THE INFLUENCE OF ARCHITECTURAL FORM ON THE SUBSEQUENT RUNNING COSTS OF OFFICE BUILDINGS IN THE CENTRAL BUSINESS DISTRICT OF NAIROBI-KENYA.

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEFINITIONS

Architectural form

"Form is the geometrical configuration of the space occupied by the structure or [building]."(Manistone, 1975:81) Or, according to Vandyke (1990:17), "Form ...represents the aspect of volume and three dimensions - length, width, and depth."

Subsequent Running cost of Office buildings

This is the aggregate expenditures on all aspects that go into the keeping acceptable standards and to sustenance of the utility and value of the office building facility as was intended at the design stage. These include labour and material costs used to service, to repair and to replace the building elements, costs of utilities like water, electricity/fuel and security, and costs of servicing, repairing and replacing elements or parts of special services or items like air conditioning and ventilation, decoration, cleaning, plumbing and lifts and other costs like insurances, local authority rates and land rents. This was measured as an annual mean in Kenyan Shillings per square metre over a period of five years from 1988 to 1992.

Office Building

In not very distant past an office consisted simply of a room, or a series of rooms, where people worked at desks or spoke on telephone. Additional space would be needed for reception areas, meetings, and to store all the bits of papers which emanated from this activities. Thus an office building can be said generally to be a building housing office activities i.e. accountancy, architects/designers, advertising agents, insurance firms etc, with a variety of equipment for instance, personal computer, a word-processor, photocopier, draughting software linked to a plotter and printer, audio-visual equipments and even mainframe computer housed in a separate machine room and linked to terminals at each work-station especially for purpose-built offices.

Central Business District (CBD)

Frederick Gibberd argues that, the Town Centre or the Central Business District is the chief administrative, business, entertainment and cultural centre of the town as a whole.

ABBREVIATIONS

B of Q	Bill of Quantities
CBD	Central Business District
ICEA	Insurance Company of East Africa
JICA	Japan International Corporation Agency
JKUAK	Jomo Kenyatta University of Agriculture and Technology
KANU	Kenya African National Union
KICC	Kenyatta International Conference Centre
LA	Local Authority
M & E	Mechanical and Electrical
MOPW	Ministry of Public Works
NCC	Nairobi City Commission
NHC	National Housing Corporation
PC	Provisional Cost
P.R.	Plot Ratio
QS	Quantity Surveyor

ABSTRACT

This is a study of form of office buildings in relation to their subsequent running costs in an urban setting. The key issue in this study is how the form perceived at the planning stage of the building facilitates the after-care of the building once constructed. The hypothesis of this study is that architectural form has an influence on the subsequent running costs of office buildings.

The literature review has established twenty three main form parameters that influence subsequent running costs. In this regard, the existing and documented or implied relationships between these form parameters and the subsequent running costs (or maintenance costs which is part of running costs) have been documented. These form parameters have been broken down into fourteen quantitative variables and twenty qualitative variables for purposes of data collection and analysis. This assisted to cover form of office buildings comprehensively. Eventually, these thirty four independent variables are regressed against the annual mean subsequent running cost per square metre; the dependent variable.

The analysis of the data collected has revealed fundamental issues that would be beneficial to the building industry. These include the establishment of the proportions of the subsequent running costs for various aspects that require running in office buildings. At the same time, it has also been established that eight out of the above thirty four variables explain about 65.830 percent of the variation in the annual mean subsequent running cost per square metre. The multiple regression cost model has been used to establish a relationship between these independent variables and the subsequent running cost. This relationship has been found to be significant at 95 degrees confidence level.

The study has concluded that a relationship exists between subsequent running cost of office buildings and architectural form parameters and hence form. At the same time, appropriate architectural form parameters have been recommended so as to minimize subsequent running costs. It is also hoped that, this study will heighten the above awareness to the building industry especially to those groups of people that play a key role in the design of office buildings to facilitate the creation of less costly designs with regard to running, especially in third world countries that to a large extent lack finances for maintenance and running purposes.

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CHAPTER 1

INTRODUCTION

Form of any building is of significance to society. This is because it could be an expression of the designer's talent, the institution using the building or the society's values and norms. However, all kinds of building forms could not be created just for the sake of fulfilling the above and as such form confcrms to some important aspects, for instance, the maintainability aspect. This implies that the user should be able to keep and restore the building form to acceptable standards and in turn the building form should offer a space that offers acceptable social, economic and health conditions so as to sustain life.

It is for this reason that, the importance of maintenance (which is part of running) was stressed in the 1984-1988 Kenyan development plan and continues to be stressed in national and international fora (Habitat 1991). The adherence to the resolutions does not only benefit the users of the buildings but also the client, designers and staff in charge of running of buildings.

1.1 Statement of the Problem

The object of running of buildings cannot be over-emphasized. It is already evident the world over that, building maintenance that is part of the running exercise, conserves physical assets of a country and ensures a functionally-efficient environment to users. It also promotes an improved quality of life by providing healthy and safe accommodation to the people. Therefore, it is for this reason that, a workshop on building maintenance strategy organised by the United Nations Centre for Human Settlement (HABITAT) and the International Academy of Architecture Sofia, held in Bulgaria on the 5th to 6th June 1991, "emphasized the importance of giving attention to maintenance requirements in the design and construction stages."

The implication form might have on maintenance costs would not be easier to appreciate until one understands or is made aware of the procedures involved in maintenance and what it constitutes generally. Lee (1981:10), has defined maintenance as "work undertaken in order to keep, restore or improve every facility, i.e. every part of a building, its services and surrounds, to a currently acceptable standard and to sustain the utility and value of the facility." This indicates that maintenance could be said to be either preservation, that is, keeping an element or object in its existing state or restoration, that is, to revive the original concept or legibility of the object. In this regard therefore, maintenance as a whole constitutes an inexhaustible list of aspects. This include replacement of missing decorative elements and decayed parts, replacement of roof covering, window replacement and cleaning, etc. However, the success or failure of maintenance (i.e achieving the results at lower cost or higher cost respectively) greatly depend on various aspects related to the building form being maintained, for instance, shape of building, size of building and articulation or appearance of building, etc. This is because wherever the form does not assist in maintenance and hence running, the maintenance staff resorts to erecting scaffolding, or the use of cranes, and in-turn contributing towards higher maintenance costs and hence running costs. On the other hand, the building needs artificial ventilation, air conditioning, artificial lighting during its lifespan, thus becoming uneconomical in the sense that, all these aspects required to facilitate proper functioning of the building are not only expensive at the construction stage but also during running of the building. This is because the extra cost incurred is unnecessary especially in the tropics if appropriate building form or shape is conceived and built. This implies that, these extra and unnecessary running costs are incurred when the architect has little experience of the after-care of the very building he conceived, and it is for this reason that the international workshop on building maintenance strategy remarked that, "many maintenance problems are the result of faulty ... architectural practices that do not take into consideration maintainability aspects." (Habitant, 1991:20).

This does not only call for professionals involved in the design team to forget and do away with the traditional conventional way of practising, that is, " provided the client can foot the bill, professionals i.e., engineers and architects are able to furnish the client or developer with practically any form they want" (Banham, 1962:30), but also to realize that elements of form and space are presented not as ends in themselves but as means to solve a problem in response to conditions of function, purpose, and context.

For this to be realized, first and foremost, there is need for a research in this direction to establish a relationship between running costs and building form so as to forecast some light into the need of appropriate building forms in this regard.

1.2 <u>Objectives of the Study</u>

(a) To establish a relationship between architectural building form and subsequent running costs.

(b) Establish extent to which running of buildings is taken into account during design.

(c) Recommend appropriate architectural office building form parameters so as to minimize running costs.

1.3 Statement of the Hypothesis

The architectural form of office buildings significantly influence the running costs of buildings in use.

This implies that the null and alternative hypotheses are as follows:

H_O:No relationship exists between architectural form and running cost.

H_A:Relationship exists between architectural form and running cost.

Hypothesis Testing. According to the central limit theorem, "as the sample size is increased, the sampling distribution of the mean approaches the normal distribution in form regardless of the form of the population distribution. For practical purposes, the sampling distribution of the mean is assumed to be approximately normal whenever the sample size is n>=30"(Kazmier, 1976:127). Thus, since the estimated parent population for the study was a bout 180 buildings, then, it was definite that the sample population would be over 30 buildings. In fact, the sample population eventually was 38 buildings. More so, since "*z* distribution is used in place of *t* distribution when n>=30"(Kazmier, 1976:314), then, the *f*-test statistic was used to test the association between the independent variables and the dependent variable at 0.05 significance level.

The hypothesis testing is as illustrated by the following formula.

$$f = \frac{\text{additional variance explained by last r regressors}}{\text{unexplained variance}}$$

$$\text{or } f = \frac{(\text{increase in } R^2)/r}{(1-R^2)/(n-k-1)} \qquad \text{or } (f = t^2)$$

where increase in R^2 is increase in coefficient of multiple determination after the r regressors have been added to the model

r is coefficient of correlation between the dependent variable and the k^{th} independent variable n is number of observations

k is total number of regression considered (i.e., both the group of r regressors being tested and any earlier regressors in the model)

then, comparison between the $f_{calculated}$ and the $f_{tabulated}$ was done. The $f_{tabulated}$ corresponds to the prescribed 0.05 significance level and the degrees of freedom.

If $f_{calculated}$ was smaller than $f_{tabulated}$ the null hypothesis was accepted.

Similarly, the F-Ratio statistic was used to test the overall significance of the coefficient of determination between the dependent variable and the independent variables (i.e. the significance of the final strength of association) in the final model at 95 percent confidence level. The 95 percent confidence level means that 5 percent sampling error accepted as due to nature is tolerable. The F-Ratio tabulated is normally obtained from tables using the k-1 and n-k-1 degrees of freedom. Where n is the number of observations and k is number of parameters estimated. While the F-Ratio calculated is obtained through the following formula:

$$\text{F-Ratio calculated} = \frac{R^2 /(K-1)}{(1-R^2)/(N-K-1)}$$

If the calculated F Ratio exceeded the tabulated value of F, the null hypothesis is accepted. However, for this research $F_{calculate}$ was automatically given by the SPSS Computer programme and the level at which it was significant. Thus, it was easier to just read the significant level(s) of the relationship obtained.

In regard to the second objective of the study, the data was analyzed by aid of descriptive statistics. This was to identify if architects give any attention to running of office buildings at the planning stage of the design stage.

1.4 Significance of the Study

When reviewing relevant researches that have already been undertaken, it is observed that Syagga(1985) dealt with the impact of building design (i.e. building morphology/size, construction materials and density) on maintenance costs of residential housing estates owned by Mombasa Municipal Council. The results obtained showed that more than 99.3% of variations in maintenance costs are accounted for by the decisions and parameters established during the preparation of design brief, sketch design, working drawings and specifications, as well as a supervision of construction. However, the only independent variables related to form or shape of buildings that were considered were building area, wall area, wall height, roof type and room height. The probable reason for the few form parameters that were considered might have been due to the fact that the Mombasa Municipal residential buildings having been designed by the same design team, had few variations in form. Secondly, residential buildings being smaller in volume did not offer a chance for many different forms.

Similarly, in Rukwaro's (1990) research on the influence of architectural design parameters on the maintenance costs of building services of office buildings in the city of Nairobi, it was observed that maintenance costs of mechanical services are determined by the height,shape and perimeter of the building. It was also found that height is a determinant of maintenance costs of electrical services. The overall maintenance costs of engineering services were found to be a function of height and perimeter of the building. Thus, although most of the independent variables Rukwaro considered (except age of building) relate to form, he did not consider all the form parameters since he was specifically interested in the parameters that affect the costs related to engineering Services.

This indicates that the relationship between form and the running costs of buildings and more particularly office buildings had not been researched on, and hence there was need for research in this area. This is supported by the fact that parameters like, volume, orientation, rhythm, area of openings, location of service core, form of horizontal circulation, depth of building, area of floor voids, materials, etc., had not been investigated in any of the earlier researches. This therefore prompted the proposal and subsequent carrying out of this study.

Secondly, this study has focused on architectural form vis-a-vis running costs compared to the above earlier researches that focused on maintenance related issues. This is because maintenance costs just forms one third of the running costs as seen in Chapter Five of this study and more importantly, "over the life of a building the running costs are usually considerably greater than the costs of construction (Stone, 1980:15)." This indicates the importance of running costs and one of the reasons as to why the author of this thesis focused on running costs and not initial costs or maintenance costs just like the earlier researches. Similarly, it should be noted that, the cost of construction is only the first cost and is far less important than the subsequent associated with running the building and operating in it.

This research therefore, was meant to enlighten the professionals who form the design team of the need to consider the running requirements of the architectural building forms they conceive. This is because, in the world over, there is a need for the construction of new buildings to house the drastically increasing population with very limited resources. This means that no funds are left available to meet the high running expenditures of the existing building stock. On the other hand, it is very important for the up-coming professionals, particularly students in the relevant fields in universities to understand the running problems brought about by "inappropriate" architectural forms so as to develop "appropriate approaches" towards eliminating them in their era of practice. Hence, this research was also intended to expand the knowledge on maintenance (which is part of running) already pioneered by Syagga(1985), among others at the University of Nairobi.

1.5 Scope of the Study

Every building is a unique problem in its own setting and circumstances, and deserves a unique solution. At the design stage, the design team tries to come to terms with various aspects such as functional, construction techniques, materials, climatic and environmental requirements, etc., within the given site boundaries and topography. This indicates that with different functional and climatic requirements different designs or forms are obtained, thus office buildings in this particular study refer to a particular function within a particular climatic or environmental condition in Nairobi. This made it possible to study different forms of office buildings accommodating similar functions within the same constraints such as, climatic, environmental factors, culture, etc. Buildings of three floors and below were not included in the study because they had been conceived, designed and build as residential buildings cum-commercial buildings (Kingoriah, 1980:271).

Spatially, the area of study is enclosed by Haile Selassie Avenue, Tom Mboya Street, University Way and extending beyond the Uhuru Highway and including Community Area that constitutes all the Government Office blocks.

1.6 Limitations of the Study

The following were the limitations encountered in the course of this research.

(i) Running systems are managed by different groups of personalities i.e. in-house estate managers, estate agents, care-takers and even owners of the building, each of whom have different objectives and goals. For instance, owners of the building are interested in paying minimum tax to the Government and as such their records are geared towards fulfilling tax purposes only.

(ii) Some Estate Managers and owners of buildings involved in managing buildings did not want to release information. For instance the researcher found it difficult to obtain information on View Park Towers and Warren House in Nairobi.

(iii) Some buildings like Cianda House that was formerly known as Caltex House had changed hands. In this regard the present owners could neither trace the running records nor the architectural drawings of the building.

(iv) Some houses like Bima House had dual management by both Estate Agents and in-house Estate Managers or Care-takers. This made it difficult to have up dated running records.

(v) Quite a number of office blocks in the CBD are owned by contractors who are still practising as contractors. These contractors only keep one record of revenue and expenditure, thus the actual running cost records for their individual buildings does not exist.

(vi) Quite a number of buildings in the CBD are owned by organisations that own other buildings in other parts of the city. These organisations don't keep separate running records for each building. Thus it was difficult to extract running records for Cargen House, for instance.

(vii) Maintenance schedule is rarely followed. This means that the information obtained might not reflect good maintenance practice. For instance painting might not be done as regularly as required.

1.7 Research Methodology

Sampling. Different forms of office buildings exist in different parts of the CBD. Since, the aim of the research was to include in the sample population buildings that would bring together all existing architectural form parameters, then, it was imperative first and foremost to know what form parameters existed.

Before the form parameters were identified, all buildings with four floors and above were listed in order of their location to facilitate easier location in the later stages of the actual study. Buildings of three floors and below were not included in the study because these were conceived, designed and build as residential buildings cum-commercial buildings. This is because the colonial planning regulations allowed businessmen to build ground floor as commercial or shops floors and first and second floors as their residential apartments (Kingoriah, 1980:271). This is supported by the fact that most of the buildings with three floors and below date back to the time before independence. This implies that the parent population constituted a large proportion of office space as most of the buildings had only the ground floor as commercial. In this regard therefore, the buildings that were considered to constitute the parent population and eventually the sample population was generally regarded as conceived, designed and built as office buildings.

Secondly, according to the current adoptive by-laws, all office buildings with four floors and above must have facilities like lifts, fire fighting equipments, etc. Thus with such sample population, it became easier and logical to compare their subsequent running costs.

Once the parent population was known, a check-list in appendix A was used to identify the following issues.

(a) To ascertain the architectural form parameters existing in each building.

(b) To ascertain whether subsequent running records existed and who kept them.

(c) To ascertain whether architectural drawings of each building existed and where they were kept.

Then, all buildings that had subsequent running cost records and architectural drawings existing were recorded. Both these issues were important because without either of them, data collection was going to be incomplete. To undertake the actual sampling of individual office buildings, these buildings were listed against their architectural form parameters. Then, to ensure that all architectural form parameters were included in the sample population, the sampling process was started by selecting all buildings with unique architectural parameters. These unique architectural parameters included broken massing, irregular or organic plan forms, triple zoned form of horizontal circulation, North-South orientation, large surfaces of glass, pitched roofs, etc. Any building that appeared more than once due to the fact that it had more than one unique architectural parameter was listed once in the list of sampled buildings. The total number of buildings obtained from this first sampling step did not meet the targeted forty buildings, so a second method of sampling had to be used. Since buildings with unique parameters had been selected, then, the remaining ones had the most common parameters. Thus the second method of sampling involved assigning the remaining buildings with numbers, then writing these numbers on small pieces of papers that were then folded to hide the number and put together on a table. Then, one piece of paper was randomly picked and the number recorded. This piece of paper was folded again and returned to the other lot and thorough mixing of these pieces of papers was done. The returning of the picked number gave each building an equal chance of being selected. Again another piece of paper was randomly picked and the number of the building on it recorded. However, if the number of the building had already been selected, it was only recorded once and the piece of paper folded again and returned to the other lot. This process was continued until the targeted fourth buildings were selected.

Data Collection and Tools used. Two categories of questionnaires were prepared for interviewing the property manager and the design team respectively. The first questionnaire in appendix B was designed to the property manager to collect all data in regard to the architectural form parameters, the subsequent running costs and any other data that would help explain the relationship between the architectural form parameters and the subsequent running cost. Since, most of the property managers did not have an architectural background, which implied that they would not be able to identify the architectural form parameters in their buildings, personal observation and consultation with the architectural drawings at the NCC and M.O.P.W. facilitated collection of all the architectural form parameters. In this regard, several tools or equipments were required to facilitate accurate data collection. These tools included, a scale rule, set square, camera, scientific calculator, and tape measure.

Four research assistants with qualifications of Diploma in Architecture assisted a great deal in collecting quantifiable architectural form parameters data from the drawings at the Nairobi City Commission (NCC) drawing office. This was necessitated by the fact that, it required one researcher one full day to measure all the quantifiable architectural form parameters of one building. This meant that it would take the principal researcher forty working days to collect all these data after spending about three months collecting the cost and qualitative architectural form parameters data. Thus the collection of the quantifiable architectural form parameters data was collected in ten instead of forty working days and the role of the principal researcher was reduced to securing all the drawings required from the registry, instructing the research assistants on what to be measured and how, and lastly counter checking that data had been collected as had been instructed.

On the other hand, all aspects of the qualitative architectural parameters were coded numerically as shown in appendix B and in the definitions of the independent variables later in this chapter. For instance, the three aspects of location of the service core, that is, internal core, semi-internal core and external core were assigned numeric values zero, one and two respectively. The pitched roof was assigned numeric value zero whereas a flat roof was assigned numeric value one. Thus the measurement of qualitative data was simply writing down the numeric value corresponding to the aspect of architectural form parameters that existed in any one building.

Subsequent running cost data for five years, from 1988 to 1992 was collected from the property manager's audited books in cases where property managers were charged with the responsibility of the sampled properties especially in the private sector. In the public sector, data was collected from payment vouchers. These vouchers had the date of payment, amount paid and the purpose of payment, which made it easier to complete the questionnaire in respect of the various running aspects.

The subsequent running cost data collection was relatively easier from willing property managers. This is due to fact that almost all property managers had up-to-date running records and even some had gone to the extent of computerizing their records. However, this would at times prove to be very difficult whenever property managers were not cooperative or in the public sector where vouchers were kept in different files and even stored in different offices. These issues have been raised on limitations of the study earlier in this report.

The second questionnaire in appendix C was directed to the design team/Architects. This was meant to check the extent to which running is considered at the planning stage. This is because form parameters are actually determined at the planning stage of the design process. Secondly, this questionnaire was meant to check if any contradiction would arise if form parameters requiring the least running cost were recommended to the design team.

The administration of the second questionnaire required the identification of the Architects who designed the sampled buildings from the architectural drawings at NCC and M.O.P.W., their telephone contacts and postal addresses, and the geographical location of their offices. It turned out that most of these

Architects who designed these buildings were no-longer located in Nairobi as most of these buildings were quite old. This implied that most of the above Architects were either out of practise, dead, or out of the country. However, the few of these Architects who happened to be located in Nairobi, turned out to be operating the major architectural offices. These Architects included Waweru Associates, Mutiso Menezes, Triad Architects, Planning System, Dagliesh Marshall, Nandhra Associates and Hughes and Pokinghorne. Although this number of Architects appears few compared to the sampled buildings, it was regarded as being representative of the Architects who had designed most of the office buildings in Nairobi. The main reasons for this were that, apart from the fact that these are the major architects operating in Nairobi, most of them had at least two of their buildings sampled. In fact, Hughes and Pokinghorne had six of their buildings sampled.

Lastly, the collection of the actual data from Architects, only involved dropping the questionnaire to their offices and arranging when to collect it. This was possible as the Architects were aware what the questionnaire entailed and as such did not experience any problem in completing them.

Secondly data was obtained from existing literature related to the building industry, Central Bureau of

Statistics and related publications and journals.

<u>Data Analysis</u>. The independent variables, that is, architectural form parameters were regressed against the annual mean subsequent running cost. This was intended to establish the relationship between the architectural form parameters and the subsequent running costs. The following mathematical or running cost model was used:

$$Y = F(X_1, X_2 \ldots\ldots\ldots\ldots X_n)$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

and, X1, $X_2, \ldots X_n$ represent the surrogate parameters in which form is manifested.

The SPSS computer package was used to analyze the data in accordance with the model above. However, there existed obvious symptoms of multicollinearity, for instance regression coefficients changed greatly in value when independent variables were dropped or added to the equation. Multicollinearity refers to the case in which two or more explanatory variables in the regression model are highly correlated, making it difficult or impossible to isolate their individual effects on the dependent variable (Salvatore, 1982:182). This problem is normally solved by regressing each variable against all the other variables and identifying pairs of variables that are highly correlated, that is, with a coefficient of correlation higher than 0.7. To decide the variable that has to be dropped from any pair of variables that were highly correlated, each independent variable in question is regressed on all the other independent variables and that with higher coefficient of determination is dropped. This means that the variation in the variable dropped is explained by the independent variables that remains in the model. However, in this research, all the highly correlated independent variables were automatically eliminated by the step-wise regression method.

Definitions of Variables

Definition of Independent Variables. In order for one to appreciate the form of any building, one has to be aware of the purpose for which the building was designed and built. Building forms can be either utilitarian or symbolic (Flon, 1984:12). For instance, particular forms of religious buildings, houses and palaces, are always a reflection of the demands of religious cult, of everyday life, or of the exercise of power in any given society. Thus, as the large volume enclosed in the building called the church means something to the form of the church building, similarly the shape of the Eiffel Tower means something to its form. This makes it imperative for one to be aware of all the elements that constitute a building so as to form a clear picture of the building or to be able to capture the form of the building. On the other hand, this enables one to differentiate between what is due to constraints (structural necessity, existing building, shape of plot, stylistic conventions, demands of the client), and what is the product of purely artistic creation, the play of forms. This implies that for one to be able to read the form of a building one has to take an interest in that building to the degree to which one sees in it 'effects' of volume, space, rhythm, colour etc, that actually constitutes the form itself.

The following are definitions of independent variables.

1. Plan shape/configuration:

This refers to the edge contour of the typical plan plane of the building. This was measured qualitatively by assigning numeric zero to geometric or pure shapes and numeric one to irregular or organic shapes.

2. Plinth area:

This means the sum total of the floor area contained in all the storeys of a building the measurements of which are taken from external faces of the enclosing walls or limits of such building. This was measured in square metres (m^2).

3. Volume of building:

This is the three dimensional space occupied by the building measured in cubic metres (m^3).

4. Building orientation:

This refers to the faces/facades of the building on which windows are located in relation to the sun. This was measured qualitatively by assigning numeral zero to North-South facades, numeral one to North East-South West or North West-South East facades, numeral two to East-West facades and numeral three to building with windows on facades facing all directions.

5. Height of building:

This is the distance between the mean level of the top of the lowest floor level or basement or part of the building and the midway of the roof if pitched or the top of the walls (or of the parapet) whichever is the higher. This was measured in linear metres (m).

6. Rhythm:

This is the distance between the centres of any two adjacent structural columns measured in linear metres (m). (Note: When lines, planes, and surfaces treatments are repeated in a regular sequence (order or arrangement), a sense of rhythm is achieved (Hepler, 1990:20))

7. Glazed area or area of openings/fenestration:

This is part of the facade or vertical face of the building that allows light into the building and is measured in square metres (m^2).

8. Roof shape:

This is a measure of the slope of the roof plane. If slope is more than ten degrees it is regarded as pitched roof otherwise regarded as flat roof. This was measured qualitatively by assigning numeral zero to pitched roofs, numeral one to flat roofs and numeral two to roofs with both flat and pitched roofs.

9. Location of service core:

This is a measure of the location of the main service core in respect to the working space. This was measured qualitatively by assigning numeral zero to internal core, numeral one to semi-internal core and numeral two to external core.

10. Form of horizontal circulation:

This is a measure of the main horizontal circulation arrangement. It is measured qualitatively by assigning numeral zero to single zone, numeral one to double zone, numeral two to triple zone and numeral three to open layout.

11. Depth of building:

This is the distance between the external envelope of the building and the immediate parallel horizontal circulation boundary. This was measured in linear metres (m).

12. Shading devices:

This refers to vertical or/and horizontal elements fixed to windows to control the intensity of light and solar radiation transmission into the building. This was measured by assigning numeral zero to presence of shading devices and numeral one to the absence of shading devices on building facades.

13. Storey height:

The height of the lowest or only storey is measured from the base of the wall, and the height of any other storey is measured from the level of the underside of the floor-structure of the storey to the level of the underside of the floor-structure next above it or, if there is no such storey comprising a gable, to half the height of the gable.

14. Floor voids or light wells:

This is the sum total of the empty floor area contained in he floor planes in all the storeys of a building that are not actually occupied by the floor structures. This is measured in square metres (m^2).

15. Plot ratio:

Plot ratio is related to the existing infra-structural facilities of an area in the CBD and is used to determine the total plinth area of the building.

$$\text{Plot Ratio} = \frac{\text{Total plinth area}}{\text{Plot area}}$$

16. Vertical escape/circulation routes:

This is the number of vertical circulation points at the ground floor of the building that assists the pedestrian to move from the ground floor to other floors and vice versa. It is measured in numerals.

17. Type of finishing material:

This is a measure of the plasticity of the finishing materials. This was measured qualitatively by assigning numeral zero to cladding finishes, numeral one to partly cladding and partly surface coating finishes and numeral two to surface coating finishes.

18. Nature of finishing material:

This refers to the extent the surfaces enclosing offices spaces and buildings were painted. This was measured qualitatively by assigning numeral zero to unpainted faces, numeral one to partly painted and partly unpainted surfaces and numeral two to painted surfaces.

19. Texture of finishing material:

This is a measure of the textural quality of the surfaces enclosing the office spaces. This was measured qualitatively by assigning numeral zero to smooth surfaces, numeral one to partly smooth and partly rough surfaces and numeral two to rough surfaces.

20. Number of storeys:

This is the sum total of storeys contained in the building, measured in numerals.

21. Massing:

This refers to a measure of the brokenness of the three dimensional shape occupied by the building. This was measured qualitatively by assigning numeral zero to pure three dimensional shapes and numeral one to irregular three dimensional shapes.

22. Ornamentation:

This is a measure of decoration on the building. It was measured qualitatively by assigning numeral zero to buildings without decoration, numeral one to small areas of decorations and numeric two to whole facade of decorations.

23. Perimeter of plan:

This is the sum total of the lengths of all sides of a typical plan of the building measured in linear metres (m).

24. Ratio of perimeter to plan area:

This refers to the numeral value obtained by dividing the perimeter of a typical floor plan above by the area of the same floor plan.

25. Age of building:

This is the time duration between the base year and the time the building was commissioned. It was measured in years.

Definition of the Dependent Variable. Subsequent Running Cost of office building is the aggregate expenditures on all aspects that go into the keeping of acceptable standards and sustenance of the utility and value of the office building facility as was intended at the design stage. These include labour and material costs used to service, to repair and to replace the building elements, costs of utilities like water, electricity or fuel and security, and costs of servicing, repairing and replacing elements or parts of special services or items like air conditioning and ventilation, decoration, cleaning, plumbing and lifts and other costs like insurances, local authority rates and land rates. This was measured as an annual mean in Kenyan Shillings per square metre over a period of five years from 1988 to 1992.

The annual subsequent running costs for each building for the years 1988 to 1992 were raised to 1992 constant prices, using the Central Bureau of Statistics construction cost indices. This is because no separate running cost data indices are prepared in Kenya today since running is considered and treated as part of the construction industry (Syagga, 1985:271). These subsequent running costs of any particular building over the five years were summed up at constant prices and divided by the total plinth area of the building to obtain the annual mean subsequent running cost per unit area.

1.8 Organization of the Study

The study was divided into seven chapters. Chapter One has dealt with the problem statement in relation to architectural building form and running costs, objectives of the study, the statement of hypothesis, the significance of the study, the scope of the study and the research methods used in the research.

Chapter Two has reviewed the design process and established the constraints encountered at the design stage. Whereas, Chapter Three has reviewed further the design process in view of these constraints and shown how the form parameters and hence form is established. Chapter Four has discussed the architectural form parameters of office buildings identified in Chapter Three in relation to running procedures or arrangements and cost and predicted possible effects on subsequent running cost of office buildings.

Chapter Five has presented the outcome of the data analysis. Firstly, it has shown the possible relationships between architectural form parameters of office buildings and the annual mean subsequent running cost. Secondly, this chapter has shown the possible relationship between architectural form of office buildings and the annual mean subsequent running cost. Whereas, Chapter Six has discussed the opinion of Nairobi Architects with regard to form parameters and running of buildings.

Lastly, Chapter Seven has drawn conclusions and recommendations in accordance with the objectives of the study outlined in Chapter One and the outcome of the data analysis presented in Chapter Five. Areas of further research have also been recommended.

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CHAPTER 2

DESIGN PROCESS AND FORM CREATION

2.1 Introduction

As defined in Chapter One, "form is the geometric configuration of the space occupied by the structure or [building]," (Manistone, 1975:81). According to Vandyke (1990:17) "form...represents the aspect of volume and three dimensions - length, width, and depth." Thus form can be said to be the final result of an architectural undertaking. Baker (1984:vi) affirms this by stating that;

> Architectural problems are resolved in terms of three dimensional form which is modulated in accordance with the problem and the site. Architectural form therefore comes into being as a response to two sets of conditions - the internal conditions generated by the problem and the external conditions determined by the site.

Similarly, Elder (1975:19) agrees with this through his statement that, "these moulding influences will control the design of the building from the very earliest stages, when the basic arrangement of volumes and spaces is being planned, leading to the determination of the building's general form." He goes on to reinforce this statement by further advising that, "once the general form of the building has been determined, the next step is to design the building's fabric and the incorporated environmental and utility services" (Elder, 1975:19). This brings to the surface a number of important issues relating to form. Firstly, once form of the building has been realized then the detailing of the building generally can commence. Secondly, there exist constraints that have to dictate the composition of form, and lastly, there exist some process of realizing this form (i.e. design process).

In this regard, this chapter has discussed and illustrated the design process, analyzed the role of all the players in the design process and eventually established all the constraints encountered in realizing architectural form. These constraints formed the design problem and have later been discussed in Chapter Three to realize architectural form elements that subsequently become the centre of discussion for the research.

2.2 Design process

Shoskkes (1990:8) has pointed out that, architect Robert Geddes has described the architect as a composer. He goes further to argue in an attempt to support this that, "indeed, getting almost any project built today requires a collaborative effort orchestrated with as much innovation and imagination as the creative act of design itself. Design is decision making, and the key to successful projects lies not only in the final form but in the process leading up to it. Poor design decisions can be costly to correct or have lasting social implications. The design of the process must be as carefully considered as the design of the form."

Contributing towards the same goal, Vandyke (1990:viii) has pointed out that, "design is a problem solving exercise" and..., "it involves a cyclical, yet progressive process of evaluation, synthesis, and refinement of design ideas." To explain this he adds, "designing is not however, simply entering in information and having a solution spew out. It is like a creative battle that is often won or lost in the initial stages of the struggle. Good design relies on solid and well-organized concepts to ensure victory. These concepts are the result of the cyclical process that is fundamental to design problem solving." Similarly, Ching (1979:10) shares the same opinion:

> The first phase of any design process is the recognition of a problematic condition and the decision to find a solution to it. Design is, above all, a wilful act, a purposeful endeavour. The designer must first document the existing conditions of a problem, define its context, and collect relevant data to be assimilated. This is the critical phase of the design process, since the nature of a solution is inexorably related to how a problem is perceived, defined, and articulated.

