Dissonances in Building Cost: An Analytic Review of the Impact of Design Variables

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ABSTRACT

The cost of building is influenced by a variety of design variables. There would however appear a paucity of readily available cost data on the impact of design variables. This research is set out with a view towards the establishing readily available cost data information as well as relevant cost indices. The research used case study from previous buildings, extensive reviews, the statistical technique of percentile as its computational technique and rates obtained from synthesized bills priced by professional Quantity Surveying firms, as relevant components of its methodology. The location of the research, Port Harcourt metropolis is situated in Niger Delta region of Nigeria. Research findings from the case study buildings as well as extensive literature review established that there exist differentials in the initial and total costs of both building plan Shapes (Square and rectangular), recording a 12.56 percentage differential. The elemental cost derived from both shapes also established differentials between 0.53 to 17.79%. The study also establishes the perimeter wall and gross floor area ratio which is an important index towards the determination of economic building shapes. The research concludes that the results, from the case study building would appear limited and as such should avoid being overgeneralized, nevertheless, it does serves to further reveal in broad terms, that the influence of plan shapes of simple buildings on cost is minimal. It recommends further, exploratory study that focuses on design and their cost implications, using cost models that input a wider range of variables.

Keywords: *Construction industry, design, plan shape, other design variables, size of building cost implications of design variables*

INTRODUCTION

Kouskoulas and Kochin (1974), postulated that the cost of a building is a function of many of variables and suggested that a set of independent variables can be selected to describe a project and define its cost. Kouskoulas and Kochin identified building locality, price index, building type, building quality and building technology as independent variables that define the cost: Seeley (1983) and Ashworth (1988) have identified the following: (Plan. Shape, Size, total height, storey height, location, the availability of mains services or the cost of their provision, the grand conditions and contour profiles, the extent of demolition and site clearance, the specification, the length of time required, the purpose of scheme, the length of time) as independent variable that define the cost buildings.

The construction industry continues to be one of the fastest growing sectors of economy, be it in

develop countries of or developing ones, the urge to reliever the best product output. In terms of good designed buildings project, which is able to satisfy the clients and ultimate users cannot be emphasized. This has again been added on to by the scarcity of resources and hence need to put the little available ones to the best use. This can be judged by having to in cur costs which cannot be dealt away with, call value for money in projects. With this new phenomenon, there is great tendency that most clients the common initial question they will ask is, what is going to cost me often followed closely by "can we do it any cheaper" (Cunningham, 2013).

Seeley further revealed that variations in this cost of similar building types can be accountable for, due to the above mentioned variables.

Shahs and Ibrahim (2005) have identified cost as one of the measure of functions and performances of building. Cost should be capable of being in order that a design can be evaluated. Building cost models will assist in proving greater understanding and possibility of perdition of the effect on the cost of changing the design variables by Architectural – Engineering firms. According to Frank (1998), in arriving at any particular design, there is a broad Relationship between the client, shape, method and material of any construction as follows: (1) The client determines the building shape. (2) The building shape determines the building material. (3) Materials determine the structure and construction.

Design variables according to Crayon research (2003) is an iterative process through which a set of requirements such as physical, aesthetic, performance and so on are creatively manipulated resulting into a design. In addition, design decisions form solutions to problems of function, form and economy for building (Pena and par shell 2001). Shahs and Ibrahim (2005), see design variables as parameters of a building that can be varied between designs while proving the same quality and amount of accommodation. The plan shape, storey height, number of storey and circulation space are some of such parameters.

Zahrani (2005), has asserted that design variable is a numerical input that is allowed to change during the design optimization (making it perfect) or a parameter or unit of a particular case, but which be varied in different cases even while providing the same accommodation. Ashworth and Skitmore (1983), have revealed that design variables form the morphological factors which influence the cost of building work. According to Marton and Jagger (1995), they form the designs forecasts, as it is the building design variables that give the information for forecasting and determining whether value can be achieved at an acceptable cost. Pena and par shell (2001), further asserted that design variables also form a basis for decision making, as solutions to problems of function, form, time and economy building according to Beet son (1987) this is because design variables represent as closely as possible, the way in which costs are actually incurred.

