Residuals versus the independent variables

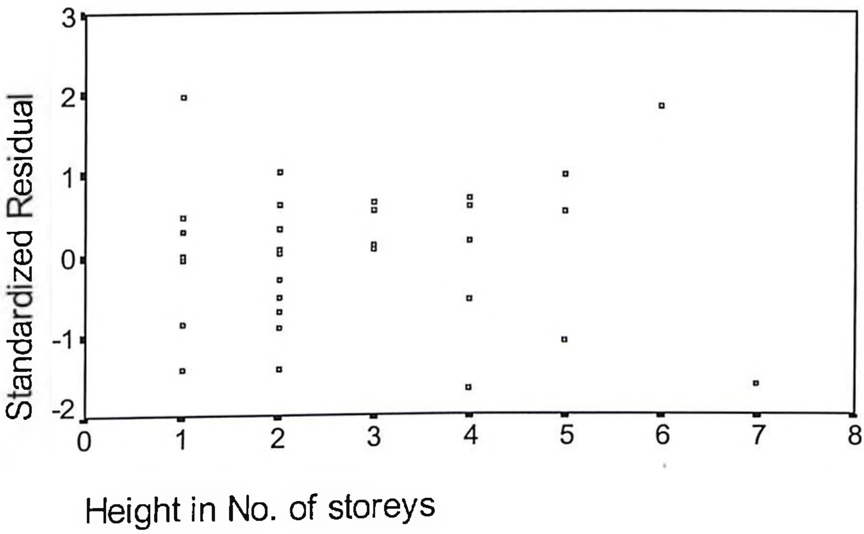
(i) Floor area



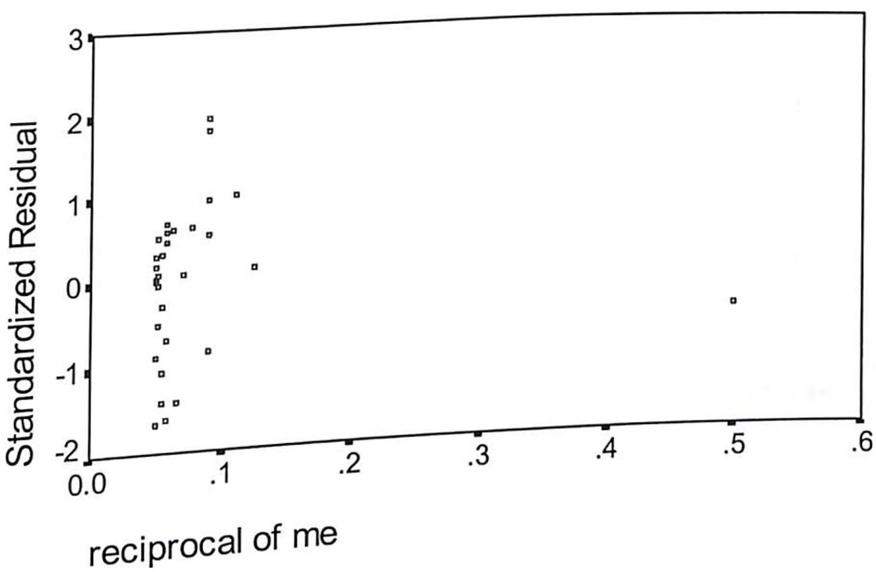
(ii) Cost



(iii) Height



(iv) Managerial efficiency (Reciprocal)



To avoid this problem, *Floor Area* is deleted from the equation and Time regressed on the rest of the variables. This reduces the R^2 value but only slightly (from 0.90645 to 0.89241) as shown on Table 4.20 meaning that the new model explains almost as much of the variability in Time as the original one. Although the standard error is slightly higher in the new model the regression coefficients thereof do not seem to give as much evidence of the presence of multicollinearity as in the original model. This is because the correlations among the independent variables in the new model are not very strong (see the correlation matrix on Table 4.13) and they could be assumed to pose no serious multicollinearity problem.