This is why, as further reported by Ching, Piet Hein, the noted Danish poet and scientist put it this way. "....The shaping of the question is part of the answer."

In this regard, when developing the design "the architect must take account of many constraints including those imposed by the client's specific and preferred requirements; factors related to the site and their environment; cost considerations, the effects of legal rights and responsibilities, planning and building legislation and procedures, together with controls exercised by the needs of building engineering services and the limitation of construction techniques (Thompson, 1990:64)." This is because, "the environment is bound to be composed of many points which combine to create planes of shape, which unite to become volumes of form, and the void remaining is called 'space'" Vandyke (1990:4). This is greatly supported by Ching (1979:10) when he states that, "the arrangement and organization of the elements of form and space will determine how architecture might promote endeavour, elicit responses, and communicate meaning." [and], "these elements of form and space are presented, therefore, not as ends in themselves, but as means to solve a problem in response to conditions of function, purpose, and context - that is architecturally." Therefore, it became very useful for this research to realize the basic elements of architectural form and space, understand how they come about and how they can be manipulated in the development of a design concept, and realize their visual implications in the implementation of a design solution. This is because, architectural order is created when these elements and systems, as constituent parts, make visible the relationships among themselves and the building as a whole. Or, when the relationships are perceived as contributing to the singular nature of the whole, then a conceptual order exists. Thus form could be said to exist.

However, it should not be forgotten that the basic elements of architectural form and space can also be realized by dismantling the existing form. But, since there is no particular building form that consists of all these elements then it became difficult to adopt this system. Therefore, the former system was adopted.

Thus, it was necessary to illustrate the design process (Table 2.1.) and later in the Chapter discuss the role of the members of the design team to realize the constraints/problems encountered in the design process. This enabled the definition of the problem whose solution (i.e. form elements) was realized in Chapter Three.

Table 2.1. The Design Process

Stage	Purpose of work and Decisions to be reached	Tasks to be done	People directly involved
(a) Inception (i) Inception (ii) Feasibility	To prepare general outline of requirements and plan future action. To provide the client with an appraisal and recommendation in order that he may determine the form in which the project is to proceed ensuring that it is feasible, functionally, technically and financially.	Set up client organisation for briefing. Consider requirements, appoint architect. Carry out studies of user requirements, site conditions, planning, design, and cost, etc., as necessary to reach decisions.	All client interests, architect. Clients' representatives, architects, engineers, and QS according to nature of project.
Preliminary sketch design	To determine general approach to layout, design and construction in order to obtain authoritative approval of the client on the outline proposals and accompanying report.	Develop the brief further. Carry out studies on user requirements, technical problems, planning, design and costs, as necessary to reach decisions.	All client interests, architects, engineers, QS and specialists as required.
Final design	To complete the brief and decide on particular proposals, including planning arrangement appearance, constructional method, outline specification, and cost, and to obtain all approvals.	Final development of the brief, full design of the project by architect, preliminary design by engineers, preparation of cost plan and full explanatory report. Submission of proposals for all approvals.	All client interests, architects, engineers, QS and specialists and all statutory and other approving authorities.
Brief should not be modified after this point.			

Source: RIBA, 1967:Part 3,220

Design details, production drawings and tender stage (i) Details design	To obtain final decision on every matter related to design, specification,and cost.	Full design of every part and component of the building by collaboration of all concerned. Complete cost checking of designs.	Architects, QS, engineers and specialists, contractor (if appointed)
Any further change in location, size, shape, cost after this time will result in abortive work.			
(ii) Production information (iii) Bills of Quantities	To prepare production information and make final detailed decisions to carry out work. To prepare and complete all information all information and arrangements for obtaining tender.	Preparation of final production information i.e. drawings, schedules and specifications. Preparation of Bills of Quantities and tender documents.	Architects, engineers and specialists, contractor (if appointed). Architects, QS, contractor (if appointed).
Tender action and construction stage (supervision period) (i) Tender action (ii) Project planning (iii) Operations on site (iv) Completion (v) Feed-Back	To complete all arrangements for appointing contractor. To enable the contractor to programme the work in accordance with contract conditions. To follow plans through to practical completion of the building. To complete all activities necessary for handing over building o client. To analyze the management, construction and performance of the project.	Receiving priced B of Q and recommending contractor. Brief site inspectorate and make arrangements to commence work on site. Hold site meetings and concentrate on construction and supervision. Commissioning and testing of services installations. Analysis of job records. Inspections of completed building. Studies of building in use.	Architects, QS, engineers, contractor, client. Contractor, sub-contractors. Architects, engineers, contractors, sub-contractors, QS, client. Architects, engineers, contractor, QS, client. Architect, engineers, QS, contractor, client.

2.3 Role Played by Respective Members of Design Team in Influencing Form

Role Played by the Client in the Design Process in Influencing Form. First and foremost once the client has considered the need to build, he sets up an organisation with a chairman to manage the matter from the client end e.g. committee or working party, departmental representatives, secretary, decision making machinery liaison representation for design team, etc. Once he has appointed the architect and henceforth appointed or confirmed appointment of the other members of the design team, then he is charged with the responsibility of providing the following information on the following issues to the architect to facilitate the kicking off of the design process.

(a) Nature of project

The Client should provide outlined description of:

(i) Function of project

(ii) Services required

(iii) Standards of finish required

(iv) Furniture and fittings to be provided

(b) Site

The Client should provide:

(i) Plot and site boundaries

(ii) Survey showing the current boundaries, beacons and levels

(iii) Details of legal position of land

(c) Accommodation requirements

The Client should provide:

(i) Schedule of areas of accommodation required with size/quantity indications

(ii) Explanation of special requirements

(iii) Explanation of special processes

(iv) Numbers of persons to be accommodated and staff to be employed and persons using the building

(v) Machinery requirements

(vi) Mechanical requirements

(vii) Any detailed special room data requirements

(d) Expenditure intended

(i) Cost limit, if any

(ii) Method of financing building

(iii) Budget if any

(iv) Any detailed requirements regarding cost.

These information provided by the client becomes the basis upon which the architect derives the brief and hence the concept of the building des.gn. The brief refers to the summary of the information (requirements and objectives) of the client presented in advance to help the design team create a built up form. The client's functional/organisational requirements enables the designer to establish the internal concept of the building. The internal concept touches on issues like, circulation arrangements, location of services, floor areas, provision of special services, etc. Also the brief enables establishment of the external factors which define the physical limitations of the building such as availability of public service, site survey, plot ratio, floor space index or residential densities, site coverage, building lines, maximum building height, adjoining buildings, right of light and right of way, proposal permissible points of vehicle access, extent of control of external elevations by local planning authority and environmental character of the area. In this regard, in drawing up the brief the design team is charged with the responsibility of making sure the most economical overall scheme is achieved. This implies that the duty of the consultants is to accommodate the client's requirements in a building form within a certain environment that consists of various external constraints. In this regard, the design process solves two sets of constraints: the internal and external constraints. The compromise of these sets of constraints becomes the solution/building form. These constraints are summarized later in this Chapter and discussed in Chapter

Three to show the realization of form elements.

Role Played by the Architect in the Design Process in Influencing Form. First and foremost, the architect is charged with the responsibility of leading the Client and the design team. The architect's field of action may vary according to the time of his appointment; however this study assumes the earliest possible appointment. This implies that the architect has management and design roles to execute, however the design function is more relevant at this level. This role changes from one stage to another.

At the inception stage, the architect carries out studies on site, user information, local conditions, etc., appropriate to facilitate preparation of the feasibility report. This includes establishing facts about boundaries, rights of light, easements, etc., making preliminary enquiries with Local Authority, Local Planning Authority, etc., and obtaining outline planning consent. All these aspects are seen to influence various form parameters and hence form later in Chapter Three.

At the preliminary sketch design stage, before the architect and hence the design team comes up with the outline proposals, the architect carries out various studies relevant to the preliminary sketch design stage. This include studying published analysis of similar projects, visit if possible, studying circulation and space association problems and trying out detail planning solutions and studying effect of planning and other controls. Secondly, in consultation with team the architect assimilates information obtained above and produces diagrammatic analysis, and then discusses possible problems. Actually, the findings from the above studies acts as guidelines and these enables him to try out various general solutions; discuss with team; modify as necessary, and decide on one general approach. After this, then the architect is able to prepare outline scheme, indicating, e.g., critical dimensions, main space locations and uses and then passes it to team to facilitate input from other team members. It should be seen here that, the facts established at the inception stage acts as the constraints whereas the information gathered from the above studies acts as the guiding design principles. Thirdly, the architect assists the Quantity Surveyor in preparation of outline cost plan, discusses and decides on cost ranges for main elements, of which eventually becomes a factor/constraint in determining the extent of the building form. Then, all the sketches and cost plan are presented to the client for his approval. The approved sketch design becomes the concept upon which the final design is based.

The final design stage at times referred to as the scheme design is the third stage in the design process. At this stage, the architect is charged with the responsibility of first, completing any outstanding user studies, carrying out further visits and interviews as necessary. Developing detail planning solutions in the light of further information and the outline scheme adopted in the scheme plan stage. Secondly, the architect consults other team members on the results of their work regarding the above. Then, the architect consults planning and other authorities on outline proposals. This enables facilitate preparation of full scheme design including planning arrangement, appearance and construction method. These scheme drawings are then passed to the Quantity Surveyor and engineers to ascertain the implementation of their input. Once the design team is fully aware of the stage of the scheme design then the design is reviewed and modified as necessary. With the engineers, the architect assists the Quantity Surveyor in preparation of final cost plan and specifications. Thus, the final design is obtained and as such it is recommended that the brief should not be modified after this stage (RIBA,1967:3,220).

The design details, production drawings and tender document stage comprises of detail design, production information, bills of quantities and tender action. Regarding the detail design, the architect carries out detail design according to programme, in close collaboration with the engineers and the Quantity Surveyor for cost checks and engineers and specialist drawings. Once all the drawings and cost checks are complete and the architect obtains team agreement that no further change in size, shape, location or cost, is necessary then, the building is said to have been achieved. This is because the building/the dimensional view of the building that is referred to as form has already been obtained and any further change in size, shape, location or cost will mean a totally different building/form and hence would result in abortive work. Secondly, this is the drawings/information upon which the final detailed decisions regarding production e.g., setting out drawings, specifications, schedules, quotations eventually included in the Bills of Quantities as Prime Cost sums are based.

Once all the tender documents are complete e.g., schedules, specifications and Bills of Quantities as per the final drawings and the contractor(s) are appointed, then the architect together with the other members of the design team makes sure the construction is undertaken and the actual building delivered to the client as per the above documents. It should be noted here that, construction is implementation of decisions undertaken in previous stages. Thus the building as an idea is realized at the design details, production drawings and tender stages, whereas this idea is realized as a physical object after the construction stage.

Role Played by the Quantity Surveyor in the Design Process in Influencing Form. Similarly, at the inception stage, the Quantity Surveyor carries out studies on site, user information, local conditions, etc., appropriate in preparation of a feasibility report. These include, considering special site problems, access, etc., appraising level of local building costs, considering probable price trends and assembling cost information on similar projects. These aspects are very important as they have a bearing on the feasibility of the project in principle. This is because these aspects give an idea of the cost range at a certain level of quality which must be within the client's cost limit for the project to be feasible.

At the preliminary sketch design stage, the Quantity Surveyor is charged with the responsibility of obtaining all significant details of client's requirements relevant to cost and contract information on site problems, etc., and re-examining, supplementing and confirming cost information assembled in the previous stage. Secondly, the Quantity Surveyor outlines design implications of cost range or cost limit. This is done by preparing cost studies of alternative structural and services solutions, and advising on economic aspects of solutions. Thirdly, the Quantity Surveyor confirms the cost limit or gives firm estimate based upon user requirements and outline designs and proposals. This enables preparation of outline cost plan in consultation with team from approximate quantities based on assumed specification. This outline cost plan acts as a guide of the distribution of cost to various building elements and in turn influences the extent and specifications of these elements.

At the final design stage the Quantity Surveyor notes architects' and consultants' standards of quality and prepares draft cost plan based on final design and statements of quality standards and functional requirements received from architect and engineers. This cost plan realized and adopted becomes a guide in the detailing of the various building elements. Thus at the design details, production drawings and tender document stage, the Quantity Surveyor(QS) is charged with the responsibility of carrying out cost studies and cost checks as the detail design is carried out and inform the architect and engineers of results immediately and if possible give advice. This is important because as the detailing process goes on, some elements might exceed their cost limit determined early in the cost plan and as such a solution needs to be sought as to the source of these extra finance, otherwise the building needs to be reduced. Anyway if the building requirements have to be met then, alternatives of such problem are either to adjust the detailing of the elements that have exceeded their cost limit so as to meet the cost limit or, to adjust the detailing of other elements to create the needed finance. Thus, the cost plan plays a great deal in moulding the individual building elements and hence the whole three dimensional building form, as all the building elements are related. Then, the Quantity Surveyor maintains liaison on drawing production as a clear understanding of the production information enables preparation of accurate Bills of Quantities, clear detailed drawings, schedules and specifications thus implying easier management of the construction process and hence the realization of the actual three dimensional building form.

Role Played by the Engineer (Civil and Structural) in the Design Process in Influencing Form. At the inception stage the civil and structural engineer carries out studies on site, user information, local conditions, etc., appropriate in preparation of feasibility report. These include obtaining geological records, rainfall figures, etc., enquiring from Local Authority(LA) about soil conditions, sewers, planned roadwork, etc., and broadly considering foundation types, types of structure, access, drainage, water supply, etc. This issues are important in the sense that, if for instance the soil is black cotton and extends to a depth that requires pile foundation that is actually very expensive, then, the project based on that particular site/location is not feasible. Thus, the engineer is then required to indicate probable optimum solutions and by aid of rough sketches show effects of alternatives. The engineer also assists in the preparation of feasibility report and in the process states the feasibility of alternative solutions by aid of sketches. This sets the ball rolling in determining some of the building elements like spacing of columns, extent of building below ground level, etc.

The preliminary sketch stage involves carrying out studies that enables determine general approach to layout, design and construction. These studies include site surveys, soil investigation and investigation on structural and civil requirements of the building. Once these studies are complete the engineer advises the architect on types of structure, methods of building, types of foundation and roads, drainage, water supply, etc. This proposal helps the architect in preparing sketch plans and the Quantity Surveyor in preparing the cost plan for the project and in particular the building elements that require civil and structural engineer's input. In addition to this, the engineer's proposals determines the spacing of columns and beams, extent of building below ground level, room heights and opening spaces left once the structural elements are in place.

At the final design stage, the civil and structural engineer lists the design criteria for confirmation by all members of the team. Once he receives final design drawings, he makes design sketches and calculations to define full scheme, e.g., section sizes and materials, foundations, drain runs, etc. This facilitates preparation of rough specification notes and in turn assists the architect and the Quantity Surveyor in finalizing the final design drawings and cost plan respectively.

At the design details, production drawings and tender documents stage, the engineer confirms the loadings, etc., then carries out detail design according to programme in close collaboration with the rest of team. He also keeps others informed of design decisions e.g., detail section sizes, concrete mixes, joint details, etc., and notes other consultants' design decisions. Working in close collaboration with rest of team is very important as a change in structural design/specification definitely influences other issues e.g., cost, etc. In this regard the engineer completes structural and civil drawings in collaboration with the other members of the team and also obtains team agreement that no further change in size, shape, location or cost, is necessary.

All these issues the civil and structural engineer is confronted with e.g., soil conditions, rainfall, Local Authority requirements/regulations, site conditions, user requirements/loading, etc., are later discussed in Chapter Three and their role in influencing form is realized. Thus the role of the engineer as such is to design a building structure/envelope that withstands the above issues.

Role Played by the Engineer (Mechanical and Electrical) in the Design Process in Influencing Form. At the inception stage the Mechanical and Electrical Engineer carry out studies on site, user information, local conditions, etc., appropriate in preparation of the feasibility report. These studies include considering functional needs, obtaining preliminary views of local supply authorities, checking services locations and capacities, climatic conditions, air pollution, etc., and analyzing information and establishing preliminary environmental and services requirements. At this point the engineer states the feasibility of alternative service design solutions and assists in preparation of the feasibility report.

In assisting to realize the outline proposals, the engineer carries out initial studies relevant to the preliminary sketch design stage. These studies involve environmental conditions, user and services requirements, appraising Mechanical and Electrical (M & E) loadings on an area or cube basis and considering possible types of installation and analyzing capital and running costs, possible sizes and effects of major services installations, main services supply requirements. Secondly, the engineer advises the architect on design implications of studies made e.g., factors which would influence efficiency, and cost of engineering elements, i.e., site utilization, building aspect and grouping, optimum construction parameters, etc., possible services solutions and ramifications of them, regulations and views of statutory authorities. Thirdly, the engineer collaborates in preparation of outline scheme/sketch plan, checks that services decisions remain valid; records details of alternative plans and assumptions. Fourthly, the engineer provides the Quantity Surveyor with cost range information for outline cost plan, agrees the Quantity Surveyor's proposals and interprets agreed standards by aid of illustration.

At the final design stage the Mechanical and Electrical Engineer carries out any outstanding studies (e.g. by detailed analysis of environmental and functional requirements establish area services requirements), prepare services schematic design based on final outline drawings; indicate preferred routing and locations of major engineering elements. Secondly, the engineer contributes to the scheme design; reviews services proposals and confirms design, routing, location and overall dimensions of major services elements. These services are usually associated with the service core and the artificial lighting and influence form of the building a great deal as realized later in Chapter Three. Thirdly, once the Mechanical and Electrical Engineer receives the final design drawings, he finalises Mechanical and Electrical final design, including form of lighting, heating, air distribution, etc. He then, presents this results to the architect and confirms sizes, locations and routing of major services elements. This in turn assists the Quantity Surveyor in finalizing cost plan. Also it is worth mentioning at this point that, if for instance the sizes of pipes passing through a column changes, then, the column size also changes. Or, if the form of lighting changes, then, the sizes of windows, depth of space and generally size of space are bound to change. Thus, all parameters of the building are related and as such, if one changes the others are bound to change and this is why close collaboration between the members of the design team is very important. Also it is for this reason that the Mechanical and Electrical Engineer must provide performance specification of the equipments specified.

During the design details, production drawings and tender stage, the Mechanical and Electrical Engineer carries out detail design including lighting fittings, heating or air-conditioning units, ceiling and cill details, etc., according to programme in close collaboration with rest of team. The detailing of such equipment e.g., determining the exact location, size, etc., of each influences the building elements. For instance, the air-conditioning units are different types with regard to the way they throw out air i.e., upwards, horizontally or inclined, and as such they require different locations. For instance the one that throws air horizontally is put in the ceiling and as such it requires extra space above the normal storey height. In this regard the Mechanical and Electrical services are bound to influence the form elements.

Lastly and similarly, such design constraints confronted by the Mechanical and Electrical Engineer e.g., functional needs, services, climate, air pollution, environment, local authority regulations, technology used, etc., are discussed later in Chapter Three to show how they influence form of office building.

2.4 Conclusion

Constraints tackled by the design team to realize building form are:

(a) Client's requirements regarding

(i) Nature of project

(ii) Accommodation requirements

(iii) Expenditure intended

(b) Site conditions i.e.

(i) Boundaries

(ii) Access

(iii) Soil conditions

(c) Environmental conditions

(d) Climatic conditions i.e.

(i) Rights of way

(ii) Rights of light

(iii) Easements, etc.

(f) Building regulation e.g. zoning

(g) Function and user requirements

(i) Circulation

(ii) Space association

(iii) Service requirements

(iv) Loading requirements

(h) Cost limits

(i) Technology and materials

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CHAPTER 3

DESIGN CONSTRAINTS AS FORM DETERMINANTS

3.1 Introduction

"Architecture is concerned with providing a form that will function aesthetically (Beedle, 1986:53)." On the other hand, the successful building is one that appropriately integrates the function or users requirements into the design as hinted by Manasseh (1962:33) that, "....the successful building developer is the man who takes the free gift of daylight, and combines with his floor space to let or sell by the foot." According to Bailey (1990:9) the users are those who will actually use the building: they may live, work, play or relax in it. They may be permanent inhabitants or employees who use it daily, or members of the general public who visit it regularly or occasionally. In this regard, Pye (1978:12) concludes that, "....plenty of people do really believe that form can follow function; that if you thoroughly analyze the activity proper to the thing you are designing, then your analysis will provide all the information needed, and the design can be derived logically from the function." This agrees with Duffy (1976:25) that "the form of the building can be too closely designed to fit the organisation's form at the time of design...." This is because any major organisational changes if not catered for in the initial design may be severely restricted by the building form. This indicates that any building has some order or "design is form - making in order (Ronner, 1935:70)." This clearly supposes that in order is creative force which in design means - where, with what, when, with how much. And thus, the nature of space or form reflects what it wants to be, since in the nature of space or form is the spirit and the will to exist a certain way. Although design must closely follow that will as already realized, the will underlying the form of office buildings does not only emanate from the aesthetic, client's and functional requirements only, but also from the factors related to site, environment, economy i.e. cost considerations, planning and building legislation and procedures, technology, together with controls exercised by the needs of building engineering services etc.

In a nut-shell therefore, the constraints realized in Chapter Two and listed below are therefore discussed in this chapter to see how they generate form elements and ultimately architectural form (and hence space) of the office buildings. This is intended to establish elements that can be said to generate form of which are used to measure form in the subsequent chapters of this study.

(a) Client's specific and preferred requirements

(b) Site

(c) Environment

(d) Climate

(e) Legal requirements

(f) Building regulations

(g) Function and user requirements

(h) Technology and materials (or form and the nature of materials)

(i) Cost limits

3.2 The Influence of Design Constraints on Building Form

Client's Specific and Preferred Requirements. Walker (1989:63) observes that, "....client or the owner of the project [is] the body that has the authority to approve expenditure on the project, the form that the project has to take, and its timing and who pays the fees." In this respect, the client adds another dimension to the challenge of creativity to both the architect and the engineer. After Walker (1989:65-69) and Beedle (1986:54-55), there are four major client categories: the developer or the speculative client, the corporate client, the institution, and the government or public client. All these categories of client influence the design and hence form of the building in one way or another.

Whatever category of client, information supplied to the consultants is similar. This touches on nature of project, site, accommodation requirements and expenditure intended (G.K., 1989). The nature of the project suggests the circulation arrangements, materials to be used, etc. Site limits, levels and ownership suggests the type of building, size, etc. Accommodation requirements suggests total plinth area, space requirements/size, planning grid, circulation arrangements, services requirements and positioning, etc. And finally the expenditure intended suggests the total plinth area/size of building, materials to be used and quality, etc.

<u>Site.</u> Thompson (1990:66) has noted that, "since most of the ideal sites have been used, nowadays it is common to find sites of awkward shape, or on steeply sloping ground, or having poor subsoil, or uninviting surrounding." In this regard, site selection and planning are often the first steps in the design process. Frequently a project coalesces around a particular site or a client's need to expand or renovate an existing facility. As reported by Shoskkes (1990:15), Robert Geddes has written (in process: Architecture #62) that, the "site is not only the setting but the stimulus for architectural form." However, what can be built on a

given site is conditioned by a number of constraints beside the physical site, including zoning, codes, restrictions incorporated in historic or redevelopment districts, covenants attached to deeds, engineering difficulties, and community social values. Further Shoskkes reports Geddes pointing out that, context is both a function of time and place. Buildings are only one element in a continually changing landscape. Thus it is very important to address the issue on how to harmoniously unify architecture, landscape, and the community. This concurs with Baker's (1984:4) who quotes Arnheim (1954:368), when discussing the site forces which underlie artistic expression thus:

> The work of art is far from being merely an image of balance....Just as the emphasis of living is on directed activity and not on empty repose, so the emphasis of work of art is not on balance, harmony, unity,but on a pattern of forces that are being balanced, ordered, unified.

For one to realize how the site actually influences the architectural form, it becomes important to analyze the factors related to the location of the site. These factors related to the site include among others the following.

(a) The actual plan shape of the site

(b) Site contours and site accesses

(c) Site orientation

(d) Boundary features and existing features on the site

(e) Topography

(f) Subsoil

(g) Services, and any underground hazards

(a) Actual plan shape of the site. It is rarely possible to build over the whole of the site. Instead the available space has to be apportioned between buildings, roads, circulation and parking areas, the landscaped and open spaces. The spaces allocated to the actual buildings obviously govern the size and shape of the buildings elements. This governs especially the ground floor or a typical floor in case of a vertically uniform building on tight sites in urban areas. Similarly, the size and shape of the site influences the volume and the form of the building it carries.

On the contrary, wherever there is flexibility of siting a building the architect may choose to use geometry to generate form, where "geometry is a formative idea in architecture that embodies the tenets of both plane and solid geometry to determine built form" and "a formative idea is understood to be a concept which a designer [or the architect for that matter] uses to influence or give form to a design. The idea offers ways to organize decisions, to provide order, and to consciously generate form (Clark, 1985:6)." Thus, depending on the nature of the site various building forms can be generated.

The geometry adopted in turn influences the structural grid used in designing the structural system of the building. This in turn similarly influences the planning, construction and servicing grids.

(b) Site contours. A steeply sloping site influences the levels of the ground floors, which could result in a split level solution, as compared to a flat floor that might result from a flat or gentle sloping site. More so, if the contours are pronounced, it is almost certain to influence the siting of the building(s) on the site, location of the entrances and even the massing.

The level of the site in relation to the roads and the site entrance influences the site access and internal road layout. This in turn influences the storey heights of the floors relate to entrance levels.

(c) Site orientation. The orientation of the site, relative to the north point, influences the position of accesses/entrances and windows. This is because the orientation governs the quality of sun the various elevations receive. There is an obvious advantage in ensuring that the rooms in which people spend most of the daylight hours have the most sun. However, within the tropics, nobody wants his office to face the East-West direction because this means receiving the maximum solar heat. Thus, it is preferable within the tropics to face the office buildings North-South so as to admit soft light and keep away the heat, which would demand an intensive air-conditioning of the office spaces. On the other hand, within the temperate regions as the direct sun is away from them, the architects have all the reasons to have their buildings facing north or south so as to capture maximum daylight.

(d) Subsoil. The subsoil influences the type of structure, and possibly the height of the buildings. It is one of the major factors that influence the cost of the building. If, due to a poor subsoil (i.e black cotton soil), pile foundation are used as alternative to extensive cutting away of the soil and back filling, it means expensive foundation costs. This implies less money available for other elements of the building. Thus, this in turn influences the overall design and form of the building.

(e) Boundary features and existing features on site. Usually, architects give consideration to any existing physical features on the site. These are bound to influence the siting of the proposed building. These features could include a lake, some attractive mature trees which need to be retained, etc. If these features have to be respected, it means siting the building outside these physical features, or incorporating them within an internal courtyard around which the building is designed. Either way, the siting and plan shape of the building are likely to be influenced. In addition there could be existing buildings on site which need to be retained, or incorporated within the new buildings. These also acts as a constraint on the design. In effect the shape and size of the plan are influenced and even the height and orientation as later realized in respect to light and noise.

(f) <u>Services, and any underground hazards.</u> Existing services either below or above ground level, influences the location of the building on the site, and could in the same cases restrict the size of the building. They could also influence the position of those rooms requiring service connections. For instance, the transformer room needs to be nearer to the electricity line.

<u>Environment.</u> According to Thompson (1990:), "the environment refers to the things surrounding the site." This is often of particular importance to the prospective occupier of a building, and is likely to influence and

act as a constraint on the design of the building. For instance, if a particular side of the plot/site looks out on to attractive countryside, this is likely to affect the siting of the building and the location of windows. Similarly, if another side of the site has a less attractive outlook, such as a railway line or motorway, the designer or architect is likely to position the less important rooms for instance toilets, stores etc, on that side of the building. If existing buildings surround certain parts of the site, the architect may plan his buildings to avoid looking out into the existing structures, in order to ensure the maximum privacy for the building's occupiers. It is therefore appreciated that the existing landscape and the buildings surrounding the side are likely to influence the juxtaposition of the building and the position of the windows. In this regard, it also influences the massing, orientation and shape of plan.

In addition to this, the occupier of any type of building is likely to need access to various facilities, including transport services, and thus would influence the building location on the site and the building entrances.

<u>Climate.</u> Climate is another factor which acts as a constraint on building design, and affects the siting and

appearance of buildings.

Climate is said to be attributed to the following:

(a) Sunlight

(b) Rainfall

(c) Wind

(d) Noise

(e) Snow

(f) Pollution (i.e dust, odour, salt, sand)

(a) Sunlight. Bossom (1934:15) argues that, "what architects know as the law of light favoured the skyscraper from its inception and has immensely influenced its subsequent development." Egypt, for instance, with its intense blue sky and dry atmosphere, is a land of deep black shadows. Hence its architecture has no heavy projecting mouldings, but tends to large flat surfaces with plain rounded columns. Whereas, in North America the light is particularly hard and white and the shadows uninteresting, it makes the Mexicans to have evolved an architecture of simple surface decorations with no cornices but with a strong emphasis on ornamented angles to form a towering silhouette. In this regard Bossom (1934:15) goes further to argue that "...it was almost a law of architecture necessity that the Americans in stretching their buildings skywards come to use the same treatments of flat surfaces, set-backs and ornamented silhouette."

Figure 3.1. Building with set-backs.

Source: Bossom (1943:15)

With a towering silhouette, it becomes evident that the daylight influences both the plan, elevations, sections and even three-dimensional aspects of the building. These influences are illustrated by the following aspects.

(i) Light and overshadowing i.e., relationship of buildings in respect to light. Duffy (1976:38) argues that with the exception of permitted openings in relation to adjacent buildings, overshadowing of one building by another is prevented by the use of such method as daylight "fan" guides rather than statutory controls; nonetheless, these influences the bulk and shape of buildings.

(ii) Light penetration into the building i.e., relationship of light and depth of building. Duffy (1976:38) argues that, depth of the office buildings as well as the proportion of glazing in the envelope may be influenced by using daylight factor methods in order to achieve acceptable light levels within the building. In contributing towards the daylight level acceptable for interiors of office buildings, Manasseh (1962:34) points out that, "the size and height of windows affect the penetration of daylight, so also does the width of each room." Further on, Manasseh generally concludes that the floor area can be divided into three zones of light; natural light, reaching 12 feet into the room; a further 10 feet where supplementary artificial light is needed; and a zone of total artificial light which in the normal shallow slab block would be used for storage, circulation and ancillaries only, in planned deep block would have a very high standard of artificial light and be used as normal office space.

Supplementary artificial light according to Manasseh (1962:36) means artificial light which is used to augment daylight, rather than that which replaces it. Thus, it becomes very evident and agrees with Manasseh (1962:36) that by increasing the space which appears to be lit by daylight, supplementary artificial lighting influences plan shapes considerably. With new buildings deep and compact blocks may be used which leave large open spaces around them, thus improving the natural light reaching them and their neighbours.

The use of supplementary artificial light has brought about the use of total artificial light in the centre of deep office blocks. This is why Duffy (1976:38) concludes that "permanent supplementary artificial lighting of interiors and the use of even greater proportions of artificial light has liberated the office from the constraint of reliance on daylight and energy consumption apart, makes deeper buildings acceptable." However, if one seriously wanted to keep to low energy consumption cost, then, the alternative would be the creation of interior courtyards, atriums, voids or light wells within the building so as to allow penetration of daylight from both directions as compared to the one direction discussed above. But, all the same this alternative has a limit to the maximum depth of building that can effectively receive enough daylight from the two mentioned directions. Thus it is very evident that the daylight penetration into the building dictates the following parameters of the building form.

(i) Depth of building,

(ii) Height of windows and hence storey

height of buildings,

(iii) Size of windows in terms of areas,

(iv) Planning and creation of light wells.

(iii) Thermal environment of buildings (i.e solar heat gain in respect to orientation of buildings). Manasseh (1962:39) argues that, "heat gains from outside are a major design problem..." However, he goes further to point out that plan use, plan form, orientation and the choice of construction and materials can make effective contributions to the design of the thermal environment. This is in agreement with Duffy (1976:51) as he points out the ways by which solar radiations affect buildings.

(i) Entering through windows absorbed by surfaces inside the building thus causing a heating effect,

(ii) Absorbed by outside surfaces of the building creating a heat input into the fabric which is partly emitted to the outside, mostly by convection, but partly conducted through the fabric and subsequently emitted to the inside.

In addition to this, Duffy (1976:51) goes further to argue that, the effects caused by heat gains can be influenced by the designer or architect and more so the transmission of heat through windows is determined by:

(i) Orientation of the window (thus, the intensity of radiation incident on its surfaces),

(ii) Size of the window,

(iii) Type of glazing (clear, heat absorbing, heat reflecting or photo-chromatic glasses), and

(iv) Shading devices, either external (grilles, louvres, canopies, awnings, shutters) or internal (blinds,curtains).

These factors are summarized in the following formula.