During design, there are constraints that exist which are entirely internal to the system or object being designed factors not under designer's control. Four types of constraints faced by designers during the design process are as (i) Radical Constraint, a range of health care policies fall under this (ii) Practical constraint in other words, the constructability issue in posed by the design (iii) Formal constraint and symbolic constraint (Charleson 2005). Gray (2001) however simplified the constraints, grouping them into two categories: Internal and external.

The research, aside dealing with the conceptual meaning of design variables and the relationship with cost of building also provides reviews on how the variables influence the cost of building: in this regard, the research draws from previous work, using review, as well as the results of the

studies of other researchers as basis. Research works are abound on variables influencing construction cost as it relates to procurement approaches, tendering and post contract management procedures and techniques, however there would seem a relatively paucity of studies on construction cost as it relates to variables influencing design. In additions, considerably numbers of studies as it relates to variables and cost have always focused on the impact of plan or others on variables on an individual/singular basis.

Prospective building clients' seldom have empirical cost data on the impact of design variables on cost. The impact of that most buildings during the tender analysis and construction stage are found to have overshot the client's budget limit. This research examines the effects changes in design variables (plan shape) have on the overall building cost and the element costs, thereby establishing relevant cost ratios for analysis application of future projects.

The quantum of building production is a function of the cost. Building built on same location and has adopted same tendering and procurement, strategic affected by the same level of economic factors but with dissonances in their design variables will result in cost differential of the buildings. Brandon (1970), cited in town send and Turner (1982) have observed that in the design process 80% of the expenditure has already been committed by the completion. The quantity surveyor may then be faced with the task of controlling only 20% of the anticipated expenditure in liaison with other members of the design team. Bathurst and Butler (1980), have also observed that decisions that border on plan shape or height are "key", these decisions have irreversible effects on a building. "Incidental" decision on the other end, which can be changed up to the time of construction without any fundamental effect on building decision, for instance the specification of tiling in bathrooms. All processes targeted towards the reduction of cost designing the design team became justifiable.

Studies on building design variables and their cost implications is beginning to take centre. Stage as an aspect of construction economics. Allsop Ainomugisha et-al (2015), have also collaborated and asserted that results from precious researchers on design variables and their cost verify why design/construction economics is taking centre stage during construction management as opposed to designing's where by architects took aesthia requirements more important. This practice has necessitated the design shifting more towards value for money in projects.

This research is one of such efforts, it undertakes an appraisal on how combinations of several of the design variables impact on building design cost, this is with a view to understanding appreciating and revealing the extent, to which variables in mist of others can influence design cost.

The research therefore seeks to undertake the following: (1) an empirical study, which compares the influence of two plan shapes (square and rectangular) of a simple building prospective. (2) Undertake an extensive and intensive review of literature that articulates the outcome of previous works of other researchers on design variables and cost of buildings. (3) Establish from the outcome to which, extent and how these variables influence building cost. (4) Establish through reviews of the results as well as from literature how alterations in design variables affects individual cost of elements of: Sub-structure, block walling, roofing , windows , doors, finishes and recordation's, electrical and mechanical service and maintenance.

REVIEW OF RELATED LITERATURE AND PREVIOUS WORKS ON DESIGN VARIABLES AND BUILDING COST.

The research provides articulated reviews on related literature highlighting the ways in which alterations in design variables can influence building cost. In this regard, the research reveals the place or impact of the followings: Perimeter wall/area ratio the size of buildings height, shape efficiency index floor efficiency ratio on buildings cost; the horizontal distribution volume and internal cube as the relevant indices. In addition, the research reports from studies on cost models which establishes several of the interrelationships and between/amongst the design variables.

Swaffield and Pasquire (1999), have postulated that the accuracy of a cost moraines system is dependent an on its ability to input and consider the effect of the building functions, level of services provision, and parameters which describe the form of the building.

Seeley (1996) asserts that the lower the perimeter to floor ratio, the more economical, the proposal will be. A circular building produces the best wall floor ratio but the saving in quantity of wall is usually more than offset by the lowered output by 20 to 30% reporting on impact of size. The larger the plan area for a given shape, the lower the perimeter/ floor ratio, that is larger buildings offering an equivalent quality of specification. An inverse relationship is expected between building size and the cost of per square meter (GFA). The research also concluded that where a choice is to be made between enclosing an area in two or more smaller buildings, in so far as the external cladding elements are concerned, it will be more economical to provide the accommodation in the larger building, there is however a need for the conclusion, deeper analysis of lightings and servicing requirements need the conclusion ineffective.