Table 4.20 Regression of Time on Cost, Cost Squared, Height & Managerial Efficiency (Reciprocal)

Dependent Variable - Actual construction time (wks)

Independent Variable	Regression Coefficient	p-value
Actual Cost - Kshs'000,00	0.381799	0.0074
Actual Cost squared	-3.85560E-04	0.0848
Height - No of storeys	5.077766	0.0305
Reciprocal of Managerial Efficiency	306.229579	0.0000
Constant	7.250201	0.2669
R^2 = 0.89241		
Standard Error = 16.38880		
$-1.6331 \leq$ Z residuals ≥ 2.2643		

From Table 4.21, the regression equation can be expressed as follows: -

$$T = 7.250 + 0.382C - 3.856C^2 + 5.078H + \frac{306.230}{ME}$$

Where:

- T - Construction Period (weeks) - from date of site possession to date of practical completion.
- C - Cost value (millions of Kshs)
- H - Building height (number of storeys)

- ME - Managerial efficiency (measured on a 20-point index)

Although *Managerial Efficiency* has difficulties of measurement as explained before, the fact that its *reciprocal* has the lowest p-value means that Managerial Efficiency is *the most significant of the three independent variables*, in describing the variability in construction time. However, the criterion used in measuring managerial efficiency in this study -i.e. percentage time & cost overruns (see section 3.4.3.3) - can not be used in a project at its pre-contract stage because at this stage, no time or cost overruns have already occurred. The measurement criteria can therefore not be relied on. Until further research establishes a better criterion of measuring managerial efficiency, this variable can therefore not be used in time prediction. Deleting the variable from the regression equation and regressing construction time on the remaining independent variables produces the results shown on Table 4.21.

Table 4.21 Regression of Time on Cost, Cost Squared & Height

Dependent Variable - Actual construction time (wks)

Variable	Regression Coefficient	P-value
Cost - Kshs '000,000	0.857791	0.0000
Cost Squared	-0.001047	0.0010
Height - No of Storeys	1.870882	0.5743
Constant	18.064314	0.0644
$R^2 = 0.73959$		
Standard Error = 25.01992		
$-1.7139 \leq Z$ residuals ≥ 2.4146		

The regression equation can therefore be re-specified as follows: -

$$\mathbf{T = 18.064 + 0.858C - 0.001C^2 + 1.871H}$$

All the independent variables in this equation can be measured at the pre-contract stage of a project. The equation can therefore be used to predict construction period at this stage.

The Standard Error -25.01992- in this regression is significantly greater than in the previous equation - 16.38880 (see Table 4.20). This means that deleting Managerial Efficiency from the equation significantly reduces the accuracy of time prediction. However, the R^2 value in this model is 0.73959, and is statistically significant (F = 25.56075, p-value = 0.0000). It means that the percentage of variability in construction time, explained by the two independent variables - cost & height together - is still statistically significant. The equation is therefore comprehensive enough to be used in predicting construction period.

The standardized regression residuals (Z residuals) range between –2 and +2 (approximately) indicating that none of the observations in this study can be considered to be outliers. This implies that all the observations of the variables - time, cost & height - belong to the same population. A prediction model created from this data is therefore sufficiently well specified. The R^2 value is higher than in Bromilow's (1969) and De Leeuw's (1988) formulae, which were 0.5233 and 0.69415 respectively. This model therefore explains more of the variation in construction time than the two past models.

The prediction equation can be interpreted as follows: -

- The greater the cost of a project, the longer it takes to construct. Increase in cost by Kshs 1 million increases the construction period by 0.858 weeks.
- The fact that the coefficient of C^2 is negative means that the increment in construction period for every increment in cost decreases as the cost increases.
- The more the number of storeys, the longer the construction period. An increase in building size by 1 storey increases the period by 1.871 weeks.
- The constant 18.064 is the value of Construction time when the values of all the independent variables are zero. The constant does not have any particular meaning *as a separate term* in this equation because the scope of the equation does not include a case where all the independent variable are zero.

The following are the ranges of the data in the sample used to formulate this equation: -

- Cost : Kshs 2.643 million - 575.676million
- Height: 1 - 7 storeys

Prediction using the equation would therefore be most reliable if it is done for measures of Cost and Height lying within these ranges.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

The objectives of this study have been achieved. The following conclusions can be made concerning the study findings: -

1. Research hypothesis **No. 1 was not rejected.** In the population from which the study sample was obtained, the actual construction period is significantly greater than the contract period estimated at the tendering stage. On average, the actual construction period is 1.595 times the construction period estimated at the tendering stage. The frequency of project delays is more than 80%. The ***deviation*** of the actual construction period from the estimated one and the *frequency* of delays imply that : -
    - The pre-contract contract period estimates in Kenya have hitherto been unrealistic. This can *partly* be attributed to the non-mathematical method of time estimating that is used in Kenya. The method seems to be rather inaccurate in accounting for the factors that influence construction time.
    - Project time performance has been rather poor in the Kenyan building industry. Project time overruns are large and are the norm rather than the exception. This could *partly* be attributed to the method of contract procurement, the traditional method, which is the one mainly used in Kenya and which all the projects investigated in this study had used. Whether construction period estimate is realistic or not, more efficient

contract procurement systems - project management, management contracting and design & build - are required in the mainstream building industry in Kenya to increase the efficiency of the management function in building projects.