$Q_s = I \times A \times i$

where Q_s = solar heat gain in watts

A = Window area in metres squared

i = Solar gain factor

I = Intensity of radiation incident on the window

(b) Rainfall. The architect needs to consider the expected rainfall on a building to enable him design the drainage system correctly, and to make the correct decisions which would prevent rain penetration. Thompson (1990:68) has observed and recommended that, flat roofs cause rain penetration due to incorrect design and construction as such the problem can be solved by using a fairly steeply sloping roof. Obviously such a decision will affect the appearance of the building. However regions like the Middle East where rainfall is low and due to hot weather the inhabitants may wish to sleep on the flat roof, the roof is more likely to be flat. Hence, this introduces the two roof alternative forms, that is, being flat or pitched, depending on the amount of rainfall, function to carried out at the rooftop and the intended appearance of the building. For instance, the need for extension of the roof garden, waving bay in case of airport, etc., all requires a flat roof. While the need for large internal space or due to large amount of rainfall may require pitched roof.

The roof type in turn influences the volume enclosed by the building, total height of the building and even the total external wall surface area.

(c) <u>Wind</u>. Wind can often drive rain into buildings through say window openings. Thus, the direction of the wind influences the location of walkways and entrances. Again the shape of buildings affects the wind strength in certain directions. Thus, if the expected wind force on a wall is considerable, it would have to be strong enough to resist such pressures, and this in turn influences the construction and materials used. The lifting of lightweight roofs by suction also needs to be considered in areas of high wind pressure. This is because, any consideration is bound to have a bearing on the overhangs.

(d) Noise. In discussing the design process Lord (1986:12) notes that:

> The form of the building may allow 'buffer' screening of sensitive spaces, and the arrangement of rooms may allow those requiring quiet conditions to be remote from noise rooms, with fenestration limited and not facing any external noise source.

This agrees with Thompson (1990:68), who notes that "particular care will be taken with the location of rooms requiring quiet conditions, including the positioning and size of windows and other openings." This is with regard to the noise originating from places such as airfields, railways, motor traffic routes, industry, and public playgrounds, of which the architect considers. This is due to the fact that such noise (i.e unwanted noise) is bound to affect the siting of the building, for instance, keeping it as far away as possible from noise sources if at all things like windows have to be provided on the sides facing these sources.

Similarly, Croome (1982:30), has pointed out that, if it is estimated that the external noise is excessive, the internal layout of a building could be changed in order to protect the more critical areas. He gives an example that, residential dwellings may need to have bathrooms and the kitchen facing the noise sources whereas, the bedrooms and living rooms are kept at the other side away from the noise sources for instance, road traffic, railways, etc. Alternatively, the external walls facing the noise source may have few or no windows in them, as the sound insulation provided by a window is much less than that of a solid wall. With regard to offices, he notes that, it may be desirable to have communication areas, corridors, stairs and lifts, situated round the perimeter of the building, thus providing extra distance and extra structure for the noise to penetrate before reaching the critical areas.

With regard to noise created internally, that is, created by mechanical and electrical services for instance, fans, ducts, pipes, sanitary fittings, cooling towers, compressors, boilers, motors, pumps, light fittings and lifts, Croome calls for the provision of separate structure for some of these systems or fittings e.g., lifts, boilers, etc., and buffer zones between the quiet areas and areas consisting these fittings or systems. Thus, this generally influences the planning layout of the building and hence determining the location of service cores, lift machine rooms, and even the circulation system.

(e) Snow. Snow is less likely to be a problem within the tropics, but, whenever snow is frequently in existence especially around the temperate regions, the designer or architect need to consider the weight of snow on the roof. Also the architect need to prevent snow entering the building in case of defect on roof. This makes it mandatory for architects to provide steeply pitched roofs to buildings built within these regions.

(f) Pollution (i.e dust, odour, salt, sand etc). The amount of dust, odour, salt, sand, and man made additions to the air, such as wastes from chimneys, affects the degree of pollution surrounding the building. The resulting pollution may damage people's health and also adversely affect building materials. This inevitably influences the choice of building materials, and hence the appearance of the buildings.

In summary therefore, it should be readily appreciated that climate varies considerably from country to country, and it is also true that there are variations between various parts of any one country. Thus, it is for this reason that architects often use the weather man to help them create buildings which mitigate the worst effects of our climate.

Legal requirements. The law affecting construction work is complicated and extensive, and acts as a considerable constraint on the design of the building. It includes the law of property and land, environmental powers, including statutory consents and planning law, and laws relating to building contracts. This makes it imperative for the architect to know how to use the building regulation i.e., the zoning ordinance and all other laws and regulations mentioned above. Thompson (1990:68) has observed that, the laws of property and land may influence the design of a building in respect to matters such as boundaries, easements, restrictive covenants, and highway laws. This is summarized in Table 3.1. below.

Table 3.1. Role of Laws of property and Land on building form.

Aspect of law	Influence on form
Boundaries	All building work is to be carried out on land which the client actually owns. Also at times exact distances from the building faces to boundary lines are relevant in order to be in conformity with certain building regulations. This influences the siting of the building.

Easements	Easements i.e. right of light, right of way, right of support, drain route, etc., must be respected. This influences the shape and size of the actual land to be occupied by the building's height, elevations, layout and generally form.
Restrictive covenants	Restrictive covenants predetermines the size and appearance of the building.
Highway laws	Such laws prescribe an improvement line i.e. a proposed widening of the street. This means less land available for building, thus influencing shape, size and planning of ground floor plan and hence the three dimensional image or form of building.

Source: Compiled by author.

Building regulations. Building regulations are concerned with the construction of buildings rather than their appearance. They are intended to ensure that the design and construction of a building ensures public health and safety. Beedle (1986:55) notes that, "...regulations are usually restraints, not opportunities. The exception is the incentive zoning that allows the builder greater height or bulk in exchange for providing certain amenities." These regulations are intended to protect the user and the public at large from malpractice by building designers and contractors. In the Kenyan situation there exist a range of legislations that affect the architect and constrain his design. These legislations include Building Code, Town Planning Act, The Public Health Act, The Local Government Act, The Land

Planning Act, etc. However, the major and most commonly used one is the Building Code. Another planning aspect mostly commonly used in conjunction with the Building Code is the zoning regulation.

Zoning. A zoning ordinance is intended 'to promote and protect public health, safety, and welfare (Beedle, 1986:59).' Such ordinances are concerned with external characteristics such as land use, site coverage, and bulk of the building. In this regard, the zoning ordinance stipulates the types of buildings to be built in every section of the urban area, the proportion of site area to be covered by the building and the maximum floor area to be provided through the plot ratio (P.R.). If say the ground coverage is 80 percent and the plot ratio is 2.5 then:

Maximum ground floor area = (80/100) x Site Area

whereas, Total Plinth area = Plot Ratio x Site Area

= 2.5 x Site Area

This implies that the zoning ordinance influences the ground coverage, total plinth area, number of storeys, height of building, etc.

The Building Code contains issues like setbacks, height, parking, loading and signing that also influence the form of building. Their influences have been summarized in Table 3.2. below.

Table 3.2. Key Issues in the Building Code and their influence on Building Form.

Aspect	Influence on Building Form
Setbacks	Fixes a building line to provide land for street and services. This reduces the plot size and hence influences the ground coverage/shape, plinth area, number of storeys, height, etc.
Height	Fixes the maximum height of habitable room at 7ft. and canopy to be not less than 9ft. 6in. above the level of the footway. This influences the amount of external walling, height of walling, etc.
Parking	The Code allows a certain number of parking spaces per 100 m2 on site or within the building. Depending on the plot size and the plot ratio which determines the total parking spaces allowable, in turn influences the size of windows, ventilation, structural system and finishing materials to the spaces and to the building in general.
Loading	The loading safety factors are well stipulated in the building By-Laws/Code. This influences the distribution and sizes of the structural elements and in turn influences form elements like, storey height, total building height, rhythm, openings, etc.
Signing	The Code fixes the height of the non-illuminate advertisement at 12ft. above the level adjoining pavements or the top edge of the fascia of the canopy to the ground floor premises, if any whichever is higher. This in turn influences form elements like, height of building, etc.

Source: Compiled by author.

Function and user requirements. From the users point of view one requires among others the following to be able to execute any task in any office building.

(i) Access into the building or space i.e entrance and horizontal and vertical circulation routes,

(ii) Safety from any danger while in the building. This safety aspect may be with regard to structure, fire, etc.,

(iii) Work place area or useable area (i.e spaces in which it is possible for people to work at desks including secondary circulation),

(iv) Support facilities, for instance:

Core: Space needed for support of building, e.g lifts, stairs, ducts, lavatories.

Special areas: Spaces which cannot be used for office workers but is dedicated to particular function functions, e.g., archives, restaurant.

(v) Protection from climate hazards i.e with regard to solar heat, sound, daylight, etc.

These user requirements brings into light a number of planning aspects that in one way or another contribute towards the determination of the building form. These planning aspects include:

(a) Primary circulation and office layouts,

(b) Depth of space,

(c) Service core,

(d) Vertical circulation/Escape routes,

(e) Planning grid and space requirements,

(f) Structural grid,

(g) Construction, and

(h) Servicing grid.

These aspects are analyzed separately as follows, to realize their contribution in evolving the office building form, from inside out. It should be remembered that as stated early, the building form evolves out of two types of constraints, that is, the internal and external constraints. The function and user requirements form part of the internal constraints.

(a) <u>Primary circulation and office layouts</u>. After Obunga (1979:45), Tutt (1976:115), and Joedicke (1962:), it is evident that five types of office space layouts exist as follows.

(i) Single zone layout,

(ii) Double zone layout,

(iii) Triple zone layout,

(iv) Open layout, and

(v) Special layout.

These types of layouts are based on the provision of primary circulation giving access to the various parts of the layout.

Primary circulation is defined by Neufert (1980:225) as circulation essential to provide access and means to escape to work place areas.

These types of layouts are summarized in Table 3.3.

Table 3.3. Office Layouts and their Characteristics.

Types of Layout	Characteristics and remarks
Single zone	- Has rooms only on one side - Considered uneconomical as it has a higher ratio of circulation space to useable space compared to other layouts.
Double zone	- Has rooms arranged on both sides of a corridor. - Considered a typical solution for 'medium' sized office building. - Makes proper orientation for least solar heat gain a critical issue.
Triple zone	- All circulation facilities and sanitary accommodation are placed in a third or central zone in the interior of the building. - Considered to be extremely economical and a typical solution for high multi-storey office buildings in which space requirements for utility cores increase so considerably that the double zone layout (with utility cores located in the office zone) becomes a questionable arrangement. - Makes lighting and ventilation of the service core a critical issue.

Open layout	- The 'office space' is approached directly from the service core. - Appears to have cheaper forms of construction due to absence of partitions. - Calls for an efficient air-conditioning system and must rely on artificial lighting as a permanent adjunct to natural lighting.
Special layout	- Are atrium like arrangements possible in single storey buildings that permit the use of a special plan that differs from the usual single, double or triple zone layouts. - Not important for multi-storey office buildings.

Source: Compiled by author.

Apart from these plan layouts determining the floor size, orientation in terms of where light is admitted from, depth, and even perimeter walling, it is also evident that they have some relationship with the location of the service core.

(b) Service core. According to Neufert (1980:225), core is space needed for support of building and consists of elevators/lifts, stairs, ducts, lavatories, cleaner's cupboards, etc.

The location of service core is very important due to the fact that, it is the origin of the main circulation especially for multi-storey buildings. After Duffy (1976:125) and Chiara (1973:636), cores can be put into three categories as listed below and illustrated in figure 3.2.

(i) Internal core i.e central core

(ii) Semi-internal core i.e perimeter core

(iii) External core i.e detached core

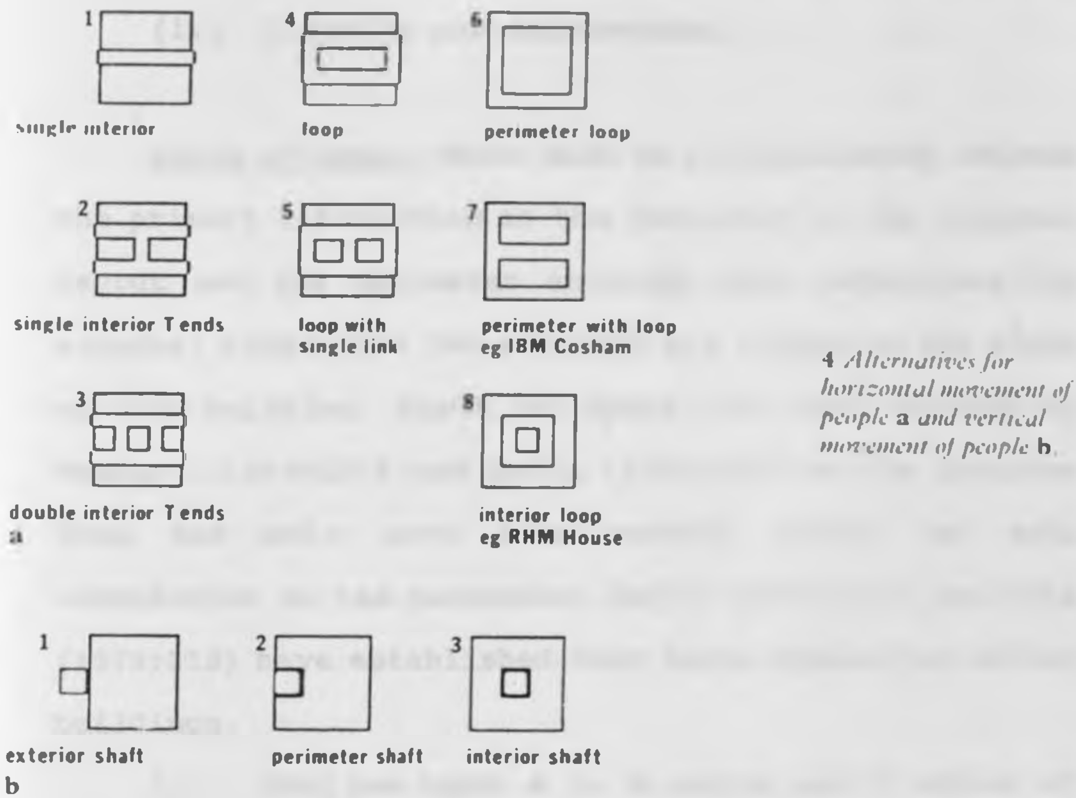

Figure 3.2. Types of Service Cores.

Source: Duffy (1976:125)

As indicated above and pointed out by Duffy (1976:125) the size and content of the core depends upon:

(i) The area and population served by each floor which influences the number and size of lifts, stairs and lavatories,

(ii) The number of floors which influences the number of lifts,

(iii) Additional elements such as tea stations and mechanical conveyors, within the core unit,and

(iv) Cleaning and maintenance.

<u>Depth of Space.</u> There must be a relationship between the primary circulation as the generator of the internal layout and the perimeter envelope that determines the external form. This two extremes are linked by the depth of the building. Depth of space has been defined by Neufert (1980:227) and Duffy (1976:125) as the distance from the main core (for central cores) or main circulation to the perimeter. Duffy (1976:125) and Tutt (1979:118) have established four basic depths for office buildings.

(i) Shallow depth 4 to 5 metres and 2 metres of circulation,

(ii) Medium depth space 6 to 10 metres and 2 metres of circulation,

(iii) Deep space 11 to 19 metres and 2 metres of circulation,

(iv) Very deep space over 20 and 26 metres as given by Tutt and Duffy respectively.

Therefore, it becomes evident that the three elements i.e., depth of space, position of primary circulation and position of core, play a great role in determining the shape of floor of office building and other associated form parameters.

(d) <u>Vertical Circulation/Escape routes</u>. Fire regulations in the Building Code clearly sets out general principles governing the provision of vertical circulation/escape routes. It is stated that no one should pass through fire to reach safety and as such an alternative escape route to a protected point must be available. Limits to the allowed instance from remote positions to protected points are based on the time taken by a person to reach the zone. The result called the travel distance is defined as the distance measured along the escape route between the furthest point in any office and either the exit door from the storey or the exit door to the open air. In this regard, Neufert (1980:228) has proposed travel distance to be regulated to 30 metres.

This limitation in turn influences the distribution of service cores and primary circulation and ultimately determines the plan size, shape and even the building form in general.

(e) <u>Planning grid and space requirements.</u> Manasseh (1962:19) points out that:

> Planning a building, especially a large office, is an extremely complex operation; but in

> essence it is the successful reconciliation of two spaces: the space which is the site and the module, for although the latter is sometimes a smaller unit than the space needed by one person, it is necessarily closely related.

This space needed by one person is referred to as the workplace. As pointed out by Duffy (1976:), much of office layouts consists of a process of joining one workplace to another until everyone is accommodated. The basic increment is the workplace. Planning grids are devices which impose an overall order and maintain individual and group space standards. Thus, this gives an indication that planning grid affects the location of partitions. This in turn influences the amount of opening and storey height that allows enough daylight into the space so created. Similarly, since this planning process takes command of the whole plan, then in turn it influences the whole form of the building. This is true as implied by Robertson (1924:100) that, the plan expresses the general lines of the conception and contains the elements necessary to its own arrangement.

(f) Structural grid. Structural grids defines zones for the major elements of the building, such as structure, and the major areas used by services. This zones are usually located in the horizontal and vertical plane. The structural grid is related to the planning grid as it depends on:

(i) The types and sizes of spaces which are required in the building

(ii) The economic spans of structural system chosen for instance, flat-plate, two-way waffle, etc

(iii) Floor loadings which are assumed to be the same for office activities (Duffy, 1976:52).

The structural grid is based on the planning grid and therefore the positions of columns and beams are determined. This in turn determines the location of partitions and window mullions. This is true although not all the mullions are structural, because it is the structural members which determine the module (and hence create some rhythm in the building). In general, the modular discipline created by structural mullions could result into room sizes. Since the partitioning created by the structural grid is the same required by planning grid, then, the two grids types merges.

If deeper office space is created, the greater the storey height is required to allow for service ducting. Similarly, the greater the height of windows to allow enough daylight into the building. In this regard, Duffy (1976:56) has reported that, a storey height of 2.70 metres is recommended in London for open plan offices.

(g) <u>Constructional grid</u>. The need for constructional grids is determined by the fact that building products and materials are made in a limited range of sizes. Therefore, planning must take account of apparently insignificant elements such as fluorescent tubes, ceiling material, partitioning material, as their cumulative impact could have a profound effect on planning. Thus, since constructional grids are mainly to locate and coordinate subsidiary building elements such as partitions and windows within the overall discipline of the structural grid, then the two grids are also merged.

(h) Servicing grid. Servicing grid is perimeter dependent. For instance, in cellular office buildings, power and telephone wiring is usually carried either in the partition or the skirting trucking. The dimension of such wiring are subordinate to the partitioning. Whereas, several types of under floor ducting are in use for the open layout, not all of which demand a strict grid of outlets for power and lighting. However, a decision must be made on the spacing of these outlets because they relate so closely to the planning of layouts.

Thus, it is evident that servicing, constructional and structural grids are related to the planning grid. This grids influence rhythm, storey height, depth of space, size of windows and generally form of the building.

Technology and Materials (form and the nature of materials). Material with aid of technology i.e., the process and means of putting it together is yet another attribute of building form. Thus, first and foremost, material in itself can be seen to have form and in this regard Meiss (1990:184) has pointed out that, "by material 'form' we mean the geometry of the volumetric envelope of an element with a view to making it capable of production, resistant, manipulable and, capable of assembly in order to serve and delight man." In supporting this Meiss has quoted Louis Kahn saying 'if you ask a brick what it wants to be, it would say,'an arch' sometimes you ask concrete to help the brick and brick is very happy.'

Thus, it becomes very evident that, certain materials therefore would harmonize with certain forms and vice versa. This could be both in structural aspects and finishing, that is, surface finish or cladding. In this regard, it has been said that Kahn's attractive aphorism conveys with great relevance the form by which man attains the greatest virtuosity using brick intelligently. With the dome brick is at its best. Kahn does not say that brick demands the vault, but he identifies the sublime use of brick in architecture when it outwits gravity.

However, since replacing or improving a structure of a building means rebuilding a new, then structural material is not relevant in this research, however the surface, volume and space it creates are areas of concern. Therefore, it is appropriate to discuss material under the following sub-headings.

(a) Massing

(b) Texture and surface modulation

(c) Cladding

(a) Massing. As already realized, the volumetric envelope is a fundamental characteristic of form. This clearly implies that, its massiveness is a particularly significant complementary attribute. Secondly, the same form can appear thin or thick, solid or hollow, as mass influences our perception of things. Thus the architects use material in collaboration with other form creating elements to convey some image or character of a building. For instance, a facade with deeply recessed windows will evoke 'fortress' and security, whereas the urban Baroque Viennese window carefully placed on the exterior surface of a wall of the same thickness is agreeably deceptive, giving the whole building an appearance of lightness and elegance. Therefore, the creation of architectural form requires a design of thickness of spatial envelopes in harmony with other more general aspects of the plan such as the site, brief, theme, space, light, and building methods.

(b) Texture and surface modulation. Meiss (1990:184) argues that, "surface modulation is the architect's touchstone." This is where the architect reveals himself either as an artist or simply as an engineer. This is because, surface modulation is free from all constraint. It is no longer a question of habits, tradition, building processes, nor of adaptation of utilitarian requirements. Thus, surface modulation is a pure creation of the mind and hence calls for the sculptor.

In this regard Meiss (1990:184) continues to argue that, "the surface texture and colour of the materials used, their combination and their jointing give the space its ultimate character, its 'status' and its 'temperature'." This argument refers to, for instance, traces of the chisel, bush hammering, joint between bricks, marks of formwork, etc. All these together with colour, model the surfaces. They inform us about attribute of the building, for example its thickness.

The precision of fashioning materials has always been an aim and a measure of human masterly of nature. Polishing, which reveals the internal structure of the material, is the ultimate stage of it. It erases the idea that the object has been made with tools, all that remains is the object itself. In this regard, it has been mentioned that the Greeks knew how to make the most of their tools to exploit the potential of reflected light which results from differences in texture of the same material.

However, each material is used within its own working logic, but with an overall objective. For instance brick has served the window well, the rational and refined combination of stone and brick guarantees the coherence of the whole. The exact places where there are changes in the form of assembly or in the material coincide with key locations in terms of the building as a whole; plinth, corners, openings, cornice, principal facade, lateral facade. The result is a design which makes it possible to accentuate edges and to introduce order on a large scale than the simple additive texture of stones.

(c) Cladding. With regard to the support structure and cladding, Meiss (1990:193) has quoted Gottfried Semper, thus:

> Form which is the expression of an idea must not contradict the material of which it is made, but it is nonetheless not indispensable for the material as such to be added to the work of art.

Thus, cladding material is used to accentuate some intended expression of form. And the way cladding goes about realizing this can be realized from its two main uses, i.e:

(i) First and foremost, cladding is used in instances which does not require fundamental alteration of the space produced by the structure. Firstly, it involves finishes like paint, rendering, wall paper, mosaics and tiles. All these adhere to the whole surface of the structure. In this regard, if the texture of the structure is sufficiently pronounced and if the cladding consists of mosaics or a thin film which is flexible at the moment of application, the texture of the support hoses through, but its irregularity is less apparent. Secondly, it involves cladding that come in a form of slabs e.g. marble, glass, metal or wood. Their geometry and joints introduce a new modulation which does not necessarily correspond to that of the hidden structure. The fixing can be hidden or visible. In this case it introduces a new texture which accompanies the rhythm of the panels.

(ii) On the other hand, cladding is used to contradict structural reality by producing different spaces and objects as is the abbey church of Einsiedeln. However, the path has become a precarious one to follow. There is no longer that unifying theme which governed the space of illusion as there was in the Baroque period. Consequently there is a risk of illusion causing alienation.

Therefore, generally material influence the planes, that enclose the building form hence dictating form parameters like, thickness of building, volume, massing, surface quality, etc.

Cost limits. Thompson (1990:68) has noted that cost controls size and quality of any building. This is because allocation of money is made at the design stage, thus clearly influencing the appearance of the building. Similarly, cost control and cost planning also influences the size of the building, because there is often a choice between a smaller building with high standards of construction and finishes, and larger building constructed to minimal standards.

Another very important aspect related to cost is time. The duration of the project, in respect to both design and construction time, also has an influence on costs, and could act as a constraint on the design of the building. This is due to the fact that costs are continually escalating, because of inflation and increases in the cost of labour and materials during the life of the project. The architect may make a decision to simplify the design and construction of the building as much as possible so as to reduce the programme time, and minimize the effect of inflation. This influences the appearance of the building.

3.3 Conclusion

Table 3.4. Summarizes the form elements brought about by the respective constraints. The possible effects of these form elements on subsequent running cost are discussed in Chapter Four.

Table 3.4. Summary of the form elements brought about by the design constraints

CONSTRAINT	FORM ELEMENTS
Client	- Usable or total plinth area - Plan shape - Circulation arrangement - Materials - Planning grid/rhythm - Location of services and quality, etc
Site	- Building size i.e. total plinth area and volume of building - Ground floor areas - Ground floor shape - Structural grid and rhythm - Building orientation - Height of building
Environment	- Location and size of windows - Orientation - Massing - Shape of plan and siting

Climate	- Roof - Volume of building - Location and size of windows - Internal layout - Location of service core and circulation - Choice of materials - Depth of building - Orientation of building - Shading device - Type of glazing - Storey height - Floor voids or light wells
Legal requirements	- Shape and size of plan - Building height and elevations - Building bulk i.e. volume and total plinth area - Total window area and floor voids for ventilation - Plot ratio
Building regulations	- Ground coverage - Total plinth area - Number of storeys - Height of building - Plan shape - Storey height - Size of windows - Rhythm - External walling
Technology and material	- Expression of material i.e. painted or unpainted - volume of building - Surface texture and modulation - Cladding i.e. thin cladding or slabs/panels cladding - Massing - Rhythm

Function and User Requirements	- Horizontal circulation and internal layout - depth of space - location of core - Number of vertical escape routes - Planning grid - Structural grid - Constructional grid - Servicing grid /perimeter grid - Rhythm - Storey height - Glazing area
Cost limits	- Size i.e. total plinth area, height, volume, etc - Material

Source: Complied from the author's literature review.

Hence the parameters that can be said to determine building form are as follows.

(1) Plan shape (ground floor or typical floor shape)

(2) Plinth area

(3) Volume of building

(4) Building orientation (i.e. N-S OR E-W)

(5) Height of building

(6) Rhythm

(7) Glazing area

(8) Roof shape

(9) Location of service core

(10) Form of horizontal circulation

(11) Depth of building

(12) Shading device

(13) Storey height

(14) Floor voids or light wells

(15) Plot ratio

(16) Vertical escape routes

(17) Material expression and finishing

(18) Surface texture and modulation

(19) Number of stories

(20) External vertical planes surface area

(21) Platonic solid of building/Massing

(22) Ornamentation

(23) Perimeter of plan

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CHAPTER 4

INFLUENCE OF FORM PARAMETERS ON SUBSEQUENT RUNNING COSTS

4.1 Introduction

This chapter addresses the relationship between architectural form parameters established in Chapter Three and subsequent running costs of office buildings. This is with an aim of establishing theoretical relationships between these form parameters and running cost of which are later investigated in Chapter Five.

As already established in Chapter Three, the building or the architectural form is the product of all the architectural form elements that individually come into being as a response to various design constraints. Thus, when analyzing architectural form it becomes more appropriate to analyze these form elements by themselves since they are easier to handle and even quantify. This is evident when evaluating design especially in relation to cost in use. This is due to the fact that, as specified by Stone (1975:54), the first step in evaluating design alternatives is to examine them physically and to write down the building elements involved and the extent to which they generate initial and running costs. Then, elements that are common i.e., physically similar to the design alternatives are eliminated since judgement is based on relative differences in costs and performance. This concurs with Bowen (1990:1129) when he quotes Sidwell and Da'abis (1882) that, "...each of the design variables chosen by the design team at the design stage has an influence on capital costs, maintenance costs and operating costs."

Therefore, since according to Rompis (1990:67), the accurate calculation of building maintenance cost depends on the condition of each of the buildings concerned, which are of different shapes and characteristics i.e., form, then, it becomes imperative to establish the relationship between the architectural form elements (established in Chapter Three) and the subsequent running cost of office buildings. This is the most probable procedure of establishing a cost model to be used in the ideal allocation of building running costs for office buildings.

These form elements now becomes form parameters of which their influence on running cost is discussed as follows.

4.2 Relationship between the Architectural Form Parameters and the Subsequent Running Cost

Plan shape and perimeter of the building plan. As already discussed in Chapter Three, the shape of a plan of any building comes into being as a response to both external and internal constraints. In reinforcing this, Stone (1975:19) has addressed the layout of buildings and the cost consequences and pointed out that, "...the layout and shape of buildings has been largely dominated by the attempt to provide a satisfactory internal environment largely by natural lighting and ventilation." Thus the shape of the plan is defined by the perimeter outline that encloses some shape that can either be regular or irregular. This gives some indication that the shape of the plan has a lot to do with the external total wall lengths of the building. Thus, as pointed out by Agrawal (1990:1116), "...optimum shape of a building refers to that configuration of the plan which gives minimum total wall length." This implies that if the shape of the building is already optimum, clearly there cannot be any further reduction in the wall lengths. This reduction would be less and less as the plan approaches its optimum shape.

On the other hand, when one addresses the issue of running cost, there is need to consider the material, time and utilities that are likely to be utilized on any particular building shape. However, a change in the outline of the building would mean change in proportion of the window to wall areas and hence alteration of the wall to floor ratio. Given that, the costs of the different materials, components, etc., of the building vary, then, it is in order to imply that a change in plan outline or shape which in turn changes the perimeter of buildings has a lot of influence on the running costs of buildings. Thus, the running cost of the building can be expressed as a function of the perimeter of the building. That is, if the perimeter increases due to the change in shape keeping all the other parameters of the building constant, it means that the running cost proportionately change. Since with the optimum shape some constant running cost is incurred, then, the relationship could be as follows.

Running cost = constant + (b x perimeter of building)

where b is a factor of slope of the relationship.

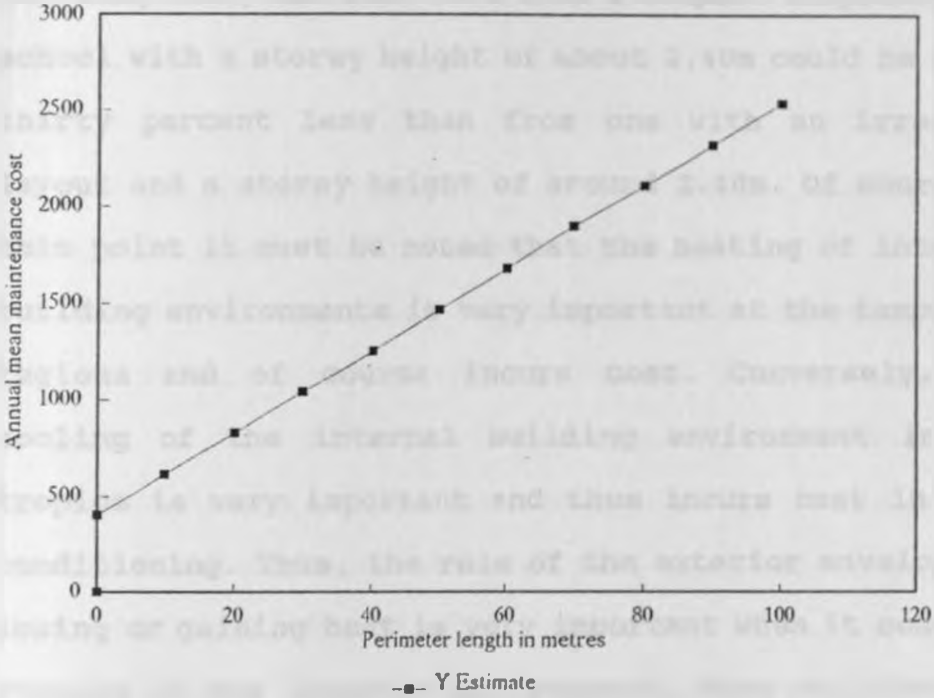
In this regard Syagga (1985:327) has found out that, perimeter length accounts for 6.333 percent in the multiple regression between design parameters and annual mean maintenance cost (which is part of running cost) and the following relationship do exist.

$$Y_m = 401.63 + 21.35X_{12}$$

where X_{12} is perimeter length.

Y_m is annual mean maintenance cost.

This relationship is illustrated in Graph 4.1.



Graph 4.1. Theoretical relationship between subsequent maintenance cost and perimeter of building.

Source: Drawn by author and based on Syagga (1985:327).

Note: The Y-intercept represents the annual mean maintenance cost for any given area when represented in an optimum shape (i.e. a circle). Then any variation in shape, which automatically means an increase in perimeter length is explained by the rest of the graph.

Similarly, as already hinted above it seems evident that the more irregular the plan shape the higher the perimeter walling. This is supported by Seeley's

(1983:207) example of the heat loss from a school building that, the heat loss from a compact single-storey school with a storey height of about 2.40m could be about thirty percent less than from one with an irregular layout and a storey height of around 2.40m. Of course at this point it must be noted that the heating of internal building environments is very important at the temperate regions and of course incurs cost. Conversely, the cooling of the internal building environment in the tropics is very important and thus incurs cost in air-conditioning. Thus, the role of the exterior envelope in losing or gaining heat is very important when it comes to running of the interior environment. More so, Harrison (1990:1091) has pointed out that, "a building which has unobstructed vertical faces will prove to be more easily cleaned than one which has overhangs or protruding bays." Similarly atrium skylights or lighting fittings which would be inaccessible by conventional use of scaffolding might employ a gantry system which can be rolled along the length of the roof space; naturally such a device needs to have a track, supported on two parallel side walls. Thus, it implies that simple prismatic shapes (i.e. the more regular or geometric the shapes) in elevation, plan or in section are advantageous in facilitating simple access, and thus lowering the running costs. On the other hand, this means that the more irregular the shape the more complicated the maintenance procedures involved and hence the higher the running costs.