Ferry and Brandon (1991), see an efficiency ratio as a multiplier measure to be adapted in adjusting the cost estimate. This efficiency ratio can only be used to compare buildings having similar floor areas and does not have optimum reference point. In a related study, Chua (1999) established a shape efficiency index, the perimeter of a floor plan to the perimeter of a square floor plan. The study concluded that, the larger the value, the more complex the shape.

Shash and Ibrahim (2005) reveal compactness and mass compactness or volume ratio ratios and the rectangular index as measures of efficiency. The compactness ratio related the perimeter of a floor plan with the same areas whilst the mass compactness or volume ratio uses hemisphere as the point of reference for considering the compactness of the buildings in three dimensions. The rectangular index also called the length/breadth index (LBI). The LBI is defined as the length to breathe ratio of a rectangular with the same area and perimeter as the buildings. In this index any right- angled plan shape of a building of a building is reduced to a rectangle having same area and perimeter as the buildings. The measure of efficiency as it relates to the compactness ratio is based on the outcome of the value of the index; the smaller the value of the index, the more complicated the shape. The reference point is the circle, (a square wall have a compactness ratio of 8.6%) efficiency and yet is probably the best cost solution in initial cost terms. Another index of measure efficiency in as it relates to design variables is height. According to Tan (1999) cost variables in building heights is affected by technology, building design, demand and institutional factors. The model was developed to determine the incremental cost of each floor as the building height increases. Safiki et-al (2015), *table of summary of analysis on building design variables* and cost from the works of previous authors, forms a basis for further extant reviews and discussions.

Furthermore, these previous studies indicate difference in the way construction costs of substructure, superstructure frame, walls, ceilings, floors, the roof, building services, finishes and the costs related to constructability due complexity like during setting out component plus energy costs, during maintenance, are affected Ibrahim et-al (2015) Ibrahim (2010) Seeley (1997) and Ferry (1999).

RESEARCH METHODOLOGY:

Based on the preposition that prospective building client seldom have empirical cost data on the impact of design variables on buildings cost during the design stage, the result of which is that most building during tender analysis and construction are found to have over shot, the client's budget's limit. This research is reasonable attempt that undertakes a case study approach that is directed towards resolving the problem of budget over shot. In addition, the research also undertakes a focused and extensive literature review craved from both print and online material that borders on considerably number of relevant studies on building design variables and their impact on building cost. Following, the research highlighted the result of the case study as well as the summary of research findings on design variables and their impact on building cost.

Research Method:

The case study of this research focuses on the comparison of cost implications of design decision on the geometrical plan shape of right angled building forms (square and rectangle). This involved the design, preparation of bills of quantities and the analysis of data from the various summary of cost, items obtained from both building shapes.

Research Design:

The design of the research fundamentally involved the following: The design of a simple block of 5NR classroom. The research examines the effects changes in design variable (plan shape) have on the overall building cost as the elemental costs.

Data for the research was generated from the design and costing of the plan shape: Square and (ii) rectangle. Bills of quantities were prepared from designs of the two shapes. The plan of the two shapes were of equal geometrical size (grossfloor area of 97.47 sqm.). Using the rates obtained from synthesized bills of quantities, priced by professional, Quantities Surveying firms in Port Harcourt (situate in the Niger Delta Region of Nigeria), the research analyzed the impact of two of the plan shapes and their cost implications (both the overall as well as elemental or component initial costs). The research also established index for the unit cost per square meter of gross floor area, from the overall building cost.

Reliability of the Cost Data:

The following processes and procedures were adopted to enhance the accuracy of data obtained: The same standard method of measurement were adopted and applied for the derivation of quantities (from the design of the two shapes).

The same unit rates were also applied for both, the rectangular and square shaped and design. The rates used for analysis are the synthesized rates from the professional firms; these rates are the rates used for tender analysis of their consultancy projects. In order to further enhance the accuracy of data, the mean values of rates obtained from the five (5) professional Quantity surveying firms, were used for the analysis. The statistical tool of percentile was employed for the analysis of data, establishing differentials between the costs of two plan shapes both for the overall cost and the element costs.