2. Research hypotheses **No. 2 & 4 were also not rejected**. Construction period is significantly influenced by project scope and environmental interference. These two constructs can be measured in terms of the following surrogates: cost value (millions of Kshs), floor area (square metres), height (number of storeys), provisional sums per unit of floor area (Kshs per squaremetre) & managerial efficiency (rated on a 20-point scale).

3. Research hypothesis **No. 3 was rejected**. Project complexity, *as defined and measured in this study*, does not have a statistically significant influence on construction period. This observation contradicts both the initial conceptualization in this study (see Section 3.4) and observations in past researches, ***perhaps*** because: -

- none of the projects investigated was complex;
- the complexity of all the projects investigated was almost equal and therefore complexity in the population from which this sample was obtained, was more of a constant than a variable;
- the surrogates used in measuring complexity in this study do not sufficiently capture the concept of complexity in building projects.

3. A mathematical model for predicting construction time at the can be expressed as follows:-

$$T = 18.064 + 0.858C - 0.001C^2 + 1.871H$$

Where:-

- T is construction period in weeks - from date of site possession to date of practical completion.
- C is cost (contract sum) measured in millions of Kshs;
- H is building height measured in number of storeys.

The R^2 value in this model is 0.73959, and is higher than in Bromilow's (1969) and De Leeuw's (1988) formulae, which were 0.5233 and 0.69415 respectively. The model is therefore better because the explanatory variables thereof explain more of the variation in construction time than the explanatory in the two past models.

5.2 Recommendations

1. The prediction model developed in this study should be applied in the private building projects in Nairobi by contractors and consultants. The model is more objective than the non-mathematical method; applying it would therefore reduce the subjectivity inherent in the non-mathematical method.

- A contractor can use it to estimate construction period during tendering in a project where estimating the period is part of the tendering process. On the other hand, a consultant can use the model to evaluate the construction period offered by a tenderer. If the period offered is significantly greater than the estimate obtained using the model, then the period should be considered unrealistic and unacceptable; the tenderer is too slow for the job. If the period offered is significantly less than the estimate obtained using the model, the period should also be considered unrealistic unless the tenderer gives a realistic and detailed method statement showing how he would achieve his time objective.

- A consultant or contractor can also use the model to estimate the required Extension of Time, especially where the need for the extension arises from increase in the scope of the works. Inserting the estimate of the final account sum and the number of storeys, at any stage of the construction process, in the equation gives the estimate of the construction period for all the work *as at that stage*. The difference between this estimate and the contract period fixed at the start of the construction work should be considered the necessary Extension of Time.

2. The prediction model developed in this study could also be applied to private building projects in the other ten *main towns* of Kenya. The towns are: Mombasa, Kisumu, Nakuru, Eldoret, Kitale, Thika, Nyeri, Kakamega, Embu and Meru. The factors that significantly influence construction time in these towns are unlikely to differ significantly from the factors that influence construction time in Nairobi because the technology (quality of materials & workmanship, organizational forms, level of mechanization etc) mainly applied in the towns is similar to the one applied in Nairobi. Also, most of the

consultants, contractors and sub-contractors who execute building projects in the main towns have their offices in Nairobi.

3. Through the Continuous Professional Development (CPD) programmes, the local professional bodies - Architectural Association of Kenya, Institute of Quantity Surveyors of Kenya etc- involved in the construction industry should sensitize the industry participants on:-
   - the benefits of accurate time prediction in construction projects;
   - the inaccuracy inherent in the non-mathematical method of predicting construction time;
   - the principles and the advantages of the mathematical method of predicting construction time.

4. A pre-contract estimate of construction time that is judged realistic on the basis of the mathematical model should be taken to be the contract period. It should also be taken as the most realistic period within which planning and scheduling of the works can be done using the established methods - Gantt charts, PERT/CPM etc. The model simply gives a realistic estimate of the *critical path* - i.e. the project period in a PERT/CPM network - without necessarily having to do the network. It should therefore be used together with these scheduling techniques and labour productivity data to produce a practicable construction schedule.