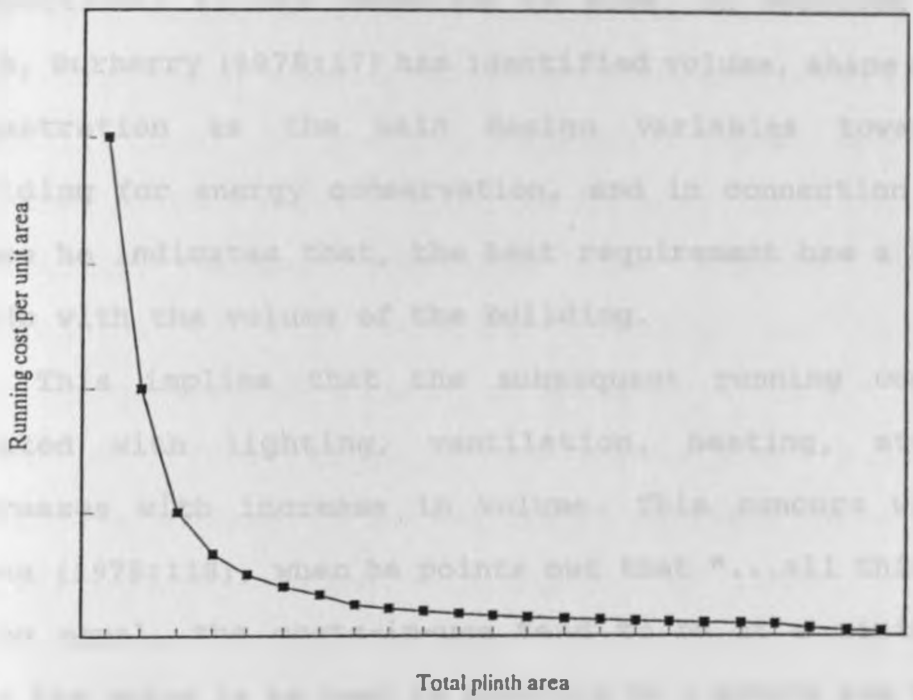
Total plinth area. This is the total floor area of a building measured in square metres.

Quite a number of researchers have addressed the issue of the size or floor area of the building in respect to the subsequent maintenance and running or operating costs, but it seems that no concrete relationship has been recorded yet. However, to set the ball rolling, Spedding (1990:1073) when reporting consequences of maintenance and running costs urges that, schools should also be grouped by area when allowances are being made for maintenance budgets, so that the effects of size rather than pupil numbers, are allowed for in the average cost per square metre. This implies that some relationship is bound to exist between the subsequent running costs and the total floor area of the building. In this regard, in trying to predict maintenance costs on hard floors, Tebbatt (1986:13) argues that, most estimates of time taken for cleaning hard floors were based on the method to be used and the area. This similarly indicates that, assuming the method of cleaning is kept constant, then, the area of the floor being cleaned is bound to be a determinant of the cost incurred. However, for those researchers who have tried to be more particular and exact like Brown and Robertson (1990:172), in the abstract of their paper entitled "comparative office building maintenance costs", they have noted that "the size of the office block also influenced the operating costs." More so, in their text (Brown and Robertson, 1990:177), have gone further to indicate that "repairs and maintenance costs decrease with size" and "general expenses and 'other' costs decrease as the building size increases." This agrees with the principle of economics of scale and suggests that the subsequent running costs of buildings is bound to decrease with increase in size or total plinth area. Thus a relationship of the of the nature shown in Graph 4.2. is most likely to exist.

Running cost = constant - (b x total plinth area)

where b is slope of the graphical illustration shown below and,

The constant = is the Y-axis intercept



Graph 4.2. Theoretical relationship between subsequent running cost and total plinth area of building.
Source: Drawn by author and based on the literature argument.

<u>Volume of building.</u> Volume is yet another aspect of size of building that measures the three-dimensional space occupied by the building in cubic metres.

Burberry (1977:123) notes that, "little variation of form affects heat loss in comparison with the major effects of increasing volume." He goes further to argue that, costs of lighting, ventilation and sound insulation are all reduced by reducing the size of the building and this reduction is generally more than directly proportional to the reduction in size. In addition to this, Burberry (1978:17) has identified volume, shape and fenestration as the main design variables towards building for energy conservation, and in connection to these he indicates that, the heat requirement has a lot to do with the volume of the building.

This implies that the subsequent running costs related with lighting, ventilation, heating, etc., increases with increase in volume. This concurs with Stone (1975:118), when he points out that "...all things being equal, the costs-in-use tend to be at a minimum when the shape is as near as possible to a sphere and the enclosing surfaces are themselves at a minimum."

However, maintenance of the structure might predominate the cost incurred in the above issues. If this happens, coupled with the fact that volume is an aspect of size, then, the economics of scale might apply and running cost would decrease with increase in volume. This is due to the fact that running cost is said to be constituted of two elements i.e. maintenance cost of the building fabric and cost incurred on utilities.

<u>Height.</u> Height of a building contributes substantially to its subsequent running through a number

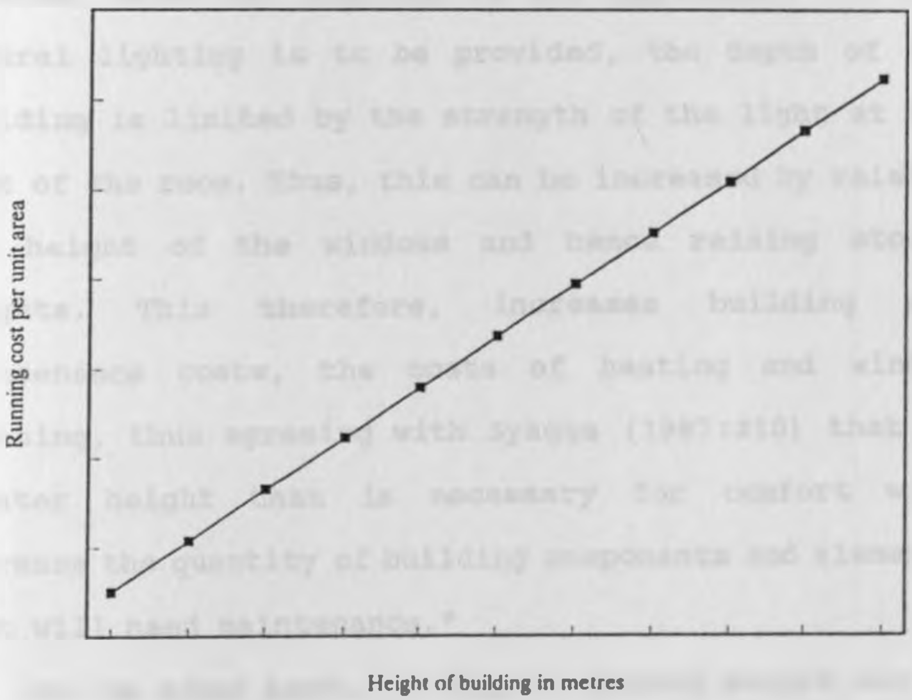
of respects. For instance, if one considers multi-storey buildings the height factor is much more important, not because of normal repairs but because such buildings have a wide variety of special services. Such services are not normally found in low-rise buildings. These special services include lifts, laundries, communal lighting and caretaking. Holmes (1987:238) has reported that "...repairs of such services increases the normal maintenance costs by a factor of between 1.4 and 2." This agrees with Stone (1975:21) who argues that "running costs rise because of the additional services necessary in multi-storey blocks." In support of these, Stone (1975:22) goes further to argue that "running costs per square foot tend to rise where extra plant needs to be operated to provide internal communication."

Regarding the other aspects in which running costs are incurred due to height, Rompis (1990:70) argues that:

> The taller a building is, the greater of role of cleaning service will be. The high risk involving tall structures, however, only hinges on the external cleaning, such as the external parts of windows viewed from the technical angle. This kind of work is connected with safety or the increasingly higher risk of job execution.

However, as a matter of fact, cleaning work is made up of internal and external cleaning of buildings. Generally, internal cleaning has lower risk compared with external cleaning. The external cleaning job needs extra involvement in equipment as well as high insurance premiums to cater for the works compensation insurance policy.

Thus, it is evident that height of the building influences the cost incurred in maintaining both the services and fabric of the building. This relationship can be said to be positive in the sense that, the increase in height increases the running cost of the building, and can graphically be represented as illustrated in Graph 4.3.



Graph 4.3. Theoretical relationship between subsequent running cost and height of building.

Source: Drawn by author and based on the literature argument.

<u>Storey height.</u> According to Syagga (1987:210), storey height or room height is a measure of vertical components and elements of a building.

In economic terms, the storey height as a building form determining parameter is very significant as pointed out by Bennie (1977:2) that, " economic design ... means a building of such depth and floor to ceiling height [or storey height] that will permit the maximum daylight penetration and full utilisation of space." This is because, when top lighting is not applicable and the natural lighting is to be provided, the depth of the building is limited by the strength of the light at the back of the room. Thus, this can be increased by raising the height of the windows and hence raising storey heights. This therefore, increases building and maintenance costs, the costs of heating and window cleaning, thus agreeing with Syagga (1987:210) that "a greater height than is necessary for comfort will increase the quantity of building components and elements that will need maintenance."

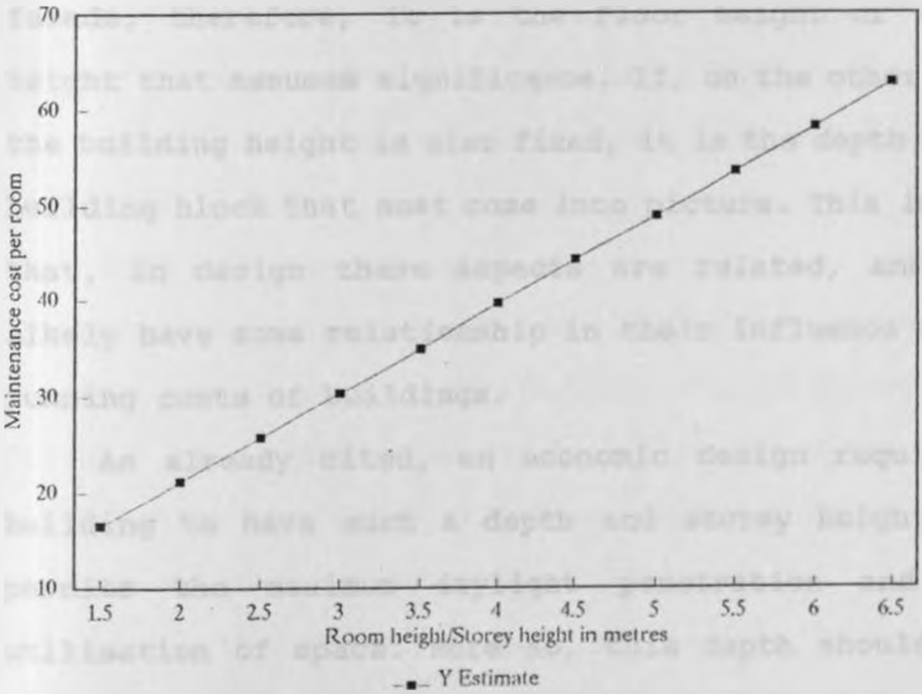
On the other hand, raising the storey height can be avoided by making use of permanent supplementary lighting, but this is bound to increase the costs of the lighting installation and its running costs. Thus in one way or another, storey height influences somehow the subsequent running costs of buildings. Hence, it is due to such reasons that Syagga (1987:210) has established that room height has a positive relationship with cost per room in the form:

$$Y_m = 2.63 + 9.25 X_{13}$$

where Y_m is maintenance cost per room

X_{13} is surrogate variable for storey height

This relationship is graphically expressed in Graph 4.4. In addition Syagga has further established that storey height or room height accounts for 0.1% of the maintenance costs of residential housing estates in Mombasa, Kenya.



Graph 4.4. Theoretical relationship between maintenance cost by storey height of building.

Source: Drawn by author and based on Syagga (1985:210).

Note: The Y-intercept represents the maintenance cost per room for the minimum acceptable room height. Any increase in room height is represented by the rest of the graph.

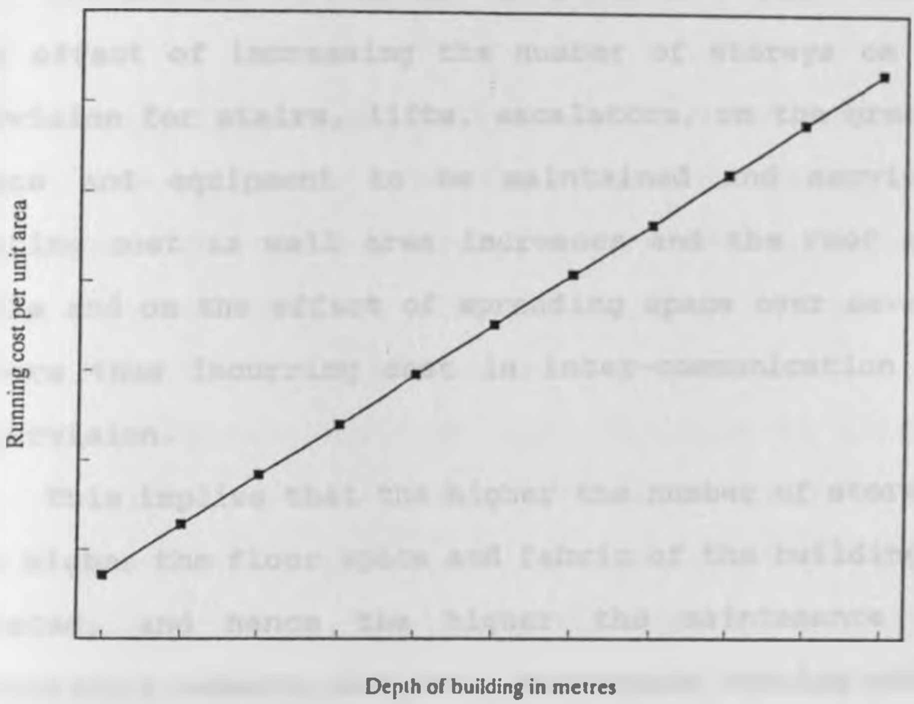
Depth of building Generally the height and storey height of the building have a lot to do with the depth of the building. As per Agrawal and Patel (1990:1122), another important aesthetic quality is that of formal balance, and as such, a whole form, a facade for example, ought to be composed in such a manner that one formal part dominates. For instance for a given width of the facade, therefore, it is the floor height or storey height that assumes significance. If, on the other hand, the building height is also fixed, it is the depth of the building block that must come into picture. This implies that, in design these aspects are related, and most likely have some relationship in their influence on the running costs of buildings.

As already cited, an economic design requires a building to have such a depth and storey height that permits the maximum daylight penetration and full utilisation of space. More so, this depth should also provide an area capable, if need be, of being broken down into individual offices without waste. Of course such space should be habitable in the sense that it is well lit and ventilated. Thus the costs of lighting and ventilation are associated with the depth of the building.

With regard to lighting, the running and subsequent maintenance cost could be minimized by providing roof lights to single-storey buildings and topmost storeys of any building. However, in case of multi-storey buildings it becomes imperative to utilise artificial lighting and as such incur running and maintenance costs. More so, it would become worse if the depth of the building is large, because this means that some areas of the building would require permanent artificial lighting and hence permanent and continuous running/maintenance costs. Thus, in one way or another the costs of lighting are increased considerably in deep buildings where roof lights are not feasible.

Similarly, ventilation also becomes more difficult in deep rooms since natural ventilation through openable windows ceases to be satisfactory. The combination of forced and natural ventilation in itself creates difficulties and often it proves easier to have sealed windows and rely on forced ventilation.

Thus, the effect of building spaces deeper than could be lit and ventilated naturally raises the capital and running costs of lighting and possibly ventilation, usually to a considerable degree. This implies that, depth of building most likely has a positive relationship with subsequent running costs as illustrated in Graph 4.5.



Graph 4.5. Theoretical relationship between subsequent running cost and depth of building.
Source: Drawn by author and based on the literature argument.

Number of storeys. Actually the number of storeys in any multi-storey building is dependent on many other design parameters. For instance, the use of deep buildings enables the building bulk and floor area to be increased without increasing the number of storeys. Generally, Stone (1975:119) has pointed out that "...the costs-in-use tends to rise quite markedly as the number of storeys rises beyond one or two."

The pattern of running costs can be traced through the effect of increasing the number of storeys on the provision for stairs, lifts, escalators, on the greater areas and equipment to be maintained and serviced, heating cost as wall area increases and the roof area falls and on the effect of spreading space over several floors thus incurring cost in inter-communication and supervision.

This implies that the higher the number of storeys, the higher the floor space and fabric of the building so created, and hence the higher the maintenance and operational demands, and hence subsequent running costs.

<u>Rhythm.</u> For the sake of this research, rhythm is taken as a measure of distance between the centre to centre of the structural grid systems. In case of a variation, the average distance is considered.

Technically, once the distance between any two adjacent structural columns for instance increases, the depth of the beams or horizontal structural elements tends to rise and thus increase the storey height and the area of walling to be built and maintained. This is because the optimum space must be provided and in case of large structural members then, more storey height for instance is required. Generally, this requires more building elements, larger surface areas to be maintained and hence higher running costs.

Orientation. Orientation deals with the direction in relation to the sun to which the windows of the building are facing. This greatly depends on the point on earth at which the building is situated, simply because the location on earth and the orientation (and size of the window) determines how much light and heat is allowed into the building and ultimately how much energy saving made. In this regard, a building situated at the poles comfortably orients its windows towards the tropics to capture the distance soft light, whereas buildings located within the tropics functions better with windows located on the north-south direction to avoid the strong east-west sun. In spite of this, the windows facing north-south might need screening and shuttering to reduce the mid-day strong sun so as to control the amount of light and heat allowed into the building.

It should be noted that a particular daylight factor is required for a particular activity (say office function). If this daylight factor is slightly reduced or increased, it might require regulation of the internal environment and thus necessitate introduction of amenities like, artificial supplementary lighting, air-conditioning and even artificial heating in some instances. This therefore, implies that some relationship between orientation of the building and running costs of lighting facilities would be existing. However, since running and maintenance costs of lighting facilities is just part of the total subsequent running costs of the building, then, it is therefore implied that a relationship between orientation and subsequent running costs of buildings would similarly be existing.

At the temperate regions, either the south or north orientation is preferred, otherwise more energy is required for lighting. Similarly within the tropics, the north-south orientation is preferred, otherwise more energy is spent on air-conditioning in an attempt to reduce the solar heat admitted into the building. Therefore, it is logical to conclude that, the north-south orientation implies low subsequent running costs whereas the east-west orientation on the other hand implies higher subsequent running costs.

Light wells or floor voids. As already realized with the depth of the building, the deeper the building the higher the running costs. Some of these costs arise due to the lack of lighting, ventilation, etc. Thus an introduction of light wells, floor voids or roof lights automatically improves the situation above and hence reduces these running costs. This strongly agrees with Stone (1975:22) when he remarks that, "running costs will tend to rise as the area lit by the roof light is reduced."

Therefore, it is appropriate to conclude that a higher percentage of floor voids implies a better circulation of air and even light in the building and hence less subsequent running costs. Thus, a negative relationship is most likely bound to exist between the proportion of floor voids in the building and the subsequent running cost. However, the higher the proportion of floor voids with full development of plot on the other hand implies higher internal space to be maintained and hence the more the building fabric that requires maintenance. In this regard therefore, it implies a positive relationship between running cost and proportion of floor voids. Thus, the actual relationship between proportion of floor voids and subsequent running cost depends on the expenditure on lighting and maintenance of the building fabric. For instance, if the expenditure on lighting predominates that on maintenance of the building fabric, then, the following relationship is bound to exist.

$$Y = a - bX$$

where Y is running cost.

a is a constant or y-intercept.

b is gradient or slope of the relationship.

X is percentage of floor voids in the building.

Form of horizontal circulation. As put forward by Agrawal and patel (1990:1121) and generally established in Chapter Three, basically, any building plan could be said to be composed of two types of functional spaces: one, primary spaces which are needed to perform the specified activities for which the building is designed and built, and second, the interactivities in a continuous and connected manner. In terms of circulation and more particularly with regard to office buildings, four types of plans are discernible:

(a) Single zone,

(b) Double zone,

(c) Triple zone, and

(d) Open layout.

More so, any building plan could be said to be best for the given value of money if it utilizes the above two spaces properly. In this regard and according to Stone (1975:19), a large number of factors need to be considered in determining the most suitable layout of buildings as the final arrangement could only be a compromise between the best solutions that meets the different needs. The most important factor for office buildings is that, the spaces for each activity should be related so as to minimize the space devoted to circulation and the time and cost of communication between the various spaces. Therefore, as already implied in Chapter Three the office building layouts try to minimize the circulation space in the ascending order of, single zone, double zone, triple zone and open layout. This implies that, in the open layout the circulation space is minimal as at times it is used as the primary space.

With regard to the running cost vis-a-vis the circulation space, it should be remembered at this stage that circulation space endures the highest level of traffic than any other part of the building. Therefore, such spaces demands the maximum attention with regard to cleaning, replacing worn out finishing material and components of the building. As well such spaces require the most attractive appearance as this is the area that is most frequented by all visitors to the building and as such demands frequent repainting, polishing, continuous lighting, etc. This clearly implies that the larger the circulation space of course relative to the total plinth area, the higher the running costs. Therefore, running costs of office buildings most likely increases in the order of open layout, triple zone, double zone and single zone. In this regard therefore, single zone is bound to experience the highest running cost.

Location of service core. The location of service core in a multi-storey building is of paramount importance. This is because, apart from being the point at which maintenance facilities are located, it is the generator of the internal layout. This implies that, the service core serves the primary space together with the horizontal circulation routes. However, it should not be forgotten that the service core in itself needs some amenities like light and air in order to function properly.

In serving the primary space, for instance, it should be noted that, the provision of adequate cleaner's sinks and cupboards would assist the cleaning staff and possibly reduce the time taken on cleaning. In large buildings therefore, it is important that facilities for cleaning are dispersed throughout the building or located at a central point, saving time in the collection and return of cleaning materials and water. Similarly, regarding circulation, the more central the service core, the more efficient the movement of resources between different floors, saving travelling time and hence reducing the travelling distance and related maintenance costs as already explained.

With regard to the functionality of the service core, of course, it is definite that it would function better with enough natural light and ventilation. However, this contradicts the above conclusion that the more central the service core, the less the maintenance cost with regard to cleaning. This is due to fact that more money is spent on artificial lighting and ventilation to keep the central core functional. Thus, it becomes uncertain to state whether a building with either internal core, semi-internal core or exterior core would have the least subsequent running cost.

Hence, any relationship that might exist between the location of service core and the subsequent running cost would depend on the cost of labour and power. If for instance, the cost of labour is insignificant while the cost of power is very high, then, buildings with internal core are bound to experience the highest running cost followed by semi-internal core, while those with external core would experience the least. On the other hand, if the cost of labour is very high while the cost of power is insignificant, then, the relationship would be vice-versa, to take care of the travelling time. Anyway, in the Kenyan situation, the cost of power seems to be escalating every day as such, the former applies.

<u>Plot ratio.</u> As already realized plot ratio is directly related to the total plinth area, for instance:-

Total plinth area = plot area x plot ratio

More so, since total plinth area is the generator of volume and all the enclosing elements of the building, then, it is logical to argue that the higher the plot ratio the more the building components including mechanical and electrical machinery to be maintained. Hence it automatically implies that plot ratio is positively related to subsequent running cost of the building. This can be expressed in the following quantitative form and illustrated as in Graph 4.6.

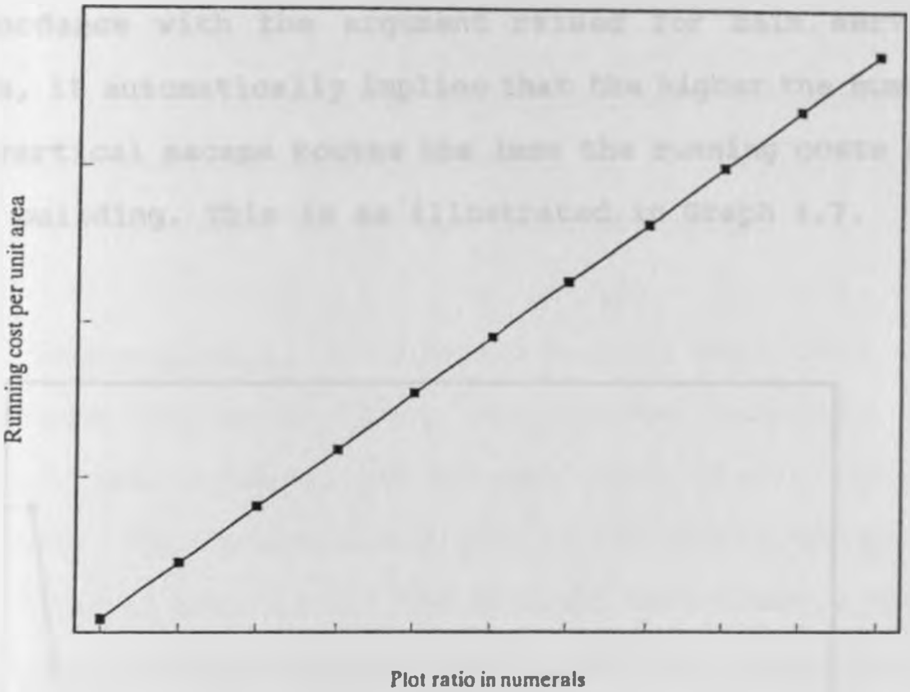
$$Y = a + bX$$

where Y is running cost

a is constant

b is a factor relating running cost and plot ratio

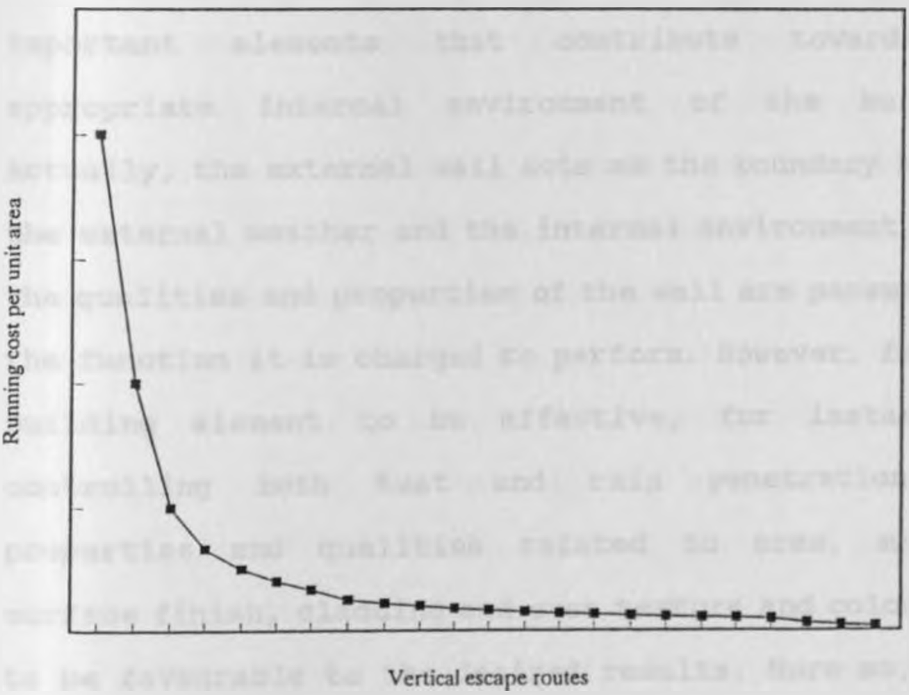
X is plot ratio



Graph 4.6. Theoretical relationship between subsequent running cost and plot ratio of the building.
Source: Drawn by author and based on the literature argument.

<u>Vertical Circulation/Escape routes.</u> These are actually vertical circulation routes/service cores. They equally assist in accommodating cleaner's rooms and facilities, stair-cases, tea rooms, and utilities like

water. In this respect they assist in reducing both the travelling time for staff involved in maintenance of the building and the circulation time and distance for the general visitors to the building. Therefore, in accordance with the argument raised for main service core, it automatically implies that the higher the number of vertical escape routes the less the running costs for the building. This is as illustrated in Graph 4.7.



Graph 4.7. Theoretical relationship between subsequent running cost and vertical escape routes of the building. Source: Drawn by author and based on the literature argument.

The graphical illustration above can be reduced to the following formula.

$$Y = a - bX$$

where Y is running cost

a is constant

b is a factor relating running cost and number of vertical escape routes

X is number of vertical escape routes

<u>External wall.</u> The external wall is one of the most important elements that contribute towards the appropriate internal environment of the building. Actually, the external wall acts as the boundary between the external weather and the internal environment. Thus, the qualities and properties of the wall are paramount to the function it is charged to perform. However, for such building element to be effective, for instance in controlling both heat and rain penetration, its properties and qualities related to area, material surface finish, cladding and even texture and colour have to be favourable to the desired results. More so, it is worth mentioning at this point that the extent to which the external wall controls the internal environment determines the amount of money that would be spent in keeping the internal environment to the desired levels of say humidity, temperature, etc. Therefore it is important

to discuss the various parameters of this envelope mentioned in this text in regard to maintenance cost and hence running cost.

(a) External wall area. External wall area is the amount of wall surface that is in contact with the external environment. In this regard, it is bound to give a hint of the labour and material required to replace the broken or damaged parts of the wall due to weathering and even the paint required to renew the exterior paint coating. This is because, "paint is the most vulnerable of building materials and its regular replacement constitutes the largest maintenance item resulting from weathering (Seeley, 1983:217)." Therefore, an optimum external wall surface area is of great importance if the total maintenance costs for the building have to be optimum. Thus actions and decisions that are bound to change the outline of the building in such a way as to result in altering the wall to floor ratio and ultimately increase the maintenance cost should be discouraged.

In this regard therefore, it is logical to conclude that a positive relationship exist between the external wall surface area and the subsequent maintenance costs and hence subsequent running cost of the building. Such relation can be reduced to an equation of the form below.

$Y = a + bX$

where Y is running cost.

a is a constant/Y intercept.

b is a factor relating running cost and the exterior wall surface area.

X is the exterior wall surface area.

(b) Material expression and finishing. Although the architect has some level of freedom to choose the finishing material to cover the structural elements of the building, it so happens that he is restricted by the economy, aesthetics and even client's requirements for instance, the means of disposal of the building. This is because, most speculative developers who put up buildings for sale, don't prefer spending a lot of funds in the finishing of the building, but rather opt for simple finishes like plaster and paint. On the other hand, those clients that develop buildings for their occupation always prefer finishing them with most durable materials like granite, marble, aluminium/other durable metals, etc., or leave them at the structural level, thus, making sure the finish is of very good quality and as such reducing the anticipated frequency of cleaning. In this regard therefore, it would be said that, "the external painting costs could be reduced by the substitution of materials which do not require painting." (Seeley, 1983:207).

This makes it evident that the choice of building finishes is very important. It concurs with Bennie (1977:3) when he notes that, "architects have a responsibility to advise a client on the best alternative materials available and should see that adequate advice is tendered on care and maintenance." This is because, "the cleaning costs of buildings, depend upon the function of spaces to be cleaned, type of finishes used and the cleaning interval (Ashworth, 1988:230)." Thus, it is for this reason that words like "tough, impact resistant decorative finish" are being used in advertisements for building products. Hence, finishing materials suitable for use in areas where low maintenance costs are required are of paramount importance.

According to Tucker (1990:166) "different schedules of maintenance activity depend on the material used for the outer wall construction". Thus, to reduce the maintenance costs, architects have to specify durable materials that are easy to clean. This is due to the fact that durable materials implies permanent surfaces which need relatively little maintenance attention, therefore, becoming more economical with regard to maintenance expenditure, although would be more expensive at the construction stage. This gives the justification as to why architects and developers nowadays are advocating for durable finishes like marble, granite and even metal unlike solid blocks or stone that were used in the early construction. This is because, these are the most durable materials to provide the external envelope with the desired qualities. This concurs with Cheung (1990:1016) that, "the primary defence of the exterior wall against climatic elements is the cladding."

Therefore, since cladding is meant to resist the impact of wind, sun, rain, snow, hot and humid summer air, cold and dry winter air, noise, odours and various air pollutants, it definitely performs better than plaster and paint. Hence it could logically be said that a building finished with plaster and paint as compared to cladding finish would cost more to maintain. Thus a building finished with cladding would cost less to run compare to that finished with a surface coating.

(c) Texture of materials. In most cases the nature of the surface finish determines the amount of light reflected from its surfaces onto the space and the time and material used for cleaning or renewing the surface. In this regard, Tebbatt (1986:18) has pointed out that, non-slip floors could be a mixed blessing. While they undoubtedly provide a valuable safeguard against the most prevalent cause of accidents, they are also more difficult to clean than smooth flooring. This is because, mopping unless undertaken with care for instance, conforms only with Shaw's definition of cleaning i.e.,'the systematic redistribution of dirt.' Soiling is picked up from the top most projections of a surface that is inherently irregular and is deposited in the lower areas. Quarry tile floors are a prime example. Here, dust is lifted from the face of the tile and deposited in the joints. After some months, the dirt builds into a relatively thick layer, heavily compacted by foot traffic, visible as neat black lines crisscrossing the floor.

On the other hand, it should be noted that smooth surfaces reflect light more regularly and in-turn provide the spaces with better if not more light than textured surfaces. In this regard, Bennie (1977:2) has pointed out that, at times experts have been encouraged to over-illuminate spaces whereas, insufficient regard is taken about the nature and colour of the surrounding wall and ceiling surfaces. This in-turn leads to excess running and maintenance costs.

Similarly, textured finish on external wall surfaces are bound to hold rain water longer than smooth surfaces. This enables rain water to easily penetrate into the walls through cracks and generally make the wall humid and as a result leads into the peeling of internal finishes, thus more expenditure on maintenance.

Thus, with these few examples, it becomes evident that textured surface costs more to maintain compared to smooth ones. Hence buildings with textured surface costs more to run than those with smooth ones.

Shading devices. Shading devices are very much related to the orientation of the building. These are simply horizontal or vertical or combination of both elements that helps to regulate the amount of sunlight entering the building through its openings. Of course its existence increases the total surface area and even total number of components of the building that requires maintenance. However, on the other hand, absence of shading devices means too much sunlight would be allowed into those buildings orientated east-west and are located within the tropics, thus in turn necessitating the installation of air-conditioning mechanisms. In this regard therefore, the cost of power, labour and material for maintenance are of great importance for one to decide the effect of shading devices on the running costs of buildings.

Ornamentation. Ornamentation just like textured surfaces needs more time, labour and material for maintenance purposes. This is due to the level of detail and carefulness required when remoulding, replacing or cleaning an ornamentation. All these would definitely cost more compared to the surfaces or buildings that don't have any ornamentation.

Platonic solid of buildings. This is the three-dimensional image of the buildings. This could be irregular due to the direct vertical projection of an irregular plan or due to many different projections. Similarly it could be regular due the fact that the plan is regular or geometric and not so many set-backs and projections are introduced in the buildings. Similarly, as already realized in the case of plan shape, an irregular platonic solid of building consists of more components of the buildings to be maintained. For instance, a cascading building form with flat roofs would require more waterproofing material due to the fact that the number of elements in contact with the flat roof are many. Similarly a building with projections and even set-backs of horizontal elements would mean that there is a likelihood of water settling in these areas if no proper drainage is provided, thus more waterproofing, inspection, cleaning and general maintenance of such areas is required. In this regard therefore, it could be concluded that irregular three-dimensional figures of buildings would definitely cost more to run compared to regular or geometric forms.

Roof shape. When addressing the maintenance consequences of design, Speight (1968:190) notes that, in low rise buildings the roof is extensive in proportion to floor area, whereas in high rise structures the ratio is less. However, comparative inaccessibility could be an important factor in determining materials and construction in relation to maintenance or renewal. In this regard, Stone (1975:25) points out that, "roof coverings depend on the shape and pitch of the roof." In relation to the maintainability of the building Stone goes further to note that "pitched roofs are usually easier to build and maintain in a weather-tight condition than are flat roofs." This implies that flat roofs are vulnerable to failure and concurs with Spedding's (1990:93) findings that "serious failures had occurred in flat roofs relatively frequently and were expensive to rectify." These is attributed to various reasons as summarized by Seeley (1983:211), i.e.:

> Flat roofs often produce serious maintenance problems due to lack of or haphazard falls, disregard of codes of practice, inadequate eaves, verge or fascia details, sharp granite chipping puncturing roofing felt with possibly sodden strawboard below supported on untreated and unventilated timber, inadequate thermal insulation, heavy condensation on underside of roof slabs, ill-conceived gutters and lack of walkways.

This concurs with Speight (1968:190).

In this regard therefore, it becomes evident that buildings with flat roofs incur more maintenance costs than those with pitched roofs. This has been supported by Hear and Swain (1977:31) when they note that, "extensive use of felt covered flat roofs have increased the percentage of roof maintenance substantially." They go further to justify this by stating that, "a felt covered flat roof may have a life of about ten years, compared with an approximate life of a tiled roof of fifty years." Hence it becomes justifiable for Spedding (1990:1074) to state that, "the preponderance of flat roofs in many countries, and the wide variety of specifications of roof coverings and deckings have necessitated some of the most expensive maintenance programmes in recent years."

However this is contrary to Syagga's (1985,307) findings that flat roofs cost less to maintain than pitched ones.

Glazing area. It is well known that the glazed windows represent a crucial element in the energy management of a building, due to their generally high thermal transmittances and their characteristics of transparency regarding an important amount of solar radiation wavelengths. But the glazed surfaces are also responsible for other functions, like the visual benefit to the occupants or the acoustic insulation, that in some case are in conflict with the energy saving requirements.

In this regard therefore, and as pointed out by

Burberry (1978:9), it is worth mentioning that, window glass is transparent to rays of the sun which can pass through it and warm up the interior of the building, however, it is opaque to the radiation coming from the surfaces inside the building due to reflection. These have led to ever increasing heating or cooling loads being applied to our buildings as pointed out by Ellenberg (1990:771). On the other hand, various attempts have been made to improve the thermal loading by use of mirrored glass, but in turn has led to the need for further controls when the reflections started to cause more problems for the neighbours than the glass solved for the occupiers. Added to this is the need for more artificial lighting in our now darkened glass windows.

With regard to the visual benefit to the occupants mentioned above, with tall buildings, the design should permit easy cleaning of all glazed areas for this to be achieved. In this regard therefore, the installation of track and equipment for cradles on multi-storey buildings would facilitate window cleaning and maintenance work. Thus, as pointed out by Hear and Swain (1977:33), it is for this reason that, window cleaning costs often represent a significant percentage of total cleaning costs.

Thus, the total area of glazing in any one building is very important. This is due to the fact that glazed area is the main parameter that determines the amount to be incurred in window cleaning, power consumed on lighting, air-conditioning, or heating of building spaces. Therefore, any change in the proportion of the windows to walls would automatically change the running costs incurred for any particular building. Hence, it is due to such reasons that Syagga (1987:210) realized that windows account for 7.4% of variation in maintenance cost of housing estates in Mombasa, Kenya.

Other parameters that influence form and hence subsequent running cost are as follows.

Age of building. According to Syagga (1987:206), the age of a building is measured from the date of occupation certificate to the base date when age comparisons are being considered.

As pointed out by various researchers, the magnitude of maintenance necessary would depend on the rate of depreciation or deterioration, which in principle increases progressively with age. Maintenance needs essentially influence the amount of money needed to carry out the works. Therefore cost of maintenance is likely to increase with building age. In this regard, Syagga (1987:206) has found out that there is a positive relationship between the age of the building and the costs of maintenance, and to be more specific age accounts for about 5% of the variation in maintenance cost. It is logical to argue that running cost would increase with age as maintenance cost is part of running cost.

4.3 Conclusion

Table 4.1. Summarizes the possible effects on subsequent running cost with regard to architectural form parameters.

Table 4.1. Possible effects on subsequent running cost with regard to the architectural form parameters.

FORM PARAMETER	POSSIBLE EFFECT ON RUNNING COST
Plan shape and perimeter of the building	- Running cost increases with increase in irregularity in the plan shape - Running cost increases with increase in perimeter length - Running cost increases with increase in perimeter area ratio
Total plinth area	Running cost decreases with increase in total plinth area
Volume of building	If cost incurred in maintaining the structure dominates cost incurred in lighting, ventilation and sound insulation, then, running cost decreases with increase in volume of building.
Height	Running cost increases with increase in height of building
Storey height	Running cost increases with increase in storey height of the building
Depth of building	Running cost increases with increase in depth of building
Number of storeys	Running cost increases with increase in number of storeys of the building
Rhythm	Running cost increases with increase in centre to centre of structural elements
Orientation	Running cost increases the more the building faces away from the north-south orientation
Light wells and floor voids	If running cost incurred in maintaining the extra building fabric exceeds the gains from easy air circulation and better lighting due to presence of light wells or floor voids, then, running cost increases with proportion of floor voids.
Form of horizontal circulation	Running cost increases with increase in ratio of circulation area to total plinth area

Source: Compiled from the author's literature review.

Table 4.1. Continued

FORM PARAMETER	POSSIBLE EFFECT ON RUNNING COST
Location of service core	The less the natural ventilation and lighting to the core the more the running cost
Plot ratio	Running cost increases with increase in plot ratio
Vertical circulation routes	Running cost decreases with increase in number of vertical escape routes
External wall	The more the external surface area the more the running cost. Cladding costs less to maintain than surface coating finishes. Rough or textured materials cost more to maintain than smooth ones.
Shading devices	If the cost incurred in maintaining the shading devices themselves is more than the cost incurred in ventilating and air-conditioning the building in their absence, then, running cost increases with presence of shading devices
Ornamentation	Running cost increases with increase in ornamentation of the building
Platonic solid of buildings	The more broken the massing of the building the more the running cost. However, this will depend on the amount of artificial energy conserved due to the fact that the more broken the building the more natural light is allowed into the building
Roof shape	Pitched roofs cost less to maintain than flat roofs
Glazing area	Running cost increases with increase in proportion of glazed exterior walling area
Age of building	Running cost increases with increase in age of the building

Source: Compiled from the author's literature review.

However, with some reason(s), not all these form parameters are relevant in the Nairobi case. In this regard, Table 4.2. summarizes the parameters for one reason or another are not relevant.

Table 4.2. Form Parameters that would not be relevant in the Nairobi case.

Form Parameter	Remark/Reason
Perimeter	Different plan shapes of the same area do not necessarily have the same perimeter
Storey height	There is little variation in storey height between Nairobi buildings
Internal wall finish nature	Most of the internal wall finishes are painted
Internal wall finish texture	Most of the internal wall finishes in Nairobi are smooth
Ceiling finish nature	Most of the ceiling finishes are painted
Number of storeys	Number of storeys multiplied by storey height above gives height of building
Ornamentation	Ornamentation is rare in Nairobi
Age of building	There has been a lot of renovations and modernization of Nairobi buildings.

Hence the following form parameters are more relevant in the Nairobi case and hence require investigation. However, the parameters in Table 4.2. above were also included in the investigation, but it was no wonder that they were not accepted by the regression model.

(i) Plot ratio of the location the building is located

(ii) Plan configuration

(iii) Ratio of perimeter length to plan area

(iv) Total plinth area

(V) Volume of the building

(vi) Building orientation

(vii) Height of building

(viii) Rhythm or distance between main structural elements

(ix) Proportion of glazed area

(x) Roof shape

(xi) Location of service core

(xii) Form of horizontal circulation

(xiii) Depth of building

(xiv) Shading devices

(xv) Proportion of floor voids

(xvi) Vertical circulation/escape routes

(xvii) External wall finish type

(xviii) External wall finish nature

(xix) External wall finish texture

(xx) Internal wall finish type

(xxi) Floor finish type

(xxii) Floor finish nature

(xxiii) Floor finish texture

(xxiv) Ceiling finish type

(xxv) Ceiling finish texture

(xxvi) Volumetric description or massing of the building

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CHAPTER 5

EVALUATION AND ANALYSIS OF RUNNING COSTS

5.1 Subsequent Running Costs

Systems of keeping subsequent running costs. Two systems of keeping running cost were in existence.

(a) Private sector. The private sector has employed or hired property managers to manage their properties. These are either hired property management consultant firms or in-house property managers. The concept used in collecting revenue and spending it in the various aspects that require running is the same. The amount paid to the property managers by the tenants for office running purposes is called service charge. This is beside the normal rent and is based on the lettable floor area of the building. To arrive at the amount charged per square foot or metre, the managers divide the amount required in their budget by the lettable area of the building. This cost per unit area so obtained is multiplied by the areas leased by the individual tenants to obtain the amount each respective tenant is supposed to pay. Then, the total amount collected is spent on all aspects of the building that require running of some kind. This cost per lettable unit area is always revised when necessary, especially after auditing of the property manager's books to make-up for the extra amount that may be required or to account for the surplus. In case of the surplus, it is regarded as an advance payment already made by the respective tenants for the following year.

The following are the aspects that require running in an office building.

(a) Electricity

(b) Water

(c) Repairs

(d) Air conditioning and ventilation

(e) Security

(f) Cleaning

(g) Lifts

(h) Painting

(i) Salaries i.e. overheads and management fees

(j) Others i.e. rates, insurance, land rent, etc.

In this regard therefore, it became much easier to collect subsequent running cost data from private developers due to the fact that their system of keeping running data was consistent and similar. This data was also found to be more reliable since the property managers account for the service charge at the end of each year.

(b) Public sector. The public sector normally uses in-house property managers who are referred to as office superintendents. The duty of these public officers and their offices is to keep records and manage the various expenditures that touch on the running of the building(s) of their respective ministries. This is unlike what used to happen in the recent past, when, especially "general maintenance or repair used to be managed by the maintenance depots that used to be under the supervision and management of the department of maintenance of the ministry of Public Works" (Okwemba, 1993). As of now, as reported by Okwemba of the department of maintenance of the ministry of Public Works, the system has changed and each ministry is allocated separate budgets to spend on the various issues of running (including maintenance) of their building(s). In this regard therefore, the researcher was also able to extract subsequent running costs data for the various aspects from their payment voucher files.

Subsequent Running Costs of Office Buildings in Nairobi. The annual mean subsequent running cost of office buildings of the sampled buildings was Ksh. 380/=60 per square metre. Whereas, the maximum and minimum annual mean subsequent running cost of office buildings was Ksh. 868/=00 and Ksh. 101/=30 respectively. These amounts were spent on National Housing Corporation building and Shelter Afrique.

Buildings that spent amounts closer to the mean were Church House that spent Ksh. 411/=60, Anniversary Towers that spent Ksh. 418/=55, Reinsurance Plaza that spent Ksh.372/=60, and National Bank Building that spent Ksh. 342/=30.

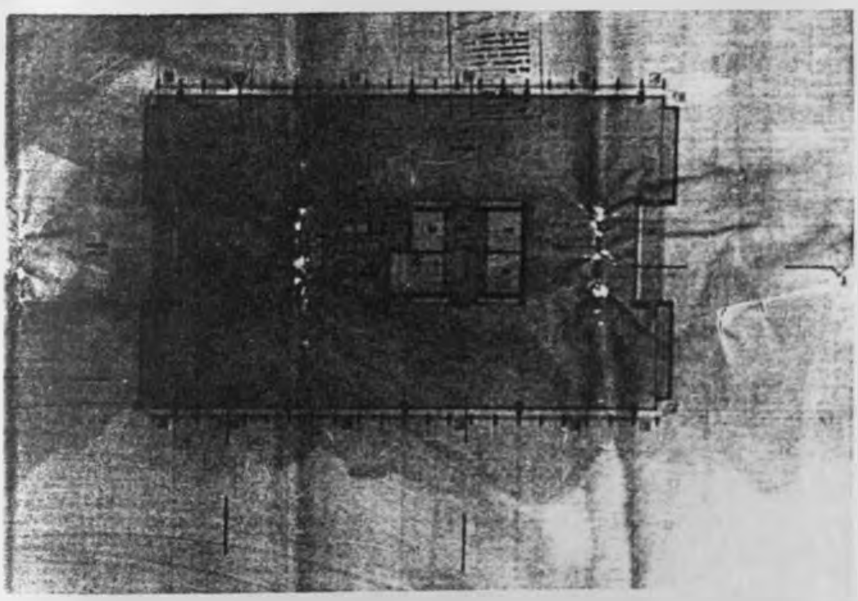


Plate 5.1. Plan of NHC house. Building that had the highest subsequent running expenditure.

Source: NCC Architectural Department.

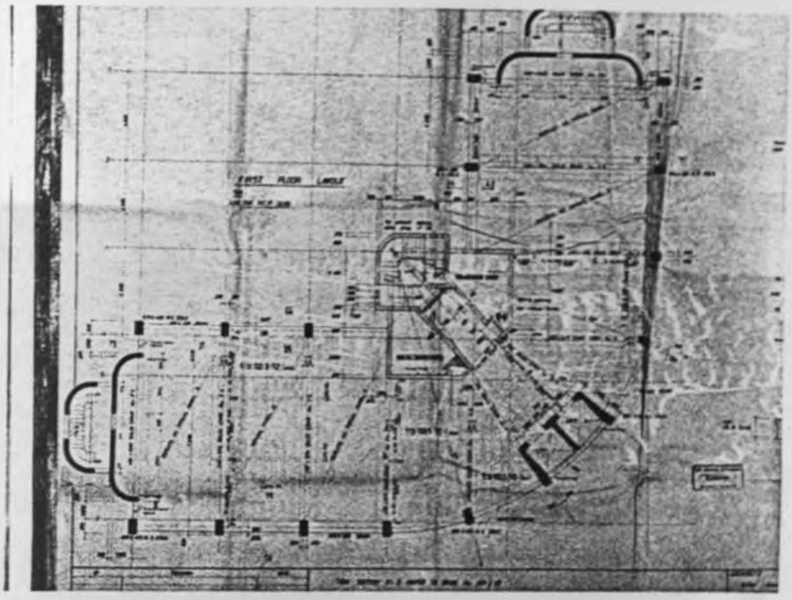


Plate 5.2. Plan of Shelter Afrique. Building that had the lowest subsequent running expenditure.

Source: NCC Architectural Department.

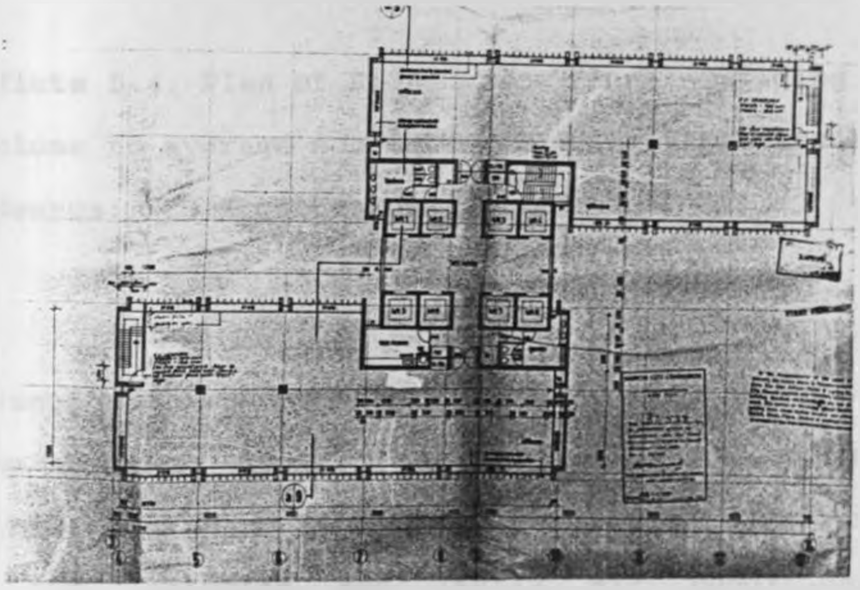


Plate 5.3. Plan of Anniversary Towers. Building that had close to average subsequent running expenditure.

Source: NCC Architectural Department.

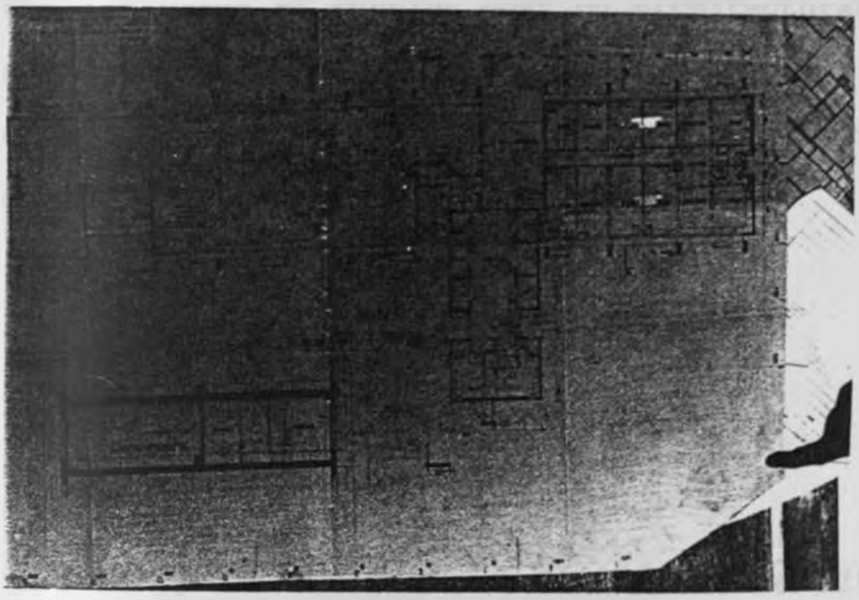


Plate 5.4. Plan of Reinsurance Plaza. Building that had close to average subsequent running expenditure
Source: NCC Architectural Department.

It has been noted (Figure 5.1.) that subsequent running expenditure was highest in electricity, followed by repairs, security or others (i.e. sum of rates, insurances, land rents, etc.), salaries, water, cleaning, lifts, painting and lastly air conditioning and ventilation. Figure 5.2. shows that utilities (i.e., electricity, water, security, salaries and others) consumes 70.2 percent while maintenance (i.e., repairs, air-conditioning and ventilation, cleaning, lifts and painting) consumes 29.8 percent of the subsequent running costs. In this regard therefore, it is logical to study the influence of running cost on architectural form as compared to the study of the influence of maintenance cost on architectural form as other researchers have done.

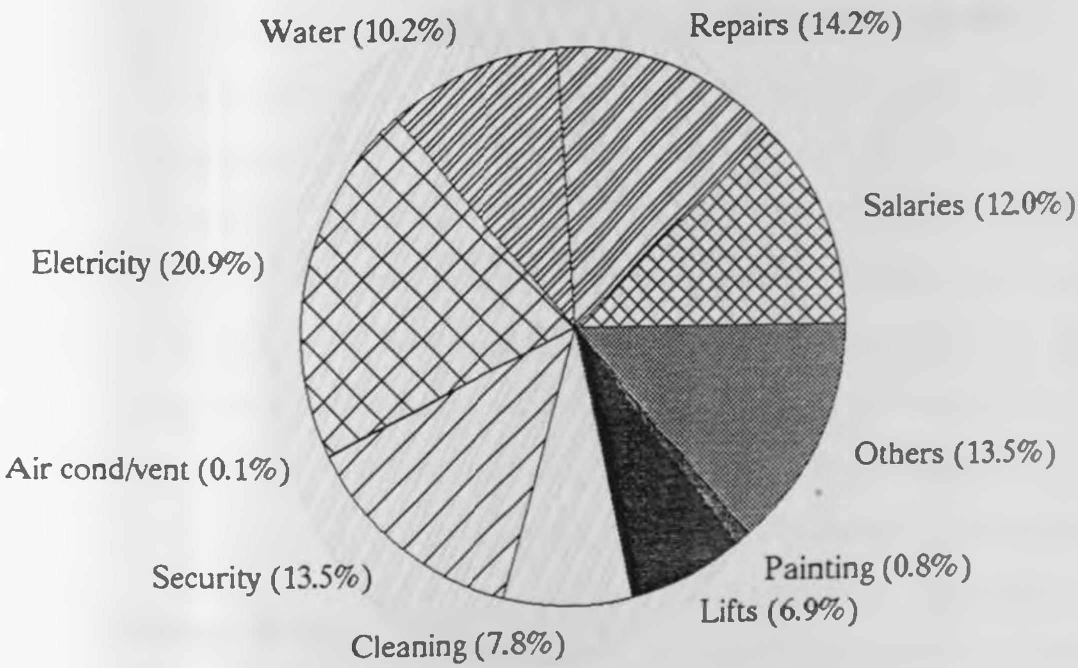


Figure 5.1. Proportions of subsequent running cost as spent on the various aspects at the 1992 constant prices. Source: Compiled from author's field data.

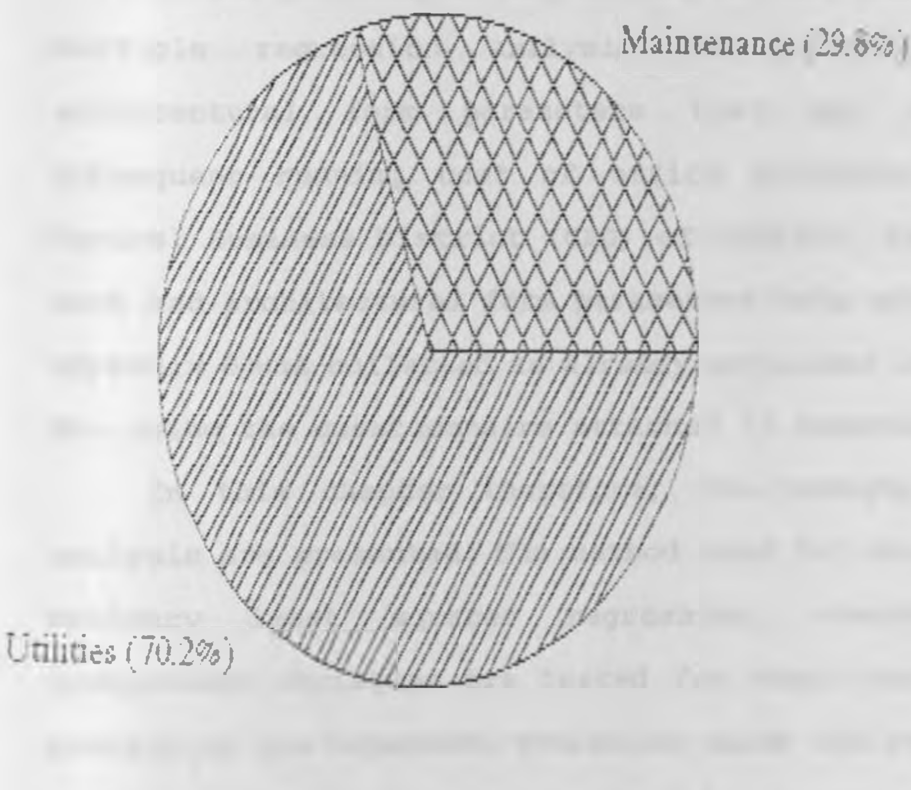


Figure 5.2. Proportions of Maintenance and Utilities in the subsequent running Cost at the 1992 constant prices.
Source: Compiled from author's field data.

5.2 Subsequent Running Cost Determinants

Chapter Four of this study has dealt with the theoretical relationship between architectural form parameters and subsequent running cost. The existing relationships between the architectural form parameters to be analyzed in this Chapter Five and the subsequent running cost of office buildings have been recorded.

It was proposed in Chapter One of this study to use multiple regression analysis to investigate the architectural form parameters that may determine subsequent running cost of office buildings in the Central Business District (CBD) of Nairobi, Kenya. The cost and architectural form parameters data attached in appendix D was collected as already explained in Chapter One using the questionnaire attached in appendix B.

In this chapter therefore, the results of the analysis are presented. The method used for analysis is ordinary least squares regression, whereby, the independent variables are tested for their strength in predicting the dependent variables using the regression coefficients. Multicollinearity is assessed using pearson's product moment correlations to determine whether the independent variables are highly correlated among themselves (Table 5.1.). This is necessary because any two independent variables having a correlation of more than 0.7 implies that one of the independent variables is redundant and hence should be dropped from the model. This dropping of redundant variables has been established by Pedhazur (1982).

The computed correlations on all the variables show there is a problem of multicollinearity.

The following independent variables were found to be highly correlated: height and number of storeys (0.983454); plinth area and volume (0.81002); plinth area and number of storeys (0.764156); volume and height (0.762655); volume and number of storeys (0.744633); plinth area and height (0.724716). This means that either of these variables can play the role of the other in the model. In this regard therefore, it would be imperative to drop one variable from each pair that would be found significant in the final model.

In order to determine the independent variables that determine subsequent running costs, all the variables were regressed on annual mean subsequent running cost using the step-wise method. This method automatically enters the most significant variables into the model and at every other time another variable is introduced into the model, the significance of the variables in the model is checked and any variable found insignificant is automatically dropped from the model. Once all the significant variables are entered into the model, then two tables are displayed, one that shows variables in the model and the other that shows variables not in the model. In this regard Table 5.2. shows variables entered and retained in the model whereas Table 5.3. shows variables either entered and rejected from the model or not entered at all. Thus, this means that variables in Table 5.2. were accepted whereas variables in Table 5.3. were rejected as remarked in the respective tables.

Then, the coefficients of correlations of the variables accepted into the model were checked. It was realized that the correlations of all the variables in the model with running cost was less than 0.7 and in fact none of the variables in the pairs that had been found highly correlated were in the model. This meant that multicollinearity had automatically been eliminated from the model. Thus, these variables accepted into the model were found to determine annual mean subsequent running cost. These variables and their characteristics have been summarized in Table 5.4.

Finally it became imperative to discuss briefly these independent variables in the final model

Table 5.1. Simple product-moment correlation matrix for all variables

	Y	X_1	X_2	X_3	X_4	X_4^*	X_5	X_6
Y								
X_1	-0.036222							
X_2	0.147085	0.253034						
X_3	-0.062153	-0.155274	-0.223105					
X_4	-0.233251	0.31788	0.038471	0.061311				
X_4^*	0.134086	-0.057602	0.164578	0.207405	-0.089594			
X_5	-0.171056	-0.291357	-0.041569	0.070739	0.273659	-0.217621		
X_6	-0.132631	-0.296636	0.04684	-0.032218	0.212189	-0.238258	0.81002	
X_7	0.221626	-0.119193	0.079284	0.061082	-0.026401	-0.102015	-0.231659	-0.149114
X_8	0.01044	0.50370**	0.011747	-0.011136	-0.211234	0.041521	0.724716**	0.76266**
X_9	0.101356	-0.195985	0.062857	-0.19611	-0.231799	-0.332835	0.012845	0.101587
X_{10}	-0.073075	-0.32476	-0.152993	0.084469	0.069721	-0.083018	0.386656*	0.459656*
X_{11}	0.2823	-0.3755	-0.3481	0.1285	-0.0836	0.0677	0.1382	0.0603
X_{12}	0.122405	-0.287164	-0.064101	0.103053	0.025377	0.127205	0.168713	0.140236
X_{13}	-0.340827	0.04998	-0.055507	0.071225	0.046904	-0.111189	0.092482	-0.048062
X_{14}	0.123313	0.113609	0.183317	-0.183019	-0.11646	-0.228996	-0.254108	0.287571
X_{15}	0.131704	0.016401	-0.052697	-0.153623	0.083762	-0.07042	-0.083785	-0.150897
X_{16}	0.028844	0.401386*	-0.167072	-0.02498	0.046872	-0.402032*	0.08572	0.141202

Signif * - 0.01 ** - 0.001

Source: Compiled from author's field data.

Table 5.1. Continued

	Y	X_1	X_2	X_3	X_4	X_4^*	X_5	X_6
X_{17}	0.247356	0.333207	0.205619	0.102513	0.139539	-0.064985	-0.291724	-0.138185
X_{18}	-0.314582	0.139323	-0.055018	0.056727	0.684042	-0.246114	0.181174	0.032527
X_{19}	0.254338	0.407227*	-0.033941	-0.41289*	0.152571	-0.059211	-0.303931	-0.262707
X_{20}	-0.133903	0.349418	0.195182	-0.234549	0.234578	-0.117754	-0.161914	-0.156202
X_{21}	0.15107	0.228151	-0.076125	-0.318721	0.103431	0.029917	-0.160621	-0.057315
X_{22}	0.060622	0.334606	0.051942	0.021587	0.169935	0.0814	-0.442583*	-0.360089
X_{23}	-0.113671	0.45216**	-0.018974	0.156323	0.229756	-0.279432	-0.241247	-0.075485
X_{24}	-0.070972	-0.149134	-0.07867	-0.030741	-0.156375	-0.137117	0.170032	0.190725
X_{25}	0.00922	-0.047843	0.189871	-0.147949	0.092147	0.138438	-0.329267	-0.213145
X_{26}	0.069361	0.43949**	-0.133843	0.093022	0.260167	0.031812	-0.054157	-0.178025
X_{27}	0.029189	0.217695	-0.168265	-0.032894	0.236114	0.029496	-0.05265	-0.090194
X_{28}	-0.147831	0.32554	0.310422	-0.118562	0.19089	0.158682	-0.313944	-0.131822
X_{29}	-0.13565	0.242105	-0.113991	0.225807	0.244399	-0.018894	-0.255689	-0.199935
X_{30}	0.135823	-0.137441	-0.170367	0.029783	-0.238399	0.015875	0.114591	0.191666
X_{31}	0.211424	-0.5289**	0.032665	0.015427	-0.188284	-0.001871	0.764156**	0.744633**
X_{32}	0.128378	-0.138152	0.104843	-0.115547	-0.191131	-0.106508	0.154444	-0.001414
X_{33}	0.089878	-0.237535	-0.154107	0.64099**	-0.045365	-0.059178	-0.014731	0.125539

Signif * - 0.01 ** - 0.001

Source: Compiled from author's field data.