5.3 Areas for further Research

A number of areas need research in order to refine on the prediction model developed in this study and reinforce its reliability and validity in the construction industry. The following are some of the areas:-

1. Establishing a method for measuring the environmental variable - managerial efficiency in a proposed building project, considering factors that can be objectively measured at the pre-contract period.

2. Establishing similar prediction models for public projects and refurbishment works.

3. Developing an expert system that combines both numerical data and experience based heuristic knowledge in the prediction of construction period.

4. Formulating schedule-based incentive schemes that could be applied in the construction industry to motivate contractors complete construction works on or even before the specified completion date.

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APPENDIX A

Letter of introduction to firms

UNIVERSITY OF NAIROBI
Department of B. E. & M,
P. O. Box 30197,
NAIROBI.

4th June, 1998

TO WHOM IT MAY CONCERN

The holder of this letter is conducting a research on the method of estimating the construction period, for part fulfillment of a Masters degree in Building Management.

Your firm has been selected out of the construction consultancy firms practicing in Kenya today, to provide the information needed in this study. Your experience represents the experiences of many others practicing in the construction industry today.

We request you to provide:-

- A **list** of the building construction projects in Nairobi, which you have been involved in from commencement to completion, between January 1, 1991 and December 31, 1997.
  (NB: The projects listed should be in the private sector and be mainly new works but not mainly refurbishments)
- **Access** to the bills of quantities, project correspondence file(s) and final account documents for three of the projects listed, that will be chosen at random from the list above.

We will highly appreciate your assistance in facilitating this research.

The information given will be used for research purposes only and your identity will remain confidential.

Please indicate whether you would like to get a copy of the research report.

Yours faithfully,

TITUS KIVAA PETER
M.A Student
(Research director)

APPENDIX B

Data Sheet

Research on the Method of Estimating a Construction Period

Details of three building construction projects chosen at random from one quantity surveying firm

No.	Information required	First project	Second project	Third project
1	PROJECT PARTICULARS			
A.	Type of building project			
	1. Residential (bungalows, maisonnetes & flats)			
	2. Commercial (shops, offices & warehouses)			
	3. Institutional (schools, colleges & hostels)			
	4. Industrial (factories etc)			
	5. Others (specify)			
B	Type of Contract			
	1. Lumpsum fluctuating price			
	2. Lumpsum fixed price			
	3. Schedule of rates			
	4. Other (specify)			
2.	PROJECT SCOPE			
A.	Contract sum (Total on tender award) Ksh.			
B.	Final Account sum Ksh.			
C.	Plinth area Squaremetres			
D.	Height No. of storeys			
3.	PROJECT ORGANISATION			
A.	Management Approach			
	1. Traditional (architect being designer & project manager, labour contract etc)			
	2. Non-traditional (design & build, project management, management contracting etc)			
B.	Number of parties involved in the project			
	1. Project managers			
	2. Architects			
	3. Quantity Surveyors			
	4. Civil/Structural engineers			
	5. Electrical engineers			
	6. Main contractor			
	7. Specialist subcontractors			

	8. Nominated suppliers			
	9. Others (specify)			
4.	CONSTRUCTION TIME			
A.	Date of tender opening			
B.	Contract period (as agreed on at time of tender award) weeks			
C.	Date of possession of site by main contractor			
D.	Extension of time weeks			
E.	Date of practical completion			
F.	Factors that occurred on site to interfere with the regular progress of the works and justify the extension of time			
	1. Shortage of building materials for the main contractor's work			
	2. Delays in payments to main contractor and specialist contractors			
	3. Shortage of building materials for specialist subcontractors' work			
	4. Exceptionally inclement weather			
	5. Variations in design			
	6. Unexpected subsoil conditions			
	7. Industrial disputes			
	8. Delays of work and material approval by architects and engineers			
	9. Unavailability and/or poor conditions of construction plant			
	10. Contractual disputes			
	11. Delays by local authorities e.g. Nairobi City Council approval of construction works.			
	12. Shortage of building components (local/imported)			
	13. Delays in issuance of permits/licenses by local authorities (e.g. KP&LC) for shifting or traversing their services			
	14. Delays in material sample tests			
	15. Delays in preparation and approval of shop drawings by contractors and designers respectively			
	16. Shortage of skilled or unskilled labour			
	17. Political wrangling on site or political interference on the works			
	18. Accidents on site			
	19. Other factors (specify)			
5.	SALIENT QUANTITIES & COSTS OF THE PROJECT			
A.	Total Area of:-			

	1. External & Internal walls SM			
	2. Windows SM			
	3. Doors SM			
B.	Total Cost of:-			
	1. Internal finishes to floors, walls & ceilings			
	2. Mechanical & Electrical installations (plumbing & internal drainage, power, lighting, air conditioning, lifts etc) Ksh.			
	3. Provisional sums (excluding contingencies) Ksh			
	4. Contingencies Ksh.			
	5. Insurance of the works (as per clause 18, 19 & 20 of the AAK conditions of contract or other conditions) Ksh.			