Table 5.1. Continued..Simple product-moment correlation matrix for all variables

	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_7								
X_8	-0.232222							
X_9	0.180936	0.163579						
X_{10}	-0.097031	0.51177**	0.003464					
X_{11}	0.219313	0.113181	0.009327	0.115897				
X_{12}	-0.225661	0.270692	-0.22054	0.357906	0.0746			
X_{13}	-0.015684	-0.046583	-0.05735	-0.171622	0.1110	0.313248		
X_{14}	0.016763	-0.25362	0.064031	-0.011314	-0.1828	-0.01995	0.1922	
X_{15}	0.064869	-0.216991	0.141375	-0.266801	-0.0455	0.1847	0.426162*	0.189074
X_{16}	0.109124	0.08156	-0.070915	-0.109836	-0.1382	-0.084244	0.050804	-0.178595
X_{17}	0.266205	-0.318998	0.186898	-0.292293	-0.0079	-0.029665	0.082958	-0.002302
X_{18}	0.098158	-0.190318	-0.156809	-0.192977	-0.0772	-0.088142	0.104432	-0.18222
X_{19}	0.064265	-0.332366	-0.22651	-0.240289	-0.0386	-0.376037*	-0.162111	0.114039
X_{20}	0.096172	-0.354397	-0.15424	-0.343603	-0.2493	-0.387745*	-0.082952	0.263697
X_{21}	0.093005	-0.15035	0.076315	0.090117	-0.1649	-0.363545	-0.148037	0.190292
X_{22}	-0.193652	-0.579431**	-0.280922	-0.198146	-0.3084	-0.124579	-0.290591	-0.012806
X_{23}	0.102611	-0.345586	-0.096892	-0.186786	-0.0648	-0.222785	-0.009487	-0.098229
X_{24}	-0.138932	0.268313	0.164939	0.344089	-0.0575	0.177434	-0.095802	-0.107968

Signif * - 0.01 ** - 0.001

Table 5.1. Continued
Simple product-moment correlation matrix for all variables

	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}
X_{25}	-0.297136	-0.283233	-0.32369	0.029799	-0.1006	0.106729	-0.073763	-0.02506
X_{26}	-0.002881	-0.282685	-0.223323	-0.341322	-0.2190	-0.340686	-0.09989	0.04434
X_{27}	-0.183502	-0.126337	-0.089577	0.121487	-0.1914	0.139732	0.027331	0.147479
X_{28}	0.252547	-0.392743*	-0.056285	-0.231411	-0.3495	-0.152915	-0.037616	-0.066903
X_{29}	0.22027	-0.356521	-0.112774	0.085253	-0.2476	-0.355702	-0.071225	-0.140143
X_{30}	0.166114	0.336575	-0.063095	0.444547*	-0.0833	0.054891	0.100618	0.044125
X_{31}	-0.242155	0.983454**	0.120399	0.521443**	0.1987	0.251503	-0.039256	-0.260952
X_{32}	0.184456	0.064823	0.218156	-0.266668	-0.0343	-0.267154	-0.18464	-0.033719
X_{33}	-0.029326	0.096036	-0.032404	0.298526	-0.0331	0.081945	-0.097088	0.085744

Signif * - 0.01   ** - 0.001
Source: Compiled from author's field data.

Table 5.1. Continued- Simple product-moment correlation matrix for all variables

	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}
X_{16}	-0.181447							
X_{17}	0.036042	0.14653						
X_{18}	0.197692	0.140424	0.061221					
X_{19}	-0.039699	0.30911	-0.034728	0.107522				
X_{20}	0.104422	0.080281	-0.026981	0.254494	0.547266**			
X_{21}	0.039585	-0.016155	-0.123337	-0.079969	0.555268**	0.436166*		
X_{22}	0.129167	0.014967	0.130173	0.340696	0.217594	0.297572	0.106339	
X_{23}	-0.179248	0.41291*	0.427696	0.31772	0.277561	0.311302	-0.029292	0.529865**
X_{24}	0.065704	-0.041857	-0.251992	-0.254749	0.099	-0.114105	-0.036346	-0.018
X_{25}	-0.126463	-0.124471	0.061919	0.1401	0.165702	0.156879	-0.087459	0.462042*
X_{26}	0.09175	0.251026	0.185761	0.094863	0.328579	0.489396**	0.351084	0.134082
X_{27}	0.159324	-0.112734	0.150771	-0.124591	0.21285	0.20927	0.33055	-0.114136
X_{28}	0.224187	-0.102786	0.233893	0.068044	0.257527	0.392396*	0.142295	0.370267
X_{29}	0.004	-0.02488	0.267619	0.192005	0.216769	0.141707	0.111687	0.251851
X_{30}	-0.144229	0.090581	-0.067764	-0.36342	0.01852	-0.189441	0.14668	-0.289303
X_{31}	-0.247487	0.001342	-0.359388	-0.167425	-0.356493	-0.340567	-0.16095	-0.591366**
X_{32}	-0.01772	-0.05656	-0.031177	-0.011225	0.096229	-0.100529	-0.236434	-0.078645
X_{33}	-0.249676	0.005477	-0.009327	-0.126771	-0.272615	-0.07313	-0.15348	-0.076013

Signif * - 0.01 ** - 0.001
Source: Compiled from author's field data.

Table 5.1. Continued..Simple product-moment correlation matrix for all variables

	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}
X_{23}								
X_{24}	0.050872							
X_{25}	0.24482	8.1E-10						
X_{26}	0.183532	-0.190963	-0.229735					
X_{27}	-0.117932	0.201167	-0.234674	0.442653*				
X_{28}	0.252672	0.155808	0.230697	0.005568	0.247899			
X_{29}	0.278333	0.030741	0.147949	0.178891	0.310656	0.391618		
X_{30}	-0.101282	0.34214	-0.106221	-0.010296	0.291254	0.069642	-0.029783	
X_{31}	-0.383241	0.223361	-0.277105	-0.289974	-0.159101	-0.397838	-0.363292	0.315278
X_{32}	-0.134818	0.2372	-0.095121	-0.018412	-0.237318	-0.094705	-0.109622	-0.10848
X_{33}	0.08727	0.108268	-0.130246	-0.088193	0.115827	-0.063261	0.129819	0.116503

Signif * - 0.01 ** - 0.001
Source: Compiled from author's field data.

Table 5.1. Continued..Simple product-moment correlation matrix for all variables

	X_{31}	X_{32}	X_{33}
X_{31}			
X_{32}	0.063056		
X_{33}	0.068154	-0.088679	

Signif * - 0.01 ** - 0.001
Source: Compiled from author's field data.

Key

Y Annual mean subsequent maintenance cost in Ksh per square metre

X_1 Age of the building

X_2 Plot ratio of the location the building is located

X_3 Plan configuration

X_4 Perimeter of building plan

X_4^* Ratio of perimeter length to plan area

X_5 Plinth area

X_6 Volume of the building

X_7 Building orientation

X_8 Height of building

X_9 Rhythm or distance between main structural elements

X_{10} Proportion of glazed area

X_{11} Roof shape

X_{12} Location of service core

X_{13} Form of horizontal circulation

X_{14} Depth of building

X_{15} Shading devices

X_{16} Storey height

X_{17} Proportion of floor voids

X_{18} Vertical escape routes

X_{19} External wall finish type

X_{20} External wall finish nature

X_{21} External wall finish texture

X_{22} Internal wall finish type

X_{23} Internal wall finish nature

X_{24} Internal wall finish texture

X_{25} Floor finish type

X_{26} Floor finish nature

X_{27} Floor finish texture

X_{28} Ceiling finish type

X_{29} Ceiling finish nature

X_{30} Ceiling finish texture

X_{31} Number of storeys

X_{32} Ornamentation

X_{33} Volumetric description or massing of the building

Table 5.2. Multiple regression of all the variables in the model.
Variables in the Equation

VARIABLE X_i	X-COEFF. B	SE B	Beta	T	Sig T.	Remark
X_{13}	-85.426903	25.374212	-0.384679	-3.367	0.0022	Accepted
X_{11}	160.891116	37.951104	0.531025	4.239	0.0002	"
X_7	57.430795	19.966342	0.320998	2.876	0.0075	"
X_2	58.552139	17.820789	0.409721	3.286	0.0027	"
X_{19}	96.911456	33.420990	0.388530	2.900	0.0071	"
X_{20}	-146.047030	36.303948	-0.618440	-4.023	0.0004	"
X_{26}	125.871054	46.249201	0.363977	2.722	0.0109	"
X_{14}	41.402349	15.439963	0.316462	2.682	0.0120	"
Constant	-408.974476	154.214498		-2.652	0.0128	"

Multiple R	= 0.81136	R Square	= 0.65830
Adjusted R Square	= 0.56403	Standard Error	= 115.54117
F	= 6.98365	Signif F	= 0.0000

Source: Compiled from author's field data.

Table 5.3. Multiple regression of all the variables in the model.
Variables not in the Equation

VARIABLE X_i	Beta In	Partial	Min Toler	T	Sig. T	Remark
X_{28}	-0.038184	-0.050936	0.439352	-0.270	0.7892	Rejected
X_{10}	-0.082055	-0.120481	0.491231	-0.642	0.5260	"
X_{18}	-0.128057	-0.197080	0.451192	-1.064	0.2965	"
X_{15}	0.056886	0.085552	0.493774	0.454	0.6531	"
X_{17}	0.058297	0.086340	0.474901	0.459	0.6501	"
X_3	0.011879	0.016912	0.497979	0.090	0.9293	"
X_{32}	-0.125357	-0.199797	0.471240	-1.079	0.2898	"
X_{30}	0.119196	0.187373	0.464612	1.009	0.3214	"
X_6	0.008278	0.012831	0.494139	0.068	0.9463	"
X_{33}	0.035130	0.054198	0.488263	0.287	0.7761	"
X_{27}	0.155235	0.221645	0.497419	1.203	0.2391	"
X_{16}	0.067469	0.099258	0.488224	0.528	0.6018	"
X_{22}	-0.049389	-0.073491	0.477143	-0.390	0.6995	"
X_{21}	0.079961	0.107113	0.493638	0.570	0.5732	"

X_{4*}	0.037406	0.058956	0.487727	0.313	0.7570	"
X_{12}	0.138893	0.195250	0.489137	1.053	0.3011	"
X_{25}	-0.044408	-0.065611	0.480117	-0.348	0.7305	"
X_9	-0.021035	-0.032846	0.498564	-0.174	0.8632	"
X_1	-0.041111	-0.050316	0.490935	-0.267	0.7917	"
X_4	-0.110994	-0.176610	0.490840	-0.949	0.3505	"
X_5	7.3888E-04	0.001127	0.495938	0.006	0.9953	"
X_8	0.099672	0.147579	0.493739	0.790	0.4364	"
X_{23}	-0.070317	-0.110281	0.476037	-0.587	0.5618	"
X_{24}	-0.0006914	-0.010845	0.495872	-0.057	0.9546	"
X_{29}	-0.091994	-0.140092	0.498389	-0.749	0.4603	"
X_{31}	0.053392	0.077651	0.496894	0.412	0.6834	"

Source: Compiled from author's field data.

Table 5.4. Multiple regression of the variables in the final model.

VARIABLE X_i	Simple r2	Multiple R^2 ACCUM.	R^2 Change	B	SE B	Beta	T	Sign T
X_{13}	0.11616	0.11616	0.11616	-85.426903	25.374212	-0.384679	-3.367	0.0022
X_{11}	0.079693	0.21988	0.10372	160.891116	37.951104	0.531025	4.239	0.0002
X_7	0.049118	0.30247	0.08259	57.430795	19.966342	0.320998	2.876	0.0075
X_2	0.021634	0.36607	0.0636	58.552139	17.820789	0.409721	3.286	0.0027
X_{19}	0.064688	0.40848	0.04241	96.911456	33.420990	0.388530	2.900	0.0071
X_{20}	0.01793	0.49897	0.09049	-146.04703	36.303948	-0.618440	-4.023	0.0004
X_{24}	0.004811	0.57357	0.0746	125.871054	46.249201	0.363977	2.722	0.0109
X_{14}	0.015206	0.65830	0.08473	41.402349	15.439963	0.316462	2.682	0.0120
Constant				-408.97448	154.21450		-2.652	0.0128

Multiple R	= 0.81136	R Square	= 0.65830
Adjusted R Square	= 0.56403	Standard Error	= 115.54117
F	= 6.98365	Signif F	= 0.0000

Source: Compiled from author's field data.

Form of Horizontal Circulation(X_{13}). Simple correlation shows that subsequent running cost of office buildings decreases with the form of horizontal circulation. This cost decreases in the order of single zone, double zone, triple zone and open layout. The derived simple regression equation is:

$$Y = 458.2987 - 75.6887X_{13}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{13} is the form of horizontal circulation.

The unstandardised b-coefficient for the equation above is -75.6887. A graph of this relationship could not be drawn because form of horizontal circulation is a dummy variable.

This relationship between subsequent running cost of office buildings and form of horizontal circulation is significant at 0.05 level. This relationship implies that if the form of horizontal circulation is changed from single zone to double zone or from double zone to triple zone or from triple zone to open layout, the subsequent running cost decreases by 75.6887 units. The form of horizontal circulation and subsequent running cost of office buildings are very correlated in the model (Table 5.1.) having a correlation of 0.340827.

Having computed the regression model, it was realized that the form of horizontal circulation of office buildings was the most important independent variable; it explains about 11.62 percent (Table 5.4.) of the variation in subsequent running cost of office buildings.

Also, form of horizontal circulation of office buildings is a significant variable in the multiple regression model. The b-coefficient is -85.426903 (Table 5.4.). This means that if the form of horizontal circulation is changed from single zone to double zone or from double zone to triple zone or from triple zone to open layout, the subsequent running cost decreases by 85.426903 units. This finding is consistent with the literature; subsequent running cost of office buildings decreases with form of horizontal circulation in the order given above. The most probable explanation for this relationship therefore, is that the ratio of circulation space to the total plinth area decreases in the order given above. In this regard therefore, the services needed (like lighting, cleaning, repair, security, etc) to keep these circulation spaces, that is, the servant spaces and the building in general, that is, the master spaces, operational, decreases proportionately. Examples of buildings illustrating this relationship are given in Table 5.5.

Table 5.5. Comparison of subsequent running cost of buildings with different forms of horizontal circulation.

Name of building	Form of Horizontal Circulation	Subsequent Running cost in Ksh.
NHC building	Single zone	867.99
Panafrican building	Double zone	689.25
Cooperative bldg	Triple zone	159.50
Laxmi plaza	Open layout	120.19

Source: Compiled from author's field data.

It is also worth mentioning here that most of the sampled buildings with an internal service core have a single zone as the form of horizontal circulation. These buildings include, National Housing Corporation, Kenindia House, Fedha Towers and Uchumi House. Also it was established that buildings with internal core costs more to run than those with semi-internal core or external core. This is illustrated by the simple regression equation below.

$$Y = 420.9844 - 39.3312X_{12}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{12} is the location of service core.

This variable was found to account for 1.4983 percent of variations in subsequent running cost. However this variable was eliminated from the model as already explained in this chapter.

This relationship between single zone form of horizontal circulation and the location of service core reinforces the explanation already given that, buildings with a single zoned form of horizontal circulation have more facilities that require running. In this regard therefore, to design for less subsequent running cost, designers should try to eliminate forms of horizontal circulation and locations of service core that cost more to run.

Thus, this implies that a change in form of horizontal circulation means change in expenditure in both maintenance of the building elements and the utilities used in the building like energy, water, security, etc. Hence, this proportional change in the running cost automatically implies the significant contribution of the variable in the multiple regression.

Roof Shape(X_{11}). A simple regression between roof shape and subsequent running costs realized that 7.9693 percent of the variations in subsequent running cost is explained by factors related to variations in roof shape. The relationship developed between roof shape and subsequent running cost is a positive one as shown below. This relationship is not significant at 0.05 level, however it is consistent with the literature findings that, buildings with flat roofs cost more to run than those with pitched roofs and hence buildings with composite roofs cost more to run than those with flat ones.

$$Y = 283.848977 + 85.516751X_{11}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{11} is the roof shape.

The unstandardised b-coefficient for the equation above is +85.516751. A graph of the relationship could not be drawn because roof shape is a dummy variable.

In the computed multiple regression model, it was realized that the roof shape accounted for nearly 10.372 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. The b-coefficient for roof shape in multiple regression model is +160.891116 (Table 5.4.). This means that buildings with flat roofs cost more to run by 160.891116 units than those with pitched roofs. Similarly, buildings with composite roofs cost more to run by 160.891116 units than those with flat roofs. This is consistent with the literature findings of this study. This means that flat roofs experience more problems in regard to drains, slopes and cracking of finishing materials compared to pitched ones. Whereas, composite roofs (i.e. pitched roof on a flat roof) experiences a multiple of problems that involve water drainage, ventilation of the enclosed space due to heat accumulation, etc.

As already mentioned above, the contribution of roof shape in the multiple regression model is significant. This is due to the fact that, a change in roof shape means a great variation in building elements and aspects that require running thus influencing in a great deal the running cost. Hence, this explains the significant contribution of the variable.

<u>Orientation (X_7).</u> Simple correlation showed that the more the building tends to face east-west or all directions, the more the subsequent running cost than those buildings facing north-south. A simple regression between subsequent running cost and orientation of the office building realized that, 4.9118 percent of the variation in subsequent running cost is explained by factors related to variations in orientation of the building. The computed simple regression equation is:

$$Y = 323.2275 + 39.6517X_7$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_7 is the orientation of the building.

The unstandardised b-coefficient for the equation above is +39.6517. This relationship between subsequent running cost and orientation of the office building is not significant at 0.05 level. A graph of the relationship could not be drawn because orientation is a dummy variable.

In the computed multiple regression model, it was realized that orientation of the building accounted for nearly 7.0647 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. The b-coefficient for orientation in multiple regression model is +57.430795 (Table 5.4.). This means that for every one unit increase in the orientation of the building, the subsequent running cost increases by 57.430795 units. This is consistent with the literature on the relationship between orientation and subsequent running cost. This is supported by the fact that the more sunlight is allowed into the building the more heat builds-up in the building and hence the more discomfort on workers and the more deterioration on the components of the building, thus more subsequent running cost. Thus, the north-south soft sunlight causes less harm than the high intensity east-west sunlight.

The most probable reason as to why the contribution of orientation is significant in the multiple regression is that, buildings in Nairobi tend to face different directions due to the plot orientations. In this regard the sunlight and heat intensities allowed into these buildings vary and as such the deterioration caused on the building elements and the required services like energy usage, air-ventilation and air-conditioning significantly vary. Thus, the variation on orientation automatically means a great variation in aspects in the building that require running and hence implying the significant contribution.

Plot Ratio (X_2). The plot of subsequent running cost versus plot ratio of office building (Graph 5.1.) shows that subsequent running cost of office buildings increases with an increase in plot ratio of the building. The computed simple regression equation is:

$$Y = 269.6006 + 21.01976X_2$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_2 is the plot ratio.

The unstandardised b-coefficient for the equation above is +21.01976. This relationship between subsequent running cost and plot ratio of the building is not significant at 0.05 level.

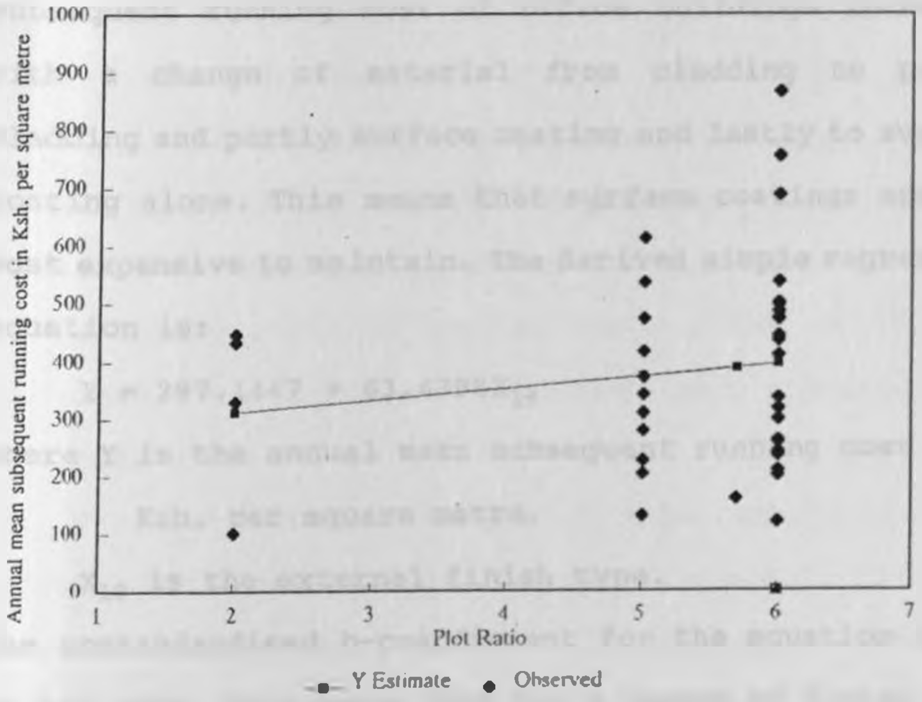
The correlation between subsequent running cost and plot ratio of the office building is 0.147085 (Table 5.1.). In this regard, plot ratio is found to explain 2.1634 percent of the variation in subsequent running cost.

In the computed multiple regression model, it was realized that plot ratio of the building accounted for nearly 6.36 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. The b-coefficient for plot ratio in multiple regression model is +58.552139 (Table 5.4.). This means that for every one unit increase in the plot ratio of the building, the subsequent running cost increases by 58.552139 units.

The positive relationship between plot ratio and subsequent running cost is consistent with the literature findings of this study. This is probably because plots of higher plot ratios have taller buildings. These buildings tend to have more walling, building infrastructure for instance lifts, water installations, etc, which increase the subsequent running cost of office building.

The contribution of plot ratio in the multiple regression model is significant as already mentioned above. This is probably because the buildings on plots of high ratios are the tallest, have high plinth areas, volume and population to deal with. In this regard, these buildings also have more and sophisticated mechanical and electrical services like lifts, air conditioning and ventilation to maintain and run. Whereas buildings on low ratios have exactly the opposite of the above. This implies that a change in plot ratio means a great change in almost all size elements of the building and hence the running cost of the building, thus implying the significance of the variable in the model.

Also, it should be noted that plot ratio determines the size of the building i.e. plinth area, volume, height, number of storeys, etc., and this is why these variables were eliminated from the model.



Graph 5.1. Plot of subsequent running cost versus plot ratio of office building.

Source: Plotted from the author's field data.

External Finish Type(X_{19}). Data collected from the sampled buildings showed that 13.2 percent of these buildings had used only cladding on their exterior walls, 42.1 percent had used both cladding and surface coatings, whereas the remaining 44.7 percent had used only surface coatings. A simple regression between this finish type and the subsequent running cost realized that, 6.4688 percent of the variations in subsequent running cost is explained by factors related to variations in this wall finish type. This simple correlation showed that subsequent running cost of office buildings increases with a change of material from cladding to partly cladding and partly surface coating and lastly to surface coating alone. This means that surface coatings are the most expensive to maintain. The derived simple regression equation is:

$$Y = 297.1447 + 63.4398X_{19}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{19} is the external finish type.

The unstandardised b-coefficient for the equation above is +63.4398. This means that for a change of finish from cladding to partly cladding and partly surface coating or from partly cladding and partly surface coating to just surface coating alone (of which represent one unit change in external finish type), the subsequent running cost increases by 63.4398 units. This relationship between subsequent running cost and external finish type is not significant at 0.05 level. A graph of this relationship could not be drawn because external finish type is a dummy variable.

After computing the multiple regression model, it was realized that the external finish type accounted for nearly 4.241 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level and consistent with the literature on the relationship between the subsequent running cost and external finish type of the office building. The b-coefficient of external finish type of the building in the multiple regression is +96.911456 (Table 5.4.). This means that for every one unit increase in the external finish type of the building as already explained, the subsequent running cost increases by 96.911456 units.

The most probable reason why the contribution of external wall type is significant in the model, is that, there is a significant variation in maintenance/running requirements of the two types of finish types. For instance, cladding i.e., marble, granite, ceramic tiles, etc., require simple cleaning by mopping or spraying with water and rare repairs. On the other hand, surface coatings i.e., plaster and paint, etc., require regular repainting and repairs (say after every three years). This means that a little alteration on the material implies a great change in maintenance and hence running expenditure on the building. Secondly, since this surfaces constitute large areas which must be kept to portray a good image of the building to the public, then, it means a proportionate expenditure on them, thus explaining the significant contribution.

External Wall Finish Nature(X_{20}). Simple correlation showed that buildings with unpainted external wall finishes cost more to maintain than those with painted exterior wall finishes. A simple regression between subsequent running cost and external wall finish nature realized that, 1.793 percent of the variation in subsequent running cost is explained by factors related to variations in external wall finish nature. The computed simple regression equation is:

$$Y = 405.5828 - 31.6219X_{20}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{20} is the external wall finish nature.

The unstandardised b-coefficient for the equation above is -31.6219. This relationship between subsequent running cost and external wall finish nature is not significant at 0.05 level. A graph of the relationship could not be drawn because external wall finish nature is a dummy variable.

In the computed multiple regression model, it was realized that the external wall finish nature of the building accounted for nearly 9.049 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. The b-coefficient for external wall finish nature in multiple regression model is -146.047030 (Table 5.4.). This means that buildings which have exterior walls partly unpainted and partly painted cost less to maintain by 146.047030 units than those buildings with all their exterior surfaces unpainted. Similarly, buildings with all their exterior surfaces painted cost less to maintain by 146.047030 units than those buildings with their exterior walls partly unpainted and partly painted. This is consistent with the literature that, unpainted exterior surfaces are more vulnerable to environmental attack, as in most cases are made of natural materials, for instance, brick, stone, marble, granite, concrete, etc. On the other hand, painted exterior surfaces provides a buffer zone between the actual material to be attacked and the environment itself. In this regard therefore, it is more logical and consistent to conclude that unpainted exterior wall finishes or surfaces cost more to maintain than painted ones. Alternatively, it seems that more attention is given to cleaning of exterior wall surfaces finished with cladding i.e., mopping, spraying with water, etc., whereas almost no attention is given to painted surfaces since any cleaning to them means repainting. This automatically shows why more money is being spent on cladded surfaces compared with painted ones.

The most probable reason why the contribution of this variable to subsequent running cost is significant is due to the fact that, exterior building surfaces are extremely large areas in any building. Since this surfaces provide the image of the building then, they must be kept in good condition thus they provide a lot of surface area that requires attention and hence implying the significance of this variable in the multiple regression.

Floor Finish Nature(X_{26}). Simple correlation showed that buildings with polished floor finishes etc., cost more to maintain than those with unpolished floors. This is consistent with the general literature regarding the relationship between subsequent running cost and nature of finishing materials in buildings. A simple regression between subsequent running cost and floor finish nature realized that, 0.4811 percent of the variation in subsequent running cost is explained by factors related to variations in floor finish nature. The computed simple regression equation is:

$$Y = 369.2555 + 23.98783X_{26}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{26} is the floor finish nature.

The unstandardised b-coefficient for the equation above is +23.98783. This relationship between subsequent running cost and floor finish nature of the office building is not significant at 0.05 level. A graph of the relationship could not be drawn because floor finish nature is a dummy variable.

In the computed multiple regression model, it was realized that the floor finish nature of the building accounted for nearly 7.46 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. The b-coefficient for floor finish nature in multiple regression model is +125.871054 (Table 5.4.). This means that buildings with partly unpolished and partly polished floors costs more to run by 125.871054 units than those with unpolished floors. Similarly, buildings with polished floors costs more to run by 125.871054 units than those with partly unpolished and partly polished floors. This is consistent with both the positive simple regression and the literature findings of this study.

This means that cladded floors requires less expenditure in cleaning i.e. mopping or sweeping unlike the polished floors that requires more in repolishing. Similarly, cladded floors by their nature of usually being hard material takes time to ware out, unlike cement screed, parquet, etc., that always requires attention in terms of renewal or polishing.

As already mentioned above, the contribution of floor finish nature to the subsequent running cost is significant in the multiple regression model. The most probable reason for this is that, plinth area of the building forms one of the largest component of the building that needs continuous running i.e. repairing, cleaning, etc. In this regard therefore, the floor finish nature on this floor surfaces provide a major building element to be given attention in the running of the building, hence implying the significant contribution. In addition to this, the nature of the floor finish determines the intensity of lighting required in the building, thus influencing the other aspects that constitutes running of the building.

Depth of Building(X_{14}). The plot of subsequent running cost versus depth of office building (Graph 5.2.) shows that subsequent running cost of office buildings increases with an increase in depth of the building. The computed simple regression equation is:

$$Y = 290.6068 + 16.13299X_{14}$$

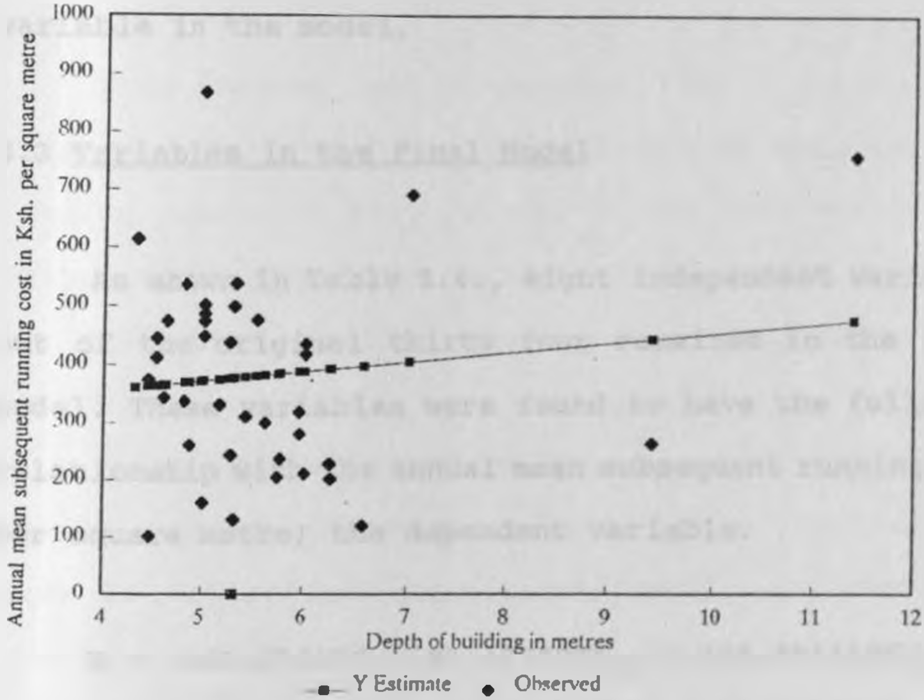
where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_{14} is the depth of the building in metres.

The unstandardised b-coefficient for the equation above is +16.13299. This relationship between subsequent running cost and depth of the building is not significant at 0.05 level.

The correlation between subsequent running cost and depth of the office building is 0.123313 (Table 5.1.) and in this regard depth was found to explain 1.5206 percent of the variation in subsequent running cost.

After computing the multiple regression model, it was realized that the depth of the building accounted for nearly 8.473 percent of the change in subsequent running cost of the office building. This contribution is significant at 0.05 level. This result is consistent with the literature on the relationship between the subsequent running cost and depth of office building. The b-coefficient for depth in multiple regression model is +41.402349 (Table 5.4.). This means that for every one unit increase in the depth of the building, the subsequent running cost increases by 41.402349 units.



Graph 5.2: Plot of subsequent running cost versus depth of office building.
Source: Plotted from the author's field data.

The average depth of office buildings is 5.58 metres, whereas the maximum and minimum are 11.4 metres and 4.3 metres respectively.

As mentioned above the contribution of depth in the model is significant. This is due to the fact that a change in depth implies a change in lighting, ventilation and maintenance requirements of the associated mechanical and electrical services. This implies a great change in the running cost, hence the significance of the variable in the model.

5.3 Variables in the Final Model

As shown in Table 5.4., eight independent variables out of the original thirty four remained in the final model. These variables were found to have the following relationship with the annual mean subsequent running cost per square metre; the dependent variable.

$$Y = -408.974476 - 85.426903X_{13} + 160.891116X_{11} + 57.430795X_{7} + 58.552139X_{2} + 96.911456X_{19} - 146.047030X_{20} + 125.871054X_{26} + 41.402349X_{14}$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_i is the form parameter of office buildings.

The coefficient of determination between these eight independent variables and subsequent running cost is

0.65830. This means that 65.830 percent of the variation in subsequent running cost is explained by these variables. This relationship was found to be significant at 95 degrees confidence level.

5.4 Conclusion

This chapter has established that a relationship exists between architectural building form and subsequent running costs. In this regard, it has been realized as stated above that about 65.830 percent of the variation in subsequent running costs is explained by form parameters.

Secondly, this chapter has proved the hypothesis stated earlier in Chapter One that, "the architectural form of office buildings significantly influence the running costs of buildings in use." Hence the alternative hypothesis is accepted.

However this chapter has only investigated the first objective of this study. The other objectives are investigated in the subsequent chapters.