APPENDIX C

Overall Construction Cost Indices 1991-97

Year/Quarter	March	June	September	December
1991	915.80	933.00	951.90	961.80
1992	1013.10	1048.10	1048.10	1131.60
1993	1459.70	1641.60	1704.60	1704.90
1994	1751.40	1807.80	1829.50	1815.00
1995	1855.80	1950.00	1950.00	1973.80
1996	1975.00	2000.00	2025.00	2075.00
1997	2100.00	2125.00	2150.00	2175.00

Source: Republic of Kenya - Statistical Abstracts (1991-96)

NB: The construction cost indices for 1996 & 97 had not yet been published by the time of this study. They were therefore estimated by a linear extrapolation of the 1991-95 indices.

APPENDIX D

Dates of Tender Opening, Cost Value of Works and Cost

Indices Applied in the Cost Adjustment to Dec. 1997 Value

	Date of Tender opening	Unadjusted Cost Value of Works(Kshs)	Cost Index Applied
1.	19/4/96	82,000,000.00	1975.00
2.	2/12/94	45,000,000.00	1829.50
3.	2/5/91	5,405,436.75	915.80
4.	25/6/91	2,302,828.00	915.80
5.	1/3/91	132,112,629.00	892.90
6.	17/12/96	75,868,000.00	2025.00
7.	2/7/97	8,232,180.00	2125.00
8.	11/10/95	52,980,006.00	1950.00
9.	31/1/96	12,952,132.70	1973.80
10	14/11/95	29,017,263.45	1950.00
11.	23/9/96	77,700,000.00	2000.00
12.	10/7/96	24,100,000.00	2000.00
13.	5/3/97	7,483,023.00	2075.00
14.	1/3/97	34,428,016.00	2075.00
15.	22/6/93	45,980,244.00	1459.70
16.	8/12/94	36,963,218.90	1829.50
17.	12/3/94	96,979,377.00	1704.90
18.	2/1/98	29,400,000.00	2175.00
19.	28/2/96	42,450,000.00	1973.80
20.	29/9/95	9,570,000.00	1950.00
21.	6/11/95	52,664,649.00	1950.00
22.	31/7/96	73,656,534.00	2000.00
23.	16/1/95	53,180,991.00	1815.00
24.	14/6/95	4,282,804.35	1855.80
25.	26/7/96	17,503,058.90	2000.00
26.	11/11/87	157,642,553.90	595.60
27.	21/10/95	80,250,000.00	1950.00
28.	23/2/94	75,450,872.00	1704.90
29.	6/2/97	24,662,742.00	2075.00
30.	21/3/96	42,000,000.00	1973.80
31.	30/4/96	2,400,000.00	1975.00

NB:-

1. The cost adjustment assumes that the price rates used in a tender are based on the overall construction cost index of the quarter immediately preceding the date of tender opening.

2. The overall construction cost index is applied on the final account sum. Though the final account is normally done many weeks after tender opening (i.e. after the defects liability period) it is assumed that most of the price rates used in the final account are the ones given in the tender.