5.5 References

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CHAPTER 6

RUNNING OF OFFICE BUILDINGS IN RELATION TO DESIGN

6.1 Introduction

Architectural form parameters come into being at the planning stage of the design stage. In this regard, it was important to consider the Design Team/Architects' view to ascertain the situations that accommodate the architectural form parameters that bring about the least subsequent running cost to enable appropriate recommendation later in this report. Thus, the various architectural form parameters were again studied. This chapter concentrates on those architectural form parameters that were found significant and accepted by the multiple regression in Chapter Five and those related.

6.2 Nairobi Architects' Opinion on the Office Building Form Parameters

Form of Horizontal Circulation (X_{13}) The data collected showed that only 68.42 percent of the sampled buildings had horizontal circulation routes that were naturally lit, whereas only 89.47 percent were naturally ventilated. This implies that in case of power failure 31.58 percent of the sampled buildings would have circulation routes that are completely dark, whereas 10.53 percent would not be ventilated. This would greatly interfere with the operations of the buildings. As already realized, form of horizontal circulation is the main contributor of subsequent running cost and as such there is need of adopting a form of horizontal circulation that would be appropriate at all times.

Interviewed architects observed that, the form of horizontal circulation in office buildings is determined by function of the building and convenience of walking/circulation distances. This meant that there is need for short, convenient and easy access routes to the working places that enable fast escape in case of danger/fire. However, the architects confirmed that any of the forms of horizontal circulation could be adopted without necessarily interfering with the architecture of the building. But, since double zone and triple zone forms of horizontal circulation were mostly found in the middle of working spaces and most likely enclosed by vertical planes, they have a likelihood of lacking natural light and ventilation. Similarly, single zone was mostly found going round internal service cores, which means that it also has a likelihood of suffering from lack of natural light and ventilation. This implies that it is only the open layout that could manage to be fully naturally ventilated and lit. In this regard therefore, it is appropriate to recommend open layouts for office buildings.

The location of service core could hinder the idea of an open layout however the design team observed that the location of the service core is determined by the function of the building, need for natural lighting and ventilation and the pedestrian approach to the building. However, most of these essentials were not met by all the sampled buildings, especially when only 89.47 percent of these buildings had service cores that were naturally ventilated and lit. In addition, only 76.32 percent of the sampled buildings had cleaners' sinks located at the ground floor or basement, thus creating a problem when it comes to cleaning of the building fabric. This is because, the fetching of water from distant water points results in waste of time and wearing of floor finishing material due to continuous traffic.

In suggesting a solution, the design team observed that it is possible to adopt external service cores in office buildings without affecting their architecture and operation. This is so because, it is much easier to ventilate or lit the external service core. Thus, if all other necessary facilities like cleaners' sinks are provided in these external cores, it would become the most recommendable location of the service core in office buildings. This is in agreement with the fact that, external service cores facilitates existence of open plans that have already been recommended.

Roof Shape (X_{11}) 15.79 percent of the sampled buildings had changed their roof shapes from flat to pitched. In addition, most of the roofs still had several problems. This is supported by the fact that 21.05, 10.53 and 13.16 percent of the sampled buildings had leaking roofs, cracked roofs and roofs that lacked falls to enable drain the rain water away, respectively.

The roofs of the sampled buildings were finished with felt, iron sheets, concrete tiles, clay tiles and asbestos. These were in the following proportions: 47.37, 15.79, 26.32, 10.53 and 2.63 percent, respectively. The design team stressed that, the problem relied on the shape of the roof and not the material used. Mr. Okwemba, the chief personnel officer in the technical (maintenance) division of the Ministry of Public Works, made it very certain by emphasizing that the "flat roofs need to be done away with."

On the other hand, the design team indicated that the roof form is influenced by aesthetics, massing of the building, subsequent running cost and function that needs to be carried on top of the roof. In this regard, they were in agreement with the property managers, who observed that it is possible to have pitched roofs on office buildings without affecting their architecture. Hence, from the architectural and management point of view the pitched roofs were recommended.

Building Orientation (X_7) The design team indicated that the main issues that dictate the office building orientation in Nairobi are, sun movement, noise from the adjacent streets, plot orientation and view. Although only 2.63 percent of the sampled buildings experienced internal space overheating, this would be due to the fact that most of the buildings especially those orientated East-West have made use of sun shading devices and as such control the amount of light and solar heat entering the building. Otherwise, the design team pointed out that the North-South orientation is the most appropriate in Nairobi if any building designed has to avoid use of artificial ventilation and air conditioning facilities. Secondly and in addition, the design team went further to advice that, it is possible to avoid orientating buildings East-West and yet achieve an acceptable office building in Nairobi. In this regard therefore, it is appropriate to recommend North-South orientation for office buildings located in Nairobi.

One of the form element that is very much related to orientation although was not significant is sun shading devices. The design team observed that shading devices are necessary when the building is orientated East-West or in all directions in Nairobi. Similarly, shading devices would be necessary in an attempt to complete or achieve the desired image or appearance of the building. However, it is not recommendable to do away with shading devices of any kind for office buildings in Nairobi unless the "site orientation extremely favours the situation" (Singh,1994). This means that shading devices could be avoided if the longer side of the plot faces North-South and the building does not require any openings in the East-West orientation or any other directions. Since this is rarely the case, then, it is more or less imperative to have shading devices on buildings, otherwise internal environments would overheat when buildings are "wrongly orientated and don't have shading devices" (Singh, 1994).

<u>Plot Ratio (X_2)</u> The design team singled out plot ratio together with plot size as the main determinants of the total plinth area of the office buildings in the CBD of Nairobi. This is despite the fact that, 31.58 percent of the sampled buildings were underdeveloped, although it would be due to the fact that plot ratio has been changing upwards, that is, plots that had plot ratio of

five say were fully developed a few years ago, whereas now they would be underdeveloped if the plot ratio has been changed to six. On the other hand, 15.79 percent of the sampled buildings were overdeveloped, whereas 13.16 and 5.26 percent of the sampled buildings experienced water shortage and NCC main truck sewer blockage respectively. Overdevelopment would arise due to laxity of the NCC personnel from performing their duties properly or due to corruption by able developers who would prefer to have more office space and don't mind parting with a few shillings in exchange of the approval from NCC. Whereas water shortage has become a common phenomena in most parts of Nairobi, however it is hoped that after the third Nairobi water project the water supply will improve and even be in excess supply until the year 2000. Finally, it was argued by the maintenance officer of Postbank Building (Queen, 1983) that the sewer blockage problems are mainly caused by the NCC personnel, because they take even two months to unblock one manhole and in the end it takes less than one month for the manhole to get blocked again. Thus, this would seem to be due to laxity from the NCC's personnel from performing their duties satisfactorily. In this regard therefore, generally, it seems that the infrastructure related to plot ratio is in order and satisfactory and as such there is no harm in developing the plots to capacity.

<u>Material Expression and Finish (i.e. External finish type(X_{19}), External wall finish nature(X_{20}) and Floor finish nature (X_{26}).</u> Different materials require different durations before demanding re-surfacing attention in regard to sanding, polishing, painting, etc. Data of the following types of finishes was given by the property managers. These finishes are: plaster and paint, mosaic tiles, fair face concrete, bush hammered concrete, timber panelling and plaster and paint on metal lath. The mean durations these finishes require are: 4.4, 6.67, 4, 3, 5, and 3 years respectively. This implies that smooth cladding like mosaic tiles and timber panelling that require 6.67 and 5 years respectively demand less frequent maintenance attention than rough surface coatings like plaster and paint, bush hammered concrete and plaster and paint on metal lath that require 4.4, 3, and 3 years respectively. This was confirmed by the property managers that, painted surfaces cost more to maintain than unpainted ones and textured or rough surfaces requires more material and time for maintenance than smooth ones.

However, as indicated by the design team, the choice of finishes for office buildings is dictated by initial construction cost, cleaning and surface protection, desired aesthetics and appearance of the building and durability of the material. Regarding the maintenance aspect of the building, the design team stated that the decision whether to use painted or unpainted and smooth or rough finishes for instance, are dictated by subsequent maintenance cost (and hence running cost) and the desired aesthetics and appearance of the building. This is because, some unpainted finishes require low maintenance cost than painted ones, and, smooth finishes require shorter time and less material for maintenance than rough ones. Thus, it is for this reason the design team agreed and recommended that since there is a big range of materials, with a proper choice, cladding type of finish usually would reduce the subsequent maintenance cost (and hence running) and at the same time achieve the desired effects on the building both architectural and functional. The advantage with cladding is that it is usually a hard unpainted material, for instance, marble, ceramics, granite, etc, that could have varying textural levels that could suit walls, floors and ceilings. Secondly, this material is appropriate when it comes to cleaning and even repair, because it is prefabricated in standard sizes making replacement easier and could be done at the least time and hence cost.

Hence, the design team recommended cladding against surface coating, unpainted finishes against painted and smooth finishes against rough ones.

Depth of Buildings (X_{14}) Data collected indicated that 34.21 percent of the sampled buildings had rooms which were naturally lit and ventilated. 61.54 percent of these rooms were located in the basements while 38.46 percent were located at the centre of the buildings. They included, stores, tea rooms, cleaners' rooms, lobbies, service cores, etc. This means that these spaces could operate without artificial lighting or ventilation. For instance the service cores that constitute lifts, toilets, lobbies and staircases and form the main vertical circulation route cannot function properly in absence of light and ventilation. This suggests that they definitely need to be located nearer to the external surfaces of the building and in turn reduce the depth of the building.

On the other hand, the interviewed architects observed that the depth of the office buildings is only influenced by the extent to which natural light can penetrate into the building. They went further to state that they are aware that the less the depth of the building the better the natural lighting and ventilation received by the internal spaces of the building. This was supported by their recommendations, that is, 14 to 15 metres for open plan layout and 6 metres for single zone (excluding the circulation space). This implies that an appropriate depth of the office space lies between 6 metres and 7.5 metres. This range is close to the mean depth of 5.58 metres realized from the data analysis. However, it is slightly off the minimum and maximum of 4.3 and 11.4 metres.

However, the depth alone cannot decide the size of the space. This is why the centre to centre of the structural elements/rhythm is important. In this regard it was found out that, 81.59, 15.79 and 2.63 percent of the sampled buildings had rectangular, square and triangular grid systems respectively. The design team observed that the type of grid system used in office buildings is influenced by planning grid or function, parking and shape of plot. On the other hand, 67 percent of the interviewed architects noted that, the location of beams and columns did not dictate the location of partitions and service points in their buildings. However, Mr. Singh of Waweru Associates noted that these structural elements would dictate the location of partitions and service points "only to an extent". However from the data collected, the maximum, minimum and mean rhythm or centre to centre of the columns was 7.5, 3.5 and 5.72 metres. Since the width of a standard parking space (Tutt, 1979) is 2.4 metres, means that a clear space of 4.8 metres and 7.2 metres are required for two and three parking spaces. Allowing for a column of diameter of 0.3 metres, it implies that a rhythm of 5.1

and 7.5 that at the same time would accommodate two and three parking spaces respectively are possible. Similarly since the standardization and modulation adopted a module of 0.1 metres it implies that any of these rhythms would be acceptable. However, 7.5 metres centre to centre of columns would demand a large cross-section of columns and much deeper beams and hence more initial and subsequent running cost. Thus to be on a safer side a minimum of 5.1 metres is more recommendable.

As mentioned above the depth of the space is influenced by amount of light reaching the deeper end of the room and in this regard the proportions of glazed area becomes important as well. It was observed that, 13.16, 15.79 and 71.05 percent of the sampled buildings had windows that occupied full room height, three quarters of room height and one half of room height respectively. However, only 78.95 percent of the sampled buildings were adequately lit with natural light and did not experience dark deeper ends within them.

On the other hand, only 63.16 percent of the sampled buildings had their windows cleaned from inside. This implies that those buildings with full height of windows and three quarters of room height as windows had cleaning problems. This is due to inaccessibility of some parts of the window glass. Thus, it is for this reason that 23.68 percent of the sampled buildings had permanent gantry fixed to their rooftops to assist in cleaning the exterior surfaces of the buildings. Examples of such buildings are, Anniversary Towers (Plate 6.1) and Cooperative Building (Plate 6.2).

Plate 6.1. Photograph of Anniversary Towers. Building with permanent gantry for cleaning purposes.

Source: Photograph taken by author 1994.

Plate 6.2. Photograph of Cooperative Building. Building with permanent gantry for cleaning purposes.
Source: Photograph taken by author 1994.

From the design perspective, the design team observed that the proportion of glazed area is influenced by amount of natural light required in the building, the desired aesthetics or image and the By-laws requirements. To reduce the subsequent running cost, the design team indicated that it is necessary to reduce the proportion of windows to a level that admits just enough natural light, because just enough window area would enable to have all windows cleaned from inside. As a result this would reduce expenses involved in erecting temporary or permanent cleaning mechanical systems and eliminate the risk on labourers that is always paid in terms of insurances and medical bills. Lastly, the design team proposed 50 percent as the appropriate proportion to glazed areas of the external walling area.

It is also worth mentioning that, the amount of light that could be called enough in any space depends on many other parameters like, surface quality of the finishes, storey height, depth of the space, etc.

The design team observed that, the storey height of office buildings is influenced by structural system and the function to be carried out inside the building. This means that if the depth of beams is higher (say one metre), the storey height is the sum of the clear height required by the function and the depth of the structure. On the other hand, the height needed by the function depends on the objects to be moved within the space. For instance, if a fork lift of 3.0 metres height would be required to move in the space and the beams depth is 1.0 metre, then, the storey height has to be 4.0 metres.

Also, the design team is aware that the higher the storey height the better the natural lighting and ventilation in the building, however, the more the building fabric that requires running. To be more specific on this, the design team recommended 3.0 metres storey height for office buildings in Nairobi to provide sufficient natural lighting and ventilation to the internal spaces. However, in case of need for false ceiling like the 28.95 percent of the sampled buildings that had false ceilings, then, a storey height of 3.5 metres would be sufficient. The 3.0 metres storey height specified here coincides with the average storey height of 3.02 metres realized from the data analysis. In this regard therefore, storey height of 3.0 metres is recommended for office buildings in Nairobi.

6.3 Extent to which Running of buildings is considered at the planning stage of the design process

It is very clear that, although running of the building is not addressed directly at the design stage, some aspects of subsequent running are addressed. These involve the attempt to reduce use of artificial lighting, frequency of replacement and cleaning of materials/finishes. This is supported by the fact that when considering the volume, proportion of glazed external surface area, location of service core, depth of working space and massing of building, the need for use of natural lighting and ventilation is paramount. Similarly, the orientation of the buildings tries to avoid too much solar heat into the building that would necessitate use of air conditioning and artificial ventilation to keep the internal environment acceptable. This is why wherever the appropriate orientation is not possible sun shading devices are used. Secondly, the change from flat roofs to pitched ones shows an attempt at trying to reduce the frequent replacement of the flat roof covering and the associated cleaning of water outlets.

Thirdly and lastly, two major issues related to subsequent running cost are the determinants of finishing materials for office buildings. These issues are, cleaning and surface protection and durability of materials. This implies that, the use of hard and smooth finishes coupled with appropriate proportions of glazed areas that allow all windows to be cleaned from inside and appropriate massing that avoids many projections that make cleaning a problem, the expenditure on cleaning could be reduced to the least possible figure. In addition, hard and standard finishing materials take a much longer duration before being damaged and as such demanding repair or replacement, and even once damaged, the fact that these finishes are standardized it makes it easier to replace at the least time and cost.

This indicates that, the issues related to energy, cleaning, repair, replacement and decoration/painting of finishing materials are addressed at the design stage. However, the issues related to conservation of water, reduction on security, plumbing and lifts mechanisms and yet obtain the required building working space are lacking. Thus, it is hoped that these research findings would create this awareness to the design team so as to trigger the investigation of a solution that requires less subsequent running cost.

6.4 Conclusion

This chapter has tried to establish the extend to which running of buildings is taken into account during design. In this regard, it has been realized that most of the issues related to running of buildings are addressed at the design stage, however, issues dealing with conservation of utilities in general are lacking.

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CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

As outlined in the organization of the study, this Chapter has drawn conclusions and recommendations in accordance with the objectives of the study outlined in Chapter One and the outcome of the data analysis presented in Chapter Five and Six.

7.2 Running Cost Model

It has been established that the following relationship exist between subsequent running cost and eight form parameters.

$$Y = -408.974476 - 85.426903X_{13} + 160.891116X_{11} + 57.430795X_{7} + 58.552139X_{2} + 96.911456X_{19} - 146.04703X_{20} + 125.871054X_{26} + 41.402349X_{14} + e$$

where Y is the annual mean subsequent running cost in Ksh. per square metre.

X_i is the form parameter of office buildings.

The confidence interval (e) of the results given by the cost model is +/-226.46.

Two of these parameters are quantitative, whereas the others are qualitative. These parameters are as illustrated in Table 7.1. below.

Table 7.1. Form Parameters in the Model.

Quantitative Form Parameters in the Model	Qualitative Form Parameters in the Model
X2 - Plot Ratio X14 - Depth of Building	X13 - Form of Horizontal Circulation X11 - Roof Shape X7 - Building Orientation X19 - External wall finish type X20 - External wall finish nature X26 - Floor finish nature

Source: Compiled by author.

In this regard therefore, for this relationship to be used as a predictive model for subsequent running costs, the qualitative variables must be assigned numeric values as in this study. On the other hand the quantitative variables should be inserted into the model when in the relevant units as specified in this study. These units are numerals for plot ratio and metres for depth, etc.

Secondly, since these variables are found to explain about 65.830 percent of the variation in subsequent running cost of which is found to be significant at 95 degrees confidence level, then, it is appropriate to conclude that form (i.e. the conglomerate of all these parameters) significantly influences subsequent running cost.

7.3 Towards Future Office Building Form in Nairobi

In accordance with the focus of the research, it was aimed at establishing architectural form parameters that could create future Office building forms in Nairobi that have the least subsequent running cost. However, cost is not the only constraint considered at the planning stage of Office buildings. Other constraints include, permanent site and neighbourhood conditions, climate, function, aesthetics/architects' desires, etc. In this regard therefore, Table 7.2 has summarized this and recommended appropriate architectural form parameters taking into account the subsequent running cost and the Architect/Design Team's opinion.

Table 7.2. Summary of architectural form parameters.

Form Parameter	Aspect of Form Parameter associated with highest maintenance cost, hence to be avoided	Aspect of Form Parameter associated with lowest maintenance cost	Aspect of Form Parameter recommended by design team	Aspect of Form Parameter recommended by this study
Form of horizontal circulation (X_{13})	Single zone	Open layout	Open layout	Open layout
Roof shape (X_{11})	Composite roof	Pitched roof	Pitched roof	Pitched roof
Building orientation (X_7)	All directions	North-South	North-South	North-South
Plot ratio (X_2)	Higher plot ratio (max. recorded was 6)	Lower plot ratio (min. recorded was 2)	Fully developed the plot	Avoid overdevelopment
External wall finish type (X_{19})	Surface coating	Cladding	Cladding	Cladding
External wall finish nature (X_{20})	Unpainted	Painted	Unpainted	Unpainted
Floor finish nature (X_{26})	Painted floor finish	Unpainted floor finish	Unpainted finishes	Unpainted finishes
Depth of building (X_{14})	Deeper building (max. recorded was 11.4 metres)	Less deeper buildings (min. recorded was 4.3 metres)	6 to 7.5 metres	6 metres

Source: Compiled from the author's field data.

However, these form parameters are related to many other parameters that were found not significant and hence rejected by the model. Thus, any decision with regard to these parameters in the final model should be made in relation to those other variables not in the model. Otherwise, it would be disastrous to disregard these variables not in the model because they could also be having a chance of significantly influencing subsequent running cost.

7.4 Further Research

Different building types have different architectural forms. This is due to the fact that these forms respond to different aspects that are particular to the function being accommodated. In this regard therefore, one expects the architectural forms of office buildings to be different from those of Residential buildings, Institutions, Hospitals, Factories, etc. On the same basis, the subsequent running cost model for these other building types would definitely be different from that established by this research. Similarly, since the form parameters are different, then, the form parameters that would be recommended for these other building types so as to minimize subsequent running cost would definitely be different.

Secondly, as already mentioned in Chapter Three, buildings of the same type would be moulded by other constraints apart from functional constraints. A number of these constraints are grouped together as climatic factors. In the literature review of this study, it has been established that different forms arise in response to different climatic factors. For instance, an office building located in Mombasa allows for a maximum natural ventilation and air circulation since Mombasa is a hot humid area unlike Nairobi. In this regard, form parameters like size of openings, proportion of voids in buildings, storey height, volume, etc., are bound to be different and hence generate a completely different office building from that that would be generated in Nairobi.

Thirdly, with the advancement in technology, the building services like lifts, lighting system, security system, etc., are taking a more prominent architectural role in creating building forms than just offering the services. For instance, panoramic lifts have these days become a feature in high rise buildings and as such tended to control or determine the total building form if not some of the architectural building parameters.

Thus, with regard to further research, it should be understood that this research dealt with one building type within a particular climatic zone. Hence, first and foremost further research should be conducted with the same building type but at different climatic zones to establish the contribution of change of climate. Secondly, once a general relationship has been established between architectural form of office buildings and subsequent running cost at a wider region, then, further research would diversify into other building types. Thirdly, a building just like any car type is rapidly changing form with change in technology and people's taste as already mentioned early. In this regard also, it becomes imperative that some further research needs to be done to see the contribution of technology change in the subsequent running cost of buildings.

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APPENDIX A

PRELIMINARY SURVEY CHECKLIST

Date of survey------------------------------------
Name of surveyor----------------------------------
Name of the building------------------------------
Number.---
Name of Street------------------------------------
Plan configuration: Geometric (G)-----Irregular (I)---
Circulation arrangement: (1)Single zone---------------
(2)Double zone-----(3)Triple zone----(4)open---------
Core position description: (1)Internal--------(2) Semi-Internal------------3)Ext.-------------------------------
Finish: (1)Cladding-------------(2)Surface finish---
External material finishing: (1)unpainted-------------
(2)painted--
External material texture: (1)smooth------------------
(2)rough--
Total number of storeys-------------------------------
Commercial storeys------------------------------------
Office storeys--
Roof: (P)pitched----------------------(F)flat--------
Massing or Volumetric description: (1) Pure volumes------
--------(2)Irregular volumes-------------------------
Does atrium/voids exist in building?(Y)Yes--(N)No.----
Openings: (1)Small openings--------(2)Medium openings----
--------------------(3)Large surfaces of glass------
Shading elements: (Y)Yes--------------(N)No--------------
Orientation / openings face: (1)N-S-----(2)W-E---------
(3)NE-SW/NW-SE----------(3)All directions-------------
Ornamentation:(1)Whole-facade--(2)Smaller-areas----
(3)None---
Does the building have definite rhythm? (Y)Yes---(N)No---
Year of commission---------------Approximate Age------
Name of care taker-----------------------------------
Telephone------------------------------Box-----------
Name of Estate agent---------------------------------
Telephone------------------------------Box.-----------
Who keeps the as-built drawings? (1)Owner-------
(2)Architect----------(3)City Hall----------------
Do records of running expenditure works exist?(Y)Yes-----
--(N)No---------For how many years?---------
Plot ratio--
Ownership: (G)Government-owned------(P)Private owned----
Who pays for the utilities like service charge, water, electricity and garbage disposal? (1)Owner-----------
(2)Client---------------

APPENDIX B

QUESTIONNAIRE TO THE PROPERTY MANAGER

TITTLE: THE INFLUENCE OF ARCHITECTURAL FORM ON THE SUBSEQUENT RUNNING COSTS OF OFFICE BUILDINGS IN THE CBD OF NAIROBI-KENYA.

1.0 **GENERAL ISSUES**

1.1 Questionnaire number------------------------------------
1.2Date---
1.3 Name of interviewer--------------------------------------
1.4 Name of respondent--------------------------------------

1.5 Occupation of respondent-------------------------------

1.6 Name of building--
1.7 Location of building or street----------------------------
1.8 Who was the architect for this building and where is he/she located? --
1.9 Ownership of building: Ownership of the building can be categorized as:
(0) Private
(1) Public
1.10 What is the age of the building ?----------------------

1.11 What is the Plot ratio of the area where the building is located? -------------------------------------

2.0 **FUNCTIONS OF OFFICE BUILDING**

Please check whether the following functions are present in the building.

Shop	- Jewellery	Yes	No
	- Shoes	Yes	No
	- Electronics	Yes	No
	- Butchery	Yes	No
	- Clothes	Yes	No
	- And others	Yes	No
Bank		Yes	No
Cafeteria		Yes	No
Cinema hall		Yes	No
Conference room		Yes	No
Office	- Governmental	Yes	No
	- Professional	Yes	No
	- Embassy	Yes	No
	- Agents of organisations	Yes	No
	- Association	Yes	No
	- Others	Yes	No

3.0 QUANTITATIVE ASPECTS OF FORM PARAMETERS

3.1 Plan Configuration: The typical plan of the building can be categorized as:
- (0) Geometric/pure shapes i.e., rectangle, square, triangle and derivatives of these three pure shapes.
- (1) Irregular/Organic shapes i.e., undefinable shapes.

3.2 Perimeter of building plan: What is the total distance a round the external envelope of the buildingplan?---------------------------------------

3.3 Plinth area: What is the total plinth area of the building?---

3.4 Volume of the building: What is the volume of the building enclosed by the exterior envelopes?--------
----

3.5 Building orientation: In which of the following directions are the openings of the building orientated?
- (0) North - South
- (1) 45 degrees from either North and South
- (2) East - West
- (3) All directions

3.6 Height of building: What is the distance between the bottommost floor level and the uppermost ceiling level?--

3.7 Rhythm: What is the distance between the centre to centre of the main structural columns? ---------
----

3.8 Proportion of glazed area:
- 3.8.1 What is the total external surface area of the building?------------------------------------
- 3.8.2 What is the total glazed area that allows light into the building? -------------------
- 3.8.3 What is the percentage of glazed area in 3.8.2 to that of the total external surface area in 3.8.1? --------------------------------

3.9 Roof shape: The shape of the roof can be described as:
- (0) Pitched
- (1) Flat
- (2) Composite roof

3.10 Location of the service core: The location of the service core can be described as:
- (0) Internal core
- (1) Semi - internal core
- (2) External core

3.11 Form of horizontal circulation: Main circulation arrangement can be described as:
- (0) Single zone
- (1) Double zone

(2) Triple zone
(3) Open layout

3.12 <u>Depth of building:</u> What is the distance between the perimeter envelope and the adjacent circulation boundary?---

3.13 <u>Shading device:</u> Does the building make use of shading devices?
(0) Yes
(1) No

3.14 <u>Storey height:</u> What is the floor to floor height? ---

3.15 <u>Proportion of floor voids or light wells:</u>
3.15.1 What is the total area of the floor voids? ---
3.15.2 What is the percentage of floor voids area to that of the total plinth area in 3.3 above? --

3.16 <u>Vertical circulation/escape routes:</u> What is the total number of both internal and external vertical routes or points? ---------------------------------

3.17 <u>External wall materials expression and finishing:</u>
3.17.1 <u>Type of finish:</u> Type of finish can be categorized as:
(0) Cladding i.e. metal, stone, etc.
(1) Partly cladding and partly surface coating
(2) Surface coating i.e. renders, plasters, varnish, stain, primers, pvc, paint, ceramics, polymers, etc
3.17.2 <u>Nature of finish:</u> Nature of finish can be categorized as:
(0) Unpainted
(1) Partly unpainted and partly painted
(2) Painted
3.17.3 <u>Finish texture:</u> The finish texture can be described as:
(0) Smooth
(1) Partly smooth and partly rough
(2) Rough i.e. bush hammered concrete, speckled plaster, etc.

3.18 <u>Internal wall materials expression and finishing:</u>
3.18.1 <u>Type of finish:</u> Type of finish can be categorized as:
(0) Cladding
(1) Partly cladding and partly surface coating
(2) Surface coating
3.18.2 <u>Nature of finish:</u> Nature of finish can be categorized as:
(0) Unpainted
(1) Partly unpainted and partly painted
(2) Painted

3.18.3 <u>Finish texture:</u> The finish texture can be described as:
(0) Smooth
(1) Partly smooth and partly rough
(2) Rough

3.19 <u>Floor materials expression and finishing:</u>

3.19.1 <u>Type of finish:</u> Type of finish can be categorized as:
(0) Cladding
(1) Partly cladding and partly surface coating
(2) Surface coating

3.19.2 <u>Nature of finish:</u> Nature of finish can be categorized as:
(0) Unpainted
(1) Partly unpainted and partly painted
(2) Painted

3.19.3 <u>Finish texture:</u> The finish texture can be described as:
(0) Smooth
(1) Partly smooth and partly rough
(2) Rough

3.20 <u>Ceiling materials expression and finishing:</u>

3.20.1 <u>Type of finish:</u> Type of finish can be categorized as:
(0) Cladding
(1) Partly cladding and partly surface coating
(2) Surface coating

3.20.2 <u>Nature of finish:</u> Nature of finish can be categorized as:
(0) Unpainted
(1) Partly unpainted and partly painted
(2) Painted

3.20.3 <u>Finish texture:</u> The finish texture can be described as:
(0) Smooth
(1) Partly smooth and partly rough
(2) Rough

3.21 <u>Number of storeys:</u> How many storeys does the building consists of? ------------------------------

3.22 <u>Ornamentation:</u> Any ornamentation or surface modulation on the building can be said to cover:
(0) Zero area
(1) Smaller areas i.e. top of windows, doors etc.
(2) Whole facade

3.23 <u>Volumetric description or massing of the building</u>: The massing of the building can be categorized as:
(0) Pure volumes i.e. cubic, cylindrical, cuboidal, pyramidal, prismatic etc.
(1) Irregular volumes i.e. broken pure volumes or their derivatives.

QUALITATIVE ASPECTS OF FORM PARAMETERS

4.1 Plan Configuration and perimeter of building plan : Please tick where appropriate.

4.1.1 Is the same module used on the facade all round the building Yes No

4.1.2 Does the building external envelope keep on changing direction at some other places apart from the definite corners Yes No

4.1.3 Do pockets of spaces along the perimeter of the building exist within which dirt or rubbish collects unnecessarily Yes No

4.1.4 How many security personnel do you employ at every typical office floor?---------
----

4.2 Total plinth area: The plot ratio of an area that influences the plinth area, is usually related to the available infrastructural facilities. Please tick where appropriate in the following statements.

4.2.1 Is the plot underdeveloped Yes No

4.2.2 Is the plot overdeveloped Yes No

4.2.3 Does the building experience water shortage Yes No

4.2.4 Do you experience problems with NCC garbage disposal Yes No

4.2.5 Do you experience problems with the NCC main truck sewer draining your building Yes No

4.3 Volume of building:

4.3.1 Does the building have voids Yes No

4.3.2 Are the working spaces and voids

4.3.2.1 Artificially lit Yes No

4.3.2.2 Artificially ventilated Yes No

4.3.2.3 Naturally lit Yes No

4.3.2.4 Naturally ventilated Yes No

4.3.2.5 Air-conditioned Yes No

4.4 Building Orientation: Do the tenants or occupiers of the building complain of the following?

4.4.1 Internal space overheating Yes No

4.4.2 Insufficient natural light Yes No

4.4.3 Too much natural light Yes No

4.5 Height of building:

4.5.1 Does the building have the following facilities?

4.5.1.1 Lifts Yes No

4.5.1.2 Dry risers and horse reels Yes No

4.5.1.3 Care - taking facilities Yes No

4.5.1.4 Communal artificial lighting Yes No

4.5.1.5 Laundries Yes No

4.5.1.6 Generator Yes No

4.5.1.7 Escalators Yes No
4.5.1.8 Staircases Yes No
4.5.2 Are the labourers involved in cleaning the external vertical surfaces/walls insured Yes No

4.6 <u>Rhythm:</u>

4.6.1 Does the partitioning create pockets of spaces that have deficiencies in the following?
4.6.1.1 Natural light Yes No
4.6.1.2 Natural ventilation Yes No
4.6.2 What types of grids are used in your building?
4.6.2.1 Square grid Yes No
4.6.2.2 Rectangular grid Yes No
4.6.2.3 Rectangular plaid grid Yes No
4.6.2.4 Parallelogram grid Yes No
4.6.2.5 Triangular grid Yes No

4.7 <u>Proportion of glazed area:</u>

4.7.1 Can all the glazed parts of the building be cleaned from the inside of the building? Yes No
4.7.2 Are the following systems used in assisting the cleaning of glazed areas?
4.7.2.1 Temporary scaffolding Yes No
4.7.2.2 Temporary gantry tied to top of building Yes No
4.7.2.3 Labourers use systems best known to them Yes No
Others Yes No
4.7.3 Do the systems used above cause more expenses i.e. insurance apart from the costs of the materials and erection? Yes No

4.8 <u>Roof shape:</u>

4.8.1 Has the roof shape changed? Yes No
4.8.2 If yes, what was the initial roof shape? --
4.8.3 Is the roof having any of the following problems?
4.8.3.1 Leaking Yes No
4.8.3.2 Cracked Yes No
4.8.3.3 Lack falls to drain rain water Yes No
4.8.4 Which of the following roof coverings are used?
Felt Yes No
Iron sheets Yes No
Concrete tiles Yes No
Clay tiles Yes No
Asbestos Yes No
4.8.5 How long does it take to replace the covering in years? ------------------------------------

4.9 <u>Location of service core:</u>

4.9.1 Please check whether the service core is:
- (i) Naturally ventilated Yes No
- (ii) Artificially ventilated Yes No
- (iii) Naturally lit Yes No
- (iv) Artificially lit Yes No

4.9.2 Do we have the cleaners sinks only located the main service core? Yes No

4.9.3 If no, do we have cleaners sinks located at every vertical staircase point? Yes No

4.10 Form of horizontal circulation:

4.10.1 Please check whether the horizontal circulation routes are:
- (i) Naturally ventilated Yes No
- (ii) Artificially ventilated Yes No
- (iii) Naturally lit Yes No
- (iv) Artificially lit Yes No

4.10.2 Do you employ security at every change of direction of the horizontal circulation routes? Yes No

4.11 Depth of building:

4.11.1 Do you have rooms in your building which cannot be naturally lit and ventilated? Yes No

4.11.2 Are these rooms located in the following places
- (i) Basement Yes No
- (ii) Centre of building Yes No

4.11.3 Which of the following rooms are not naturally lit and ventilated?
- (i) Stores Yes No
- (ii) Tea rooms Yes No
- (iii) Cleaners rooms Yes No

4.11.4 Do you have some spaces in the building that you regard as wasted after partitioning because they cannot be naturally lit and ventilated? Yes No

4.12 Shading devices: Check volume and orientation of building

4.13 Storey height:

4.13.1 Do you have a false ceiling in your building? Yes No

4.13.2 Which of the following is the approximate proportion of the height of the window to the useable storey height?
- (i) Window occupies full height of room Yes No
- (ii) Window occupies 3/4 of height of room Yes No
- (iii) Window occupies 1/2 of height of room Yes No
- (iv) Window occupies 1/4 of height of room Yes No

4.13.3 Is the deeper end of your room satisfactorily lit by natural light? Yes No

4.14 <u>Proportion of floor voids or light wells:</u>
Do you think an introduction of the floor voids or light wells to the wasted areas mentioned in 4.11.4 above can assist these areas into becoming habitable? Yes No

4.15 <u>Vertical escape routes:</u>

4.15.1 Do all the locations of the vertical routes provide the following?

(i) Cleaners rooms	Yes	No
(ii) Staircases	Yes	No
(iii) Tea rooms	Yes	No
(iv) Water points	Yes	No

4.15.2 Does all the vertical routes discharge to the ground floor (or same other floor) and eventually discharge people through same exit/entrance. Yes No

4.15.3 Do you employ security personnel at every vertical route? Yes No

4.16 <u>Number of storeys:</u> Check height of building.