APPENDIX E

Adjusted Data

	T	CA	A	H	WWD PA	TE	I	INCOPA	PROV PA	FME PA	ME	CSTO	TMO
1	68	90.30	3569	5	1.15	53	36	1250	2110	6860	18	5	28
2	102	54.14	2141	5	1.15	42	36	1250	2110	6860	11	10	143
3	32	12.84	600	1	1.11	32	28	1420	7070	3540	20	-5	0
4	34	5.37	268	1	1.40	34	28	1570	520	7320	20	0	0
5	252	313.76	13645	4	0.50	47	36	2230	8320	5100	2	181	436
6	40	81.49	3260	1	0.17	26	45	1830	2170	9420	15	-20	54
7	32	8.43	526	1	0.45	16	15	460	2200	6700	11	-39	100
8	71	59.09	3695	4	0.47	52	36	1420	650	4910	17	-19	37
9	66	14.27	449	3	1.42	40	28	1400	3740	7490	13	13	65
10	40	32.37	1035	2	1.18	30	45	920	3560	8530	17	9	33
11.	60	83.41	4825	2	0.99	52	28	530	640	2690	18	12	15
12.	80	26.21	1469	2	0.92	28	28	650	1240	3680	9	21	186
13.	37	7.84	615	2	1.15	32	10	850	0	4110	19	0	16
14.	52	36.09	4760	4	1.88	40	15	220	330	1850	17	15	30
15.	66	68.51	2246	1	0.67	49	105	450	2450	8610	17	5	35
16.	64	43.94	1980	3	0.80	40	66	360	150	7550	14	16	60
17.	144	123.72	4350	6	1.22	52	190	1410	590	14400	11	3	177
18.	27	29.40	1812	4	1.30	25	36	640	560	5300	20	3	8
19.	64	46.78	2133	4	1.03	60	66	1140	0	8170	20	-15	7
20.	18	10.67	426	2	1.61	14	21	170	0	6960	18	9	29
21.	58	58.74	1949	2	0.89	58	28	4900	4980	12400	20	-23	0
22.	60	80.10	2562	1	1.32	60	55	1890	5480	14930	19	11	0
23.	80	63.73	3578	3	1.41	40	36	900	6840	4360	11	-8	100
24.	76	5.02	160	1	1.01	27	10	3520	2200	7190	11	4	181
25.	30	19.03	1376	2	0.99	30	10	870	470	5960	19	14	0
26.	155	575.68	6768	3	1.99	104	45	2160	460	11640	8	84	49
27.	72	89.51	3616	7	0.71	52	153	460	130	10640	17	5	38
28.	78	96.26	6156	5	1.82	65	21	690	650	3290	19	7	19
29.	31	25.85	2585	2	1.06	25	21	330	60	2270	18	7	24
30.	65	46.28	1912	2	2.08	55	10	220	1160	6220	16	40	18
31.	20	2.64	202	2	1.66	20	10	1040	370	4100	20	0	0

Key:-

- T- Actual construction time in weeks
- TE – Estimated construction time in weeks
- CA- Actual cost value in millions of Kshs adjusted to Dec. 1997 cost index (2175)
- Floor area in sqauremetres

- H- Height in number of storeys
- WWDPA- Area of walls, windows and doors per unit of floor area
- FMEPA- Cost of internal finishes and mechanical & electrical installations per unit of floor area in Kshs/sm.
- I -Number of interactions amongst teams
- INCOPA- Cost of insurance & contingencies per unit of floor area in Kshs/sm.
- PROVPA- Cost of provisional sums per unit of floor area in Kshs/sm.
- CSTO- Cost overruns in %
- TMO- Time overruns in %
- ME – Managerial efficiency measured by an index

APPENDIX F

Factors that caused delay of the works

	Factor	No. of occurrences	% No. of occurrences
	1. Shortage of building materials for the main contractor's work	10	32.26
	2. Delays in payments to main contractor and specialist contractors	14	45.16
	3. Shortage of building materials for specialist subcontractors' work	8	25.81
	4. Exceptionally inclement weather	2	6.45
	5. Variations in design	25	80.65
	6. Unexpected subsoil conditions	6	19.35
	7. Industrial disputes	2	6.45
	8. Delays of work and material approval by architects and engineers	3	9.68
	9. Unavailability and/or poor conditions of construction plant	0	0
	10. Contractual disputes	6	19.35
	11. Delays by local authorities e.g. Nairobi City Council approval of construction works.	5	16.13
	12. Shortage of building components (local/imported)	2	6.45
	13. Delays in issuance of permits/licenses by local authorities (e.g. KP&LC) for shifting or traversing their services	6	19.35
	14. Delays in material sample tests	0	0
	15. Delays in preparation and approval of shop drawings by contractors and designers respectively	0	0
	16. Shortage of skilled or unskilled labour	0	0
	17. Political wrangling on site or political interference on the works	0	0
	18. Accidents on site	0	0
	19. Other factors (specify)	2	6.45