4.17 <u>Ornamentation:</u>
If you have some ornamentation in your building does it require more time, labour and material to maintain i.e. paint, clean etc, than those areas without ornamentation. Yes No

4.18 <u>Volumetric description or massing of the building:</u>

4.18.1 Does your building have some projections or setbacks that becomes a nuisance in maintenance Yes No

4.18.2 Which of these projections exist in your building?

(i) Roofs	Yes	No
(ii) Floor decks	Yes	No
(iii) Walls	Yes	No
(iv) Horizontal and vertical shading devices	Yes	No

4.19 <u>Material expression and finish:</u>
After what interval in years do the following finishes demand attention of re-surfacing in regard to cleaning, sanding, polishing, painting, etc. Note that this does not refer to the daily cleaning.

- Marble____________________
- Granite____________________
- Aluminium and other metals____________________
- Brick cladding____________________
- Quarry stone____________________
- Renders - rough cast____________________
- wood-float or smooth render____________________
- Plaster and paint____________________

- Mosaic tiles____
- Ceramic tiles_______________________________________
- Fair face concrete__________________________________
- Bush hammered concrete______________________________
- Wall paper____
- Timber panelling____________________________________
- Washed terrazzo_____________________________________
- Polished terrazzo___________________________________
- Metal lath and plaster and paint____________________
- Parquet____
- Floor screed____
- PVC____

4.19.2 Does a painted surface or one that requires polishing, or varnishing, cost more to maintain than one that does not require polish, paint or varnish. Yes No

4.19.3 Does a textured or rough surface require more paint, varnish or polish than a smooth one? Yes No

4.19.4 Does a textured or rough surface require more time to clear than a smooth surface given the same labour? Yes No

5.0 RUNNING COST ISSUES

5.1 IN - HOUSE MAINTENANCE COSTS

ITEM	RUNNING COST FOR THE YEAR				
	1988	1989	1990	1991	1992
Labour i.e. salaries					
Material for general repair					
Others (transport, insurance, rates, storage, decanting costs, financing, etc)					

5.2. UTILITIES

Water					
Electricity or Fuel					
Security					
Toilet papers, etc.					

5.3. MAINTENANCE BY CONTRACT OF SPECIAL SERVICES OR ITEMS

Air conditioning and ventilation					
Painting or decoration					
Cleaning					
Plumbing					
Lifts					
Total					
Total updated to 1992 constant cost					

APPENDIX C

QUESTIONNAIRE TO THE DESIGN TEAM/ARCHITECT

TITTLE:THE INFLUENCE OF ARCHITECTURAL FORM ON THE SUBSEQUENT RUNNING COSTS OF OFFICE BUILDINGS IN THE CBD OF NAIROBI-KENYA.

1 GENERAL ISSUES

1.1 Questionnaire number------------------------------------
1.2Date--
1.3 Name of interviewer-------------------------------------
1.4 Name of respondent---------------------------------------
----
1.5 Occupation of respondent---------------------------------
----
1.6 Name of building---
1.7 Location of building or street------------------------

2.0 QUALITATIVE ASPECTS OF FORM PARAMETERS

2.1 Plan Configuration / shape

2.1.1 The Plan configuration or shape of Office buildings usually takes different forms for different buildings.Some of these forms are square, rectangular, triangular, etc, all with straight edges and some are irregular or organic with zig-zag or curvilinear edges. Which of the following factors actually influenced the plan form of your building?

(1) Plot shape
(2) Function of building
(3) Initial construction cost
(4) Subsequent maintenance cost
(5) Aesthetics desired by the design team
(6) Climatic factors
(7) Total plinth area to perimeter walling ratio
(8)
(9)

2.1.2 Which of the following plan forms does the design team consider more expensive to maintain/run?

(1) Regular forms
(2) Irregular forms

2.1.3 If from above, irregular forms are more expensive to maintain/run, what do you think would be the major contributors of the extra running cost when compared with regular forms?

(1)
(2)

(3)
(4)
(5)

2.1.4 Is it possible to exclude irregularity in the plan form and yet obtain the desired office building without being referred to as a bad form or design.

(1) Yes
(2) No

2.2 <u>Total plinth area:</u> Which of the following influenced the amount of plinth area in your building?

(1) Plot ratio together with size of plot
(2) Client's request i.e. building was designed to accommodate a function requiring a known a mount of space.
(3) Initial construction cost
(4)

2.3 <u>Volume of the building:</u>

2.3.1 In spite of the fact that office buildings might be situated within the same location having the same plot ratio, one with voids or atrium inside is bound to have a higher enclosed volume and external surface area. Do you think the design team is aware that the extra volume or external surface area requires some extra running cost.

(1) Yes
(2) No

2.3.2 If yes, which of the issues below do you think contributes towards this extra cost?

(1) Artificial lighting required to lit the space
(2) Artificial ventilation
(3) Painting or redecoration of the space
(4) Cleaning of the space
(5)
(6)

2.3.3 On the other hand, voids, atrium, or light wells makes some spaces in the building habitable by introducing natural light and ventilation. This in turn reduces some of the costs that would be incurred in their absence. What do you think necessitated voids or atrium in your office building?

(1) To ensure effective natural ventilation
(2) To ensure effective natural lighting in the building
(3) To achieve the volume required for a particular function
(4) To strengthen the functionality of the building by introducing visual

linkages

(5) Not applicable

2.3.4 Do you think it will be in order to compromise such qualities brought about by voids or atrium for the sake of reducing the cost incurred in maintaining the extra building fabric.

(1) Yes
(2) No

2.4 Building orientation: The orientation of the building and the nature of shading devices determines the amount of heat and light entering the building. Excessive heat entering the building necessitates the use of artificial air-conditioning and ventilation.

2.4.1 Which of the following issues dictated the orientation of your office building?

(1) Sun movement
(2) Noise from the adjacent streets
(3) Plot orientation
(4) View
(5) Pedestrian approach to the building

(6)

2.4.2 Which orientation is most appropriate in Nairobi to avoid the use of artificial air-conditioning and ventilation.

(1) North - South
(2) East - West

2.4.3 Is it possible to avoid orientating buildings East - West and yet achieve an acceptable office building in Nairobi?

(1) Yes
(2) No

2.5 Height of buildings:

2.5.1 Which of the following influenced the height of your building?

(1) Image conceived by architect or aesthetics
(2) Initial cost of construction
(3) Plot ratio
(4) Cleaning procedures to be used in maintaining the building
(5) Heights limits
(6) Construction and mechanical technology available

2.5.2 From your own observation, does height act as an obstacle to the running of buildings in Nairobi?

(1) Yes
(2) No

2.5.3 Which of the following explains how height

acts as obstacle to running of the building?
(1) Some parts of the building are inaccessible for maintenance
(2) Horizontal projections obstruct any gantry to be used
(3)
(4)
(5)

2.5.4 If your building form required cleaning and maintenance systems in respect to its height, were these systems conceived together with the building form?
(1) Yes
(2) No

2.5.5 Is it possible to have reduced the height of your building without affecting its architecture and operation?
(1) Yes
(2) No

2.6 <u>Rhythm:</u>

2.6.1 What influenced the centre to centre of columns or beams in your building?
(1) Planning grid or function
(2) Parking
(3) Shape of plot
(4)
(5)

2.6.2 Did the location of beams and columns dictate the location of partitions, service points (i.e. sockets, light points), etc?
(1) Yes
(2) No

2.7 <u>Proportion of glazed area:</u>

2.7.1 What influenced the proportion of openings on the external envelope of your building?
(1) Amount of natural light required in the building
(2) The desired aesthetics or image
(3) Initial construction cost
(4) Cost of subsequent cleaning
(5) By-laws requirements
(6)
(7)

2.7.2 Since the openings (or glazed parts of the external envelope) serves a very important purpose of admitting natural light into the building. This part needs to be clean and functional throughout the year. Which of the following measures did you take at the design stage to make sure this is achieved?
(1) Track and equipment for cradles were

installed
(2) Design team made sure all windows are cleaned from inside
(3) No measures were taken
(4)
(5)

2.7.3 Generally, do you think if the proportion of openings on the external wall is reduced to a level that is not excessive i.e. just enough to admit light into the building, the maintenance and running cost will be reduced and why?
(1) Yes
(2) No

<u>Reasons</u>
(1) Small proportion of windows will be cleaned from inside
(2) High costs involved in erecting temporary cleaning mechanisms will be avoided
(3)
(4)
(5)

2.7.7 What do you think should be the lowest proportion of openings on the external wall inpercentage?--------------------------------
----

2.8 <u>Roof shape:</u>

2.8.1 Which of the following influenced the roof form of your building?
(1) Initial construction cost
(2) Aesthetics or massing of the building
(3) Subsequent maintenance cost
(4) Client's or government's policy
(5) Function that needs to be carried at the roof top
(6)

2.8.2 Which of the following roof shapes requires higher initial cost of construction?
(1) Pitched
(2) Flat

2.8.3 Is it possible to have pitched roofs on office buildings without affecting their architecture?
(1) Yes
(2) No

2.9 <u>Location of the service core:</u>

2.9.1 Which of the following played a major role in determining the location of the service core in your building?
(1) Function of the building
(2) Need of natural lighting and

ventilation to the service core
(3) Initial construction cost
(4) Pedestrian approach to the building
(5)

2.9.2 Is it possible to adopt external cores in office buildings without affecting their architecture and operation?
(1) Yes
(2) No

2.10 <u>Form of horizontal circulation:</u>

2.10.1 Which of the following played a major role in determining the form of horizontal circulation of your building?
(1) Function of the building
(2) The need of natural lighting and ventilation to the circulation areas
(3) Total built-up area and the maximum height the building can go
(4) Pedestrian approach
(5)
(6)

2.10.2 Is it possible to adopt the single zone form of circulation without affecting the architecture and operation of office buildings?
(1) Yes
(2) No

2.11 <u>Depth of building:</u>

2.11.1 Which of the following influenced the distance between the external envelope and the immediate horizontal circulation boundary of your building?
(1) Extent to which natural light can penetrate into the building
(2) Function to be carried out in the building
(3) Size and shape of plot
(4)
(5)

2.11.2 Is the design team aware that the less the depth of building the better the natural lighting and ventilation received by the internal spaces of the building.
(1) Yes
(2) No

2.11.3 What is the average depth of spaces that can be recommended for office buildings in metres?--
----

2.12 <u>Storey height:</u>

2.12.1 Which of the following influenced the storey height of your building?

(1) Size of windows that have to in-turn determine the amount of natural light and ventilation required
(2) Structural system
(3) Function to be carried out inside the building
(4) Location of services, for instance , air conditioning units that may be located within the ceiling space
(5) Initial cost that has to be kept low
(6)
(7)

2.12.2 Is the design team aware that the higher the storey height the better the natural lighting and ventilation in the building, however, the more the building fabric that requires maintenance?

(1) Yes
(2) No

2.12.3 What storey height (together with the average depth recommended in 2.11.3 above) can be recommended for office buildings in Nairobi to provide sufficient natural lighting and ventilation to its internal spaces?--
----

2.13 <u>Shading devices:</u> Shading devices regulates the intensity of light entering the building.

2.13.1 If your building has made use of shading devices, what actually necessitated them?

(1) Orientation of building
(2) Desired image/appearance of the building
(3)
(4)

2.13.2 Which of the following orientations require use of shading devices in Nairobi?

(1) North - South
(2) East - West
(3) All - directions

2.13.3 Is it recommendable to do away with shading devices of any kind for office buildings in Nairobi?

(1) Yes
(2) No

2.13.4 If your building does not make use of shading devices, which of the following problems does it experience and similarly which of the following solutions have been adopted?

PROBLEMS

(1) The internal environment overheats

(2)
(3)
(4)

SOLUTIONS

(1) Introduced air-conditioning
(2) Blocked the windows and introduced artificial lighting
(3)
(4)

2.14 <u>Vertical escape routes or vertical circulation points:</u>

2.14.1 Which of the following influenced the location or number of vertical escape routes in your building?

(1) Shape and size of plot together with the fire regulations
(2) Maintenance requirements i.e. the location of cleaner's rooms
(3) Initial costs that has to be kept low
(4) Functional requirements
(5)
(6)

2.14.2 Does the presence of these vertical points bring about maximum attention to cleanliness and general maintenance of the building?

(1) Yes
(2) No

2.14.3 If yes, which of the following do you think would be the reason for this?

(1) Due to the presence of people in such parts of the building there is need to keep to the standard desired for the whole building
(2)
(3)

2.15 <u>Number of storeys:</u>

2.15.1 Which of the following influenced the number of storeys in your building?

(1) Initial construction cost
(2) Size of plot together with building regulations
(3) The image desired by the architect
(4) Maintenance requirements
(5) The total plinth area required
(6) Height limits
(7)
(8)

2.15.2 Is the design team aware that the higher the number of storeys the more sophisticated are the procedures and equipments required to maintain especially the exterior envelope of

the building?
(1) Yes
(2) No

2.15.3 What has the design team done to make sure that the subsequent running cost arising due to higher number of storeys has been kept low.
(1) Installed permanent maintenance infrastructure
(2) Used exterior materials that require least maintenance
(3)
(4)
(5)

2.16 <u>Ornamentation:</u>

2.16.1 What necessitated ornamentation on your building?
(1) Aesthetics and beaut to the building
(2) Function of the building
(3)
(4)

2.16.2 Ornamentation adds to the aesthetics and quality of the building that is eventually built. However, it requires serious maintenance especially on the side of cleaning. Is the design team aware of this?
(1) Yes
(2) No

2.16.3 If yes, what steps have been undertaken to ensure that these quality is kept at a lower maintenance cost?
(1) Used materials that require least maintenance
(2)
(3)
(4) Avoided ornamentation all together

2.16.4 If ornamentation was avoided would it affect the architecture and operation of your building?
(1) Yes
(2) No

2.17 <u>Volumetric description or massing of the building:</u>

2.17.1 The massing of your office building was intended to:
(1) Achieve the image conceived by the architect
(2) Minimize the use of artificial lighting and ventilation
(3) To obey the right of light regulation
(4) To achieve a maximum built-up area at the lowest initial construction cost
(5) Others (indicate)

(6)

2.17.2 These masses of buildings can either be pure volumes (i.e. cuboidal, pyramidal, prismatic, cylindrical etc) or irregular volumes (i.e. broken pure volumes for instance those that are cascading). Is the design team aware that the subsequent running costs i.e. costs of lighting, cleaning etc varies with the two categories of massing?

(1) Yes
(2) No

2.17.3 Were any steps taken at the design stage to ease these subsequent running cost?

(1) Yes
(2) No

2.17.4 If yes, what are these steps?

(1) Admit enough natural lighting to avoid use of artificial lighting
(2) Admit enough natural ventilation to avoid use of artificial ventilation
(3) Reduce building irregularity to ease cleaning and maintenance
(4)
(5)

2.17.5 Is it possible to avoid the irregular volumes/massing and yet don't affect the architecture and operation of the office buildings?

(1) Yes
(2) No

2.18 <u>Materials expression and finish:</u>

2.18.1 The finishing material can either be cladding or surface coating. Which of the following dictated the choice between the two for your building and why?

(1) Initial construction cost
(2) Cleaning and surface protection
(3) Desired aesthetics and appearance of building
(4) Function of the building
(5) Durability of the material
(6) Wear
(7) Comfort criteria
(8) Special requirements

REASONS

(1) Surface coating keeps initial cost low
(2) Cladding keeps maintenance cost low
(3) The function of the building/space demanded the type of finish used

(4)

2.18.2 Will all the effects (both architectural and functional) of the building be made if cladding was used?
(1) Yes
(2) No

2.18.3 The surfaces of these finishes can either be painted or stay unpainted. What dictated this and why?
(1) Initial cost of construction
(2) Subsequent maintenance cost
(3) Desired aesthetics and appearance of building
(4) Function of the building
(5) Type of finish used above
(6)
(7)

REASONS
(1) Some painted finishes require low initial cost
(2) Some unpainted finishes require low maintenance cost
(3) The function demanded painted finish
(4) The function demanded unpainted finish
(5)

2.18.4 Will all the desired effects of the building be made if unpainted material or the material that does not require frequent attention was used?
(1) Yes
(2) No

2.18.5 The finished surfaces can either be smooth or rough. What dictated this?
(1) Initial cost of construction
(2) Subsequent maintenance cost
(3) Desired aesthetics and appearance of building
(4) Function of the building
(5)

2.18.6 Whatever the finish on the building, will all the effects of the building be made if smooth surfaces were used?
(1) Yes
(2) No

APPENDIX D

DATA FOR SELECTED 38 OFFICE BUILDINGS

Building	Y	X_1	X_2	X_3	X_4	X_4^*
EABSt	539.06	3	6	0	72.94	0.2887
LAXMI	120.19	10	6	0	80.47	0.3219
UNIAFRIC	537.53	30	5	0	239.42	0.1256
KENINDIA	613.62	10	5	0	148.8	0.2296
HUGHES	317.33	12	6	0	223.1	0.2268
FEDHA	335.86	8	6	0	153.2	0.1083
PANAFRICAN	689.25	60	6	0	181.5	0.1973
KIMATHI	755.16	13	6	0	117	0.1313
MUTUAL	202.24	87	6	0	200.95	0.0898
CORNER	437.85	9	6	1	139.27	0.2986
AGIP	279.94	29	5	0	219.2	0.1704
JOGOO A	310.38	39	5	0	348	0.182
NAT. BANK BLDG	342.28	16	5	0	146.5	0.3296
SALAMA	263.55	38	6	0	154	0.1375
QUEENSWAY	236.08	60	6	0	167.4	0.1432
TOWN HOUSE	474.92	29	6	0	129	0.2348
PROTECTION	475.04	12	5	0	104	0.2262
NHC	867.99	19	6	0	101.19	0.1656
REINSURANCE	372.64	12	5	0	221.98	0.2169
UCHUMI	243.34	19	6	0	110.34	0.1483
POSTBANK	299.77	8	6	0	119.15	0.2581
M.O.P.W	449.10	26	2	0	120.07	0.223
CAPITAL HILL	435.11	3	2	1	161.8	0.1388
SHELTER AFRIQUE	101.33	13	2	1	137.5	0.0961
UTALII	204.78	14	5	0	252.3	0.1678
TRANSCOM	330.21	18	2	0	174.2	0.1867
ELECTRICITY	499.25	18	6	0	278.38	0.1576
ICEA	486.56	12	6	1	180.9	0.1992
CITY HOUSE	444.87	33	6	0	146	0.2558
HARAMBEE PLAZA	131.56	8	5	1	183.33	0.1303
COOP. BLDG	159.50	14	5.7	0	127.4	0.0973
ANN. TOWERS	418.55	3	5	0	165.54	0.1997
CHURCH HOUSE	411.62	39	6	1	221.4	0.673
TUMAINI HOUSE	210.88	30	6	0	241.7	0.1608
MAENDELEO	227.59	14	5	0	156	0.1692
JUBILEE PLACE	476.34	42	6	0	89.9	0.2258
JUBILEE EX.	502.20	39	6	1	238.62	0.1724
JUBILEE HOUSE	260.02	42	6	0	299.3	0.1651
Mean	380.62	23.4	5.3	0.18	167.79	0.201
Maximum	867.99	87	6	1	299.3	0.6730
Minimum	101.33	3	2	0	72.94	0.0898

Source: Field data 1993.

APPENDIX D. Continued

Building	X_5	X_6	X_7	X_8	X_9
EABS	1401.42	5657.3	3	18.21	5.89
LAXMI	1777.78	6247.4	2	21.18	5.8
UNIAFRIC	9527.5	77584.3	2	27.63	7.01
KENINDIA	13088.65	44329.14	2	54.6	7.05
HUGHES	11336.51	33095.64	1	35.48	6.096
FEDHA	16073.81	129233	2	70.5	5.4
PANAFRICAN	6481	22853	2	24.5	4.88
KIMATHI	4508	21411	2	35.75	6
MUTUAL	11355	39539	2	20.1168	5.2768
CORNER	14937	45840	3	66.1	5.15
AGIP	11574	40541	2	23.4	7.3
JOGOO A	10832	37284	2	19.5	4.4
NAT. BANK BLDG	12883	81478	2	84.615	6.6
SALAMA	6006	17284	0	13.95	6
QUEENSWAY	7865	34249	0	35.13	5.77
TOWN HOUSE	4944	16744	2	30.48	6
PROTECTION	5152.79	16312	3	36.77	5.3
NHC	10037	34520	2	51.66	7.16
REINSURANCE	24309	112941	0	75.2	6.5
UCHUMI	22647	66828	0	72	7.16
POSTBANK	13142	80010	1	73.6	4.75
M.O.P.W	10777	29819	0	49.26	3.657
CAPITAL HILL	7602	22457	2	35	7.5
SHELTER AFRIQUE	10308	31165	2	22.5	4.8
UTALII	21703	70970	2	41.6	5.49
TRANSCOM	9022	31144	0	34.87	4.8
ELECTRICITY	17498	61289	2	45.72	4.8
ICEA	22170	80370	0	66	3.6
CITY HOUSE	4567	13701	0	24	6
HARAMBEE PLAZA	18182	60321	2	48.27	6
COOP. BLDG	14073	69941	0	89.57	7
ANN. TOWERS	27931	82870	1	91	6
CHURCH HOUSE	5264.22	14597.65	0	23	3.5
TUMAINI HOUSE	4158	13482	1	21	4.75
MAENDELEO	5168.33	32684	2	34.73	6.3
JUBILEE PLACE	2915	8742	2	21	6
JUBILEE EX.	6016.9	38948	2	28.5	6.5
JUBILEE HOUSE	14463	43515	2	24	5
Mean	11097.29	43947.27	1.4	41.8524	5.7155
Maximum	27931	129233	3	91	7.5
Minimum	1401.42	5657.3	0	13.95	3.5

Source: Field data 1993.

APPENDIX D. Continued

Building	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
EABS	14.41	1	1	0	5.296	0
LAXMI	11.63	1	1	3	6.5532	1
UNIAFRIC	11.32	1	1	1	4.8	1
KENINDIA	19.82	1	0	0	4.3	0
HUGHES	34.58	1	1	1	5.94	1
FEDHA	49.55	1	0	0	4.8	0
PANAFRICAN	19.3	0	1	1	7	0
KIMATHI	45.95	1	1	1	11.4	0
MUTUAL	21.5	0	0	1	6.2484	0
CORNER	42.02	1	1	1	5.25	0
AGIP	59.9	1	1	1	5.945	0
JOGOO A	30	0	1	1	5.4	1
NAT. BANK BLDG	63.43	1	1	1	4.575	0
SALAMA	35.87	1	1	1	9.4	1
QUEENSWAY	20.46	1	1	3	5.75	1
TOWN HOUSE	20.47	1	1	1	5	0
PROTECTION	37.37	1	2	1	4.6	1
NHC	35.41	2	0	0	4.97	0
REINSURANCE	55.63	2	2	1	4.42	0
UCHUMI	16.77	1	0	0	5.26	0
POSTBANK	34.4	1	2	1	5.6	0
M.O.P.W	34.47	2	1	1	5	0
CAPITAL HILL	36.3	2	1	1	6	1
SHELTER AFRIQUE	46.34	1	1	1	4.45	0
UTALII	22.79	1	1	1	5.73	1
TRANSCOM	32.104	2	1	1	5.15	0
ELECTRICITY	54.09	2	1	1	5.28	0
ICEA	51.94	1	2	1	5	0
CITY HOUSE	22.79	2	1	1	4.5	0
HARAMBEE PLAZA	22.146	1	1	3	5.297	0
COOP. BLDG	61.03	0	2	0	5	0
ANN. TOWERS	40.22	2	2	3	6	1
CHURCH HOUSE	30.42	1	1	0	4.5	0
TUMAINI HOUSE	18.05	1	1	1	6	0
MAENDELEO	39.66	1	1	1	6.24	0
JUBILEE PLACE	23.789	1	1	1	5.5	1
JUBILEE EX.	23.8	2	1	1	5	0
JUBILEE HOUSE	37.46	1	1	1	4.86	0
Mean	34.239	1.34	1.03	1.03	5.579	0.28
Maximum	63.43	2	2	3	11.4	1
Minimum	11.32	0	0	0	4.3	0

Source: Field data 1993.

APPENDIX D. Continued

Building	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}	X_{22}
EABS	2.97	27.03	2	1	0	0	2
LAXMI	2.7	13.69	2	1	1	1	1
UNIAFRIC	3.12	36.62	3	1	1	1	2
KENINDIA	3	2.86	2	2	2	2	1
HUGHES	2.895	0	3	1	1	1	1
FEDHA	3	0	2	1	1	1	1
PANAFRICAN	3.3	42.2	2	2	0	1	1
KIMATHI	3	0	1	2	2	2	1
MUTUAL	3.9624	4.5	3	2	2	1	2
CORNER	2.9	2.88	2	0	0	0	1
AGIP	2.6	28.1	2	0	0	1	1
JOGOO A	3	0	5	2	1	2	2
NAT. BANK BLDG	3.125	3.26	2	2	0	2	1
SALAMA	2.4	0	2	1	1	1	2
QUEENSWAY	3.25	20.3	2	2	1	1	1
TOWN HOUSE	3.048	0	2	2	1	1	1
PROTECTION	3.135	0	2	1	0	0	2
NHC	2.8956	1.73	2	2	0	1	1
REINSURANCE	3.1	0.18	2	1	0	1	1
UCHUMI	3	0	3	1	1	1	1
POSTBANK	3.04	1.249	2	1	1	1	1
M.O.P.W	3.16992	0	2	2	1	1	1
CAPITAL HILL	3.15	3.49	3	1	0	1	1
SHELTER AFRIQUE	3.15	0	3	1	1	1	2
UTALII	2.9	2.19	3	2	2	0	1
TRANSCOM	3.16992	0	2	2	0	1	1
ELECTRICITY	3.048	18.6148	4	2	1	1	2
ICEA	3.1	2.7118	2	1	0	0	1
CITY HOUSE	3	0	2	1	0	0	1
HARAMBEE PLAZA	3	5.34	3	0	0	0	1
COOP. BLDG	3.1	3.68	2	0	0	0	1
ANN. TOWERS	3	1	3	0	0	0	0
CHURCH HOUSE	2.55	1.47	2	1	1	1	2
TUMAINI HOUSE	3	8.08	5	2	2	0	2
MAENDELEO	2.99	0.58	2	2	1	1	1
JUBILEE PLACE	3	24.99	2	2	2	2	2
JUBILEE EX.	3.25	65.3	3	1	1	0	1
JUBILEE HOUSE	3	0.29	3	2	2	2	1
Mean	3.03	8.4825	2.5	1.32	0.8	0.9	1.3
Maximum	3.96	65.3	5	2	2	2	2
Minimum	2.4	0	1	0	0	0	0

Source: Field data 1993

APPENDIX D. Continued

Building	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}
EABS	1	0	1	0	0	2
LAXMI	1	0	2	0	0	2
UNIAFRIC	2	0	1	1	1	2
KENINDIA	1	1	1	1	1	2
HUGHES	0	0	1	1	1	1
FEDHA	1	0	1	0	0	2
PANAFRICAN	1	0	1	1	1	1
KIMATHI	1	0	1	1	1	1
MUTUAL	2	0	1	1	0	2
CORNER	1	0	1	1	0	1
AGIP	1	0	1	0	1	2
JOGOO A	1	0	1	1	1	2
NAT. BANK BLDG	1	1	1	0	1	2
SALAMA	1	1	1	0	1	2
QUEENSWAY	2	1	0	1	1	2
TOWN HOUSE	1	0	1	0	1	2
PROTECTION	1	1	2	0	0	2
NHC	1	1	1	0	0	1
REINSURANCE	1	1	1	0	0	1
UCHUMI	1	0	0	1	0	1
POSTBANK	1	0	1	0	0	1
M.O.P.W	1	0	1	1	1	1
CAPITAL HILL	1	0	0	0	0	1
SHELTER AFRIQUE	2	1	1	1	1	1
UTALII	1	1	1	1	1	2
TRANSCOM	1	0	1	1	1	1
ELECTRICITY	2	0	2	0	0	1
ICEA	1	1	1	0	1	2
CITY HOUSE	1	0	1	0	0	1
HARAMBEE PLAZA	1	0	1	0	0	1
COOP. BLDG	1	1	1	0	1	1
ANN. TOWERS	0	0	0	0	1	1
CHURCH HOUSE	1	0	1	1	1	2
TUMAINI HOUSE	2	0	2	0	0	2
MAENDELEO	1	1	1	0	1	2
JUBILEE PLACE	1	0	1	1	1	2
JUBILEE EX.	2	0	1	1	1	2
JUBILEE HOUSE	1	0	1	1	1	2
Mean	1.13	0.32	1	0.47	0.61	1.55
Maximum	2	1	2	1	1	2
Minimum	0	0	0	0	0	1

Source: Field data 1993.

APPENDIX D. Continued

Building	X[illegible]	X[illegible]	X[illegible]	X[illegible]	X[illegible]
EABS	2	0	6	1	0
LAXMI	2	0	7	0	0
UNIAFRIC	2	0	5	0	0
KENINDIA	2	1	17	0	0
HUGHES	2	0	11	0	0
FEDHA	2	1	22	0	1
PANAFRICAN	2	1	6	1	0
KIMATHI	1	1	10	0	1
MUTUAL	2	0	5	0	0
CORNER	2	1	23	0	0
AGIP	2	1	9	0	0
JOGOO A	2	0	6	0	0
NAT. BANK BLDG	2	2	24	0	0
SALAMA	2	0	5	0	0
QUEENSWAY	2	1	10	0	0
TOWN HOUSE	2	0	10	0	0
PROTECTION	1	1	10	1	0
NHC	2	0	15	2	0
REINSURANCE	1	0	24	0	0
UCHUMI	1	0	24	2	0
POSTBANK	1	0	22	0	0
M.O.P.W	2	1	15	0	0
CAPITAL HILL	2	0	10	0	1
SHELTER AFRIQUE	2	1	7	0	1
UTALII	2	0	13	2	0
TRANSCOM	2	0	11	0	0
ELECTRICITY	2	0	16	0	0
ICEA	2	1	21	0	1
CITY HOUSE	1	0	8	0	0
HARAMBEE PLAZA	2	0	15	1	1
COOP. BLDG	2	0	25	0	1
ANN. TOWERS	1	1	29	0	0
CHURCH HOUSE	2	0	8	0	1
TUMAINI HOUSE	2	0	7	0	0
MAENDELEO	2	1	11	1	1
JUBILEE PLACE	2	0	7	0	0
JUBILEE EX.	2	0	8	0	1
JUBILEE HOUSE	2	0	9	0	0
Mean	1.82	0.39	12.92	0.29	0.26
Maximum	2	2	29	2	1
Minimum	1	0	5	0	0

Source: Field data 1993.