APPENDIX G

Correlation Analysis

Coefficients of correlation among all the variables

	T	CA	A	H	WWDPA	FMEPA
T	1.0000	.7361	.8350	.4263	-.0751	.2166
	P= .	P= .000	P= .000	P= .017	P= .688	P= .242
CA	.7361	1.0000	.7142	.2405	.1437	.3081
	P= .000	P= .	P= .000	P= .192	P= .441	P= .092
A	.8350	.7142	1.0000	.4457	-.0749	-.0185
	P= .000	P= .000	P= .	P= .012	P= .689	P= .921
H	.4263	.2405	.4457	1.0000	.0893	.0802
	P= .017	P= .192	P= .012	P= .	P= .633	P= .668
WWDPA	-.0751	.1437	-.0749	.0893	1.0000	-.1066
	P= .688	P= .441	P= .689	P= .633	P= .	P= .568
FMEPA	.2166	.3081	-.0185	.0802	-.1066	1.0000
	P= .242	P= .092	P= .921	P= .668	P= .568	P= .
I	.3180	.1888	.1818	.5224	-.2318	.5989
	P= .081	P= .309	P= .328	P= .003	P= .210	P= .000
INCOPA	.2449	.2225	.0614	-.1811	-.1289	.4692
	P= .184	P= .229	P= .743	P= .330	P= .490	P= .008
PROVPA	.4733	.3988	.3745	-.1933	-.0903	.2013
	P= .007	P= .026	P= .038	P= .297	P= .629	P= .277
ME	-.7900	-.5394	-.5290	-.1527	.1772	-.0842
	P= .000	P= .002	P= .002	P= .412	P= .340	P= .652

Coefficients of correlation among all the variables (cont'd)

	I	INCOPA	PROVPA	ME
T	.3180	.2449	.4733	-.7900
	P= .081	P= .184	P= .007	P= .000
CA	.1888	.2225	.3988	-.5394
	P= .309	P= .229	P= .026	P= .002
A	.1818	.0614	.3745	-.5290
	P= .328	P= .743	P= .038	P= .002
H	.5224	-.1811	-.1933	-.1527
	P= .003	P= .330	P= .297	P= .412
WWDPA	-.2318	-.1289	-.0903	.1772
	P= .210	P= .490	P= .629	P= .340
FMEPA	.5989	.4692	.2013	-.0842
	P= .000	P= .008	P= .277	P= .652
I	1.0000	-.0890	-.0784	-.1218
	P= .	P= .634	P= .675	P= .514
INCOPA	-.0890	1.0000	.4501	-.1284
	P= .634	P= .	P= .011	P= .491
PROVPA	-.0784	.4501	1.0000	-.4318
	P= .675	P= .011	P= .	P= .015
ME	-.1218	-.1284	-.4318	1.0000
	P= .514	P= .491	P= .015	P= .

(Coefficient / 2-tailed Significance)
" . " is printed if a coefficient cannot be computed

APPENDIX H

Regression Analyses

Appendix H1 Regression of T on CA

Dependent Variable. T Actual construction time (wks)
Independent variables.
1. CASQ Adjusted actual cost squared
2. CA Adjusted actual cost (millions of Kshs)

Multiple R .85818
R Square .73647
Adjusted R Square .71765
Standard Error 24.71577

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	2	47800.36875	23900.18438
Residual	28	17104.34092	610.86932

F = 39.12487 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
CA	.904466	.136767	2.139981	6.613	.0000
CASQ	-.001123	2.4696E-04	-1.471587	-4.548	.0001
(Constant)	21.259319	7.406166		2.870	.0077

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*ZRESID	-1.9220	2.3272	.0000	.9661	31

Appendix H2 Regression of log T on log CA

Dependent Variable LGT log of T
Independent variable LGCA log of CA

Multiple R	.74374
R Square	.55315
Adjusted R Square	.53774
Standard Error	.17205

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	1.06270	1.06270
Residual	29	.85847	.02960

F = 35.89913 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
LGCA	.362302	.060468	.743742	5.992	.0000
(Constant)	1.183393	.099484		11.895	.0000

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*ZRESID	-1.7476	2.5777	.0000	.9832	31

Appendix H3 Regression of log(log T) on log(log CA)

Dependent Variable LGLGT log (log t)
Independent Variable LGLGCA log (log ca)

Multiple R	.68533
R Square	.46967
Adjusted R Square	.45139
Standard Error	.04682

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	.05630	.05630
Residual	29	.06357	.00219

F = 25.68343 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
LGLGCA	.248329	.049001	.685328	5.068	.0000
(Constant)	.197631	.011667		16.940	.0000

NB: It is assumed that all the projects in this study belong to one De Leeuw's (1988) group because the sample is too small to produce many sufficiently large groups.

Appendix H4 **Regression of T on A**

Dependent Variable: T - Actual construction time (wks)
Independent Variable: A - Floor area in sq.metres

Multiple R	.83499
R Square	.69722
Adjusted R Square	.68677
Standard Error	26.03191

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	1	45252.56269	45252.56269
Residual	29	19652.14699	677.66024

F = 66.77766 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
A	.014503	.001775	.834994	8.172	.0000
(Constant)	27.291824	6.734748		4.052	.0003

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*ZRESID	-1.7028	2.0598	.0000	.9832	31

Appendix H5 **Regression of T on all the significant variables**

Dependent Variable. T Actual construction time (wks)

Block Number 1. Method: Enter

Independent Variable(s) Entered on Step Number
1. RME reciprocal of managerial efficiency
2. H Height in No. of storeys
3. CASQ actual cost squared
4. PROVPA Cost of provisional sums in Kshs/ SM of
5. A Floor area in sq.metres
6. CA Adjusted actual cost in millions of Kshs

Multiple R	.95224
R Square	.90676
Adjusted R Square	.88345
Standard Error	15.87935

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	6	58853.02197	9808.83700
Residual	24	6051.68770	252.15365

F = 38.90024 *Signif F* = .0000

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

Variable	B	SE B	Beta	T	Sig T
CA	.646133	.211168	1.528760	3.060	.0054
CASQ	-7.41918E-04	3.0764E-04	-.972133	-2.412	.0239
A	-.006179	.003478	-.355737	-1.776	.0884
H	6.227526	2.388015	.217044	2.608	.0154
PROVPA	4.75199E-04	.001681	.024029	.283	.7798
RME	367.973225	65.824041	.635483	5.590	.0000
(Constant)	2.060667	7.140687		.289	.7754

Block Number 2. Method: Backward Criterion POUT .1000
CA CASQ A H PROVPA RME

Variable(s) Removed on Step Number
7.. PROVPA Cost of provisional sums in Kshs/ SM of

Multiple R	.95208
R Square	.90645
Adjusted R Square	.88774
Standard Error	15.58442

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	5	58832.85986	11766.57197
Residual	25	6071.84982	242.87399

F = 48.44723 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
CA	.667657	.193315	1.579685	3.454	.0020
CASQ	-7.70468E-04	2.8520E-04	-1.009542	-2.702	.0122
A	-.006417	.003312	-.369445	-1.937	.0641
H	5.964712	2.158869	.207884	2.763	.0106
RME	375.107021	59.668364	.647803	6.287	.0000
(Constant)	2.821211	6.491929		.435	.6676

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

Variable	Beta In	Partial	Min Toler	T	Sig T
PROVPA	.024029	.057625	.015563	.283	.7798

End Block Number 2 POUT = .100 Limits reached.

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*ZRESID	-1.6536	1.9768	.0000	.9129	31

Appendix H6 Regression of T on CA, CASQ, H & RME

Dependent Variable.. T Actual construction time (wks)
Independent Variable(s) Entered on Step Number
1.. RME reciprocal of managerial efficiency
2.. H Height in No. of storeys
3.. CASQ actual cost squared
4.. CA Adjusted actual cost in millions of Kshs

Multiple R	.94467
R Square	.89241
Adjusted R Square	.87585
Standard Error	16.38880

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	4	57921.29991	14480.32498
Residual	26	6983.40976	268.59268

F = 53.91184 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
CA	.381799	.131341	.903341	2.907	.0074
CASQ	-3.85560E-04	2.1517E-04	-.505198	-1.792	.0848
H	5.077766	2.218661	.176972	2.289	.0305
RME	306.229579	50.393142	.528853	6.077	.0000
(Constant)	7.250201	6.389691		1.135	.2669

Appendix H7 Regression of T on CA, CASQ & H

Dependent Variable - T Actual constr. time (wks)

Independent Variables

1.. CASQ actual cost squared
2.. H Height in No. of storeys
3.. CA Adjusted actual cost in millions of Kshs

Multiple R .85999
R Square .73959
Adjusted R Square .71065
Standard Error 25.01992

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	3	48002.80960	16000.93653
Residual	27	16901.90007	625.99630

F = 25.56075 Signif F = .0000

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

Variable	B	SE B	Beta	T	Sig T
CA	.857791	.160950	2.029547	5.330	.0000
CASQ	-.001047	2.8331E-04	-1.372266	-3.697	.0010
H	1.870882	3.289904	.065205	.569	.5743
(Constant)	18.064314	9.368852		1.928	.0644

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
*ZRESID	-1.7139	2.4146	.0000	.9487	31

Total Cases = 31