Descriptive Statistics:

Graphs in the form of charts established the trends in overall cost as well as the elemental costs for both plan shapes.

The rationale behind the choice of the design variable (plan shape)

(1) The choice of the design variable (plan shape) is predicated on the premise that the ratio of the perimeter wall area and floor area is an important index in the determination of

economy unit cost of buildings. This is in turn function of the plan shape of buildings.

(2) The other design variables of storey height, total height, size of building in the determination and appraisal of unit cost of buildings also adopts and applies the ratio (perimeter wall area and floor area).

Fig 4.1 below show identified building design variables from previous studies

DESCRIPTIVE ANALYSIS

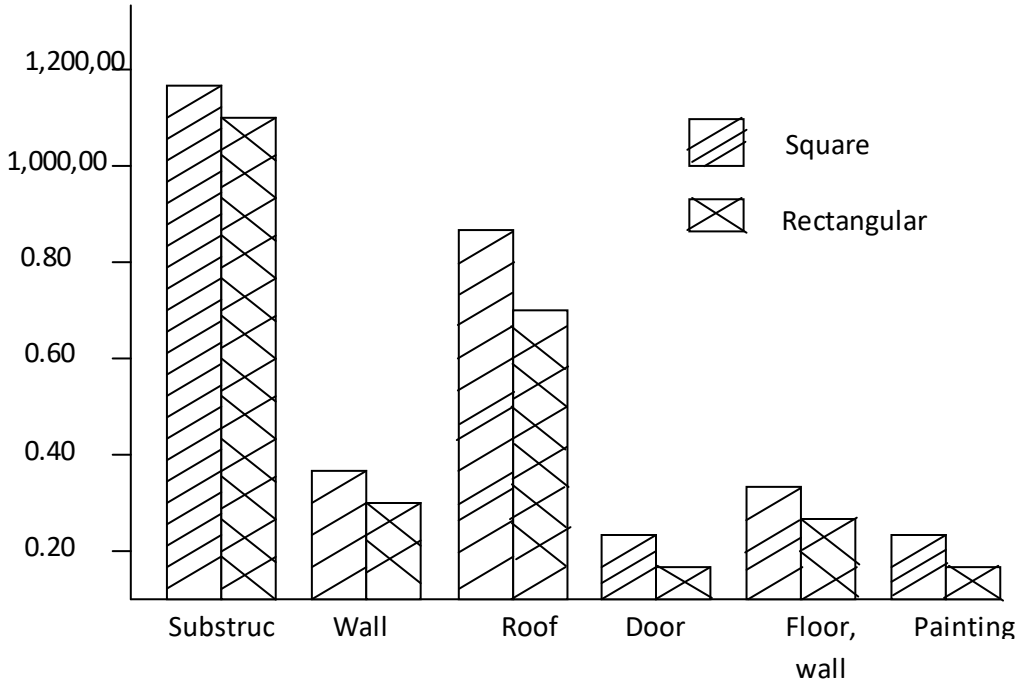

Figure 4.1: Cost trends and analysis between square and rectangular shaped classrooms buildings.

ASSUMPTIONS AND LIMITATIONS OF THE RESEARCH

The empirical validity of the research outcome is based on the following:

- The design adopted for the research, is a simple domestic building. It is assumed that the effect of location, topography, client and economy variables on cost have been considered the pricing strategies of rates. The cost do not include for certain building components: plumbing (mechanical and electrical services). The research focused on the analysis of a simple classroom block (square and rectangular shaped). The specifications are as contained in the bill of quantities used for the synthesis of rates. The same sets of specifications were adopted for the different plan shapes (square and rectangle).

The descriptive statistics establishes as follows:

The total cost of the rectangular shape classroom building is higher than that of the square shape. The rectangular shaped indicated the following: An overall cost of 3, 044,444 substructures, concrete work, wall roof, door and window, floor, paint elements recorded ₦1,132, 304, ₦289, 030, ₦487, 600, ₦628, 402, ₦169,330, ₦229, 690, ₦117, 108 as cost respectively. The square shaped indicated the following: An overall cost of N3, 781, 792, whilst substructure, concrete work, wall, roof, door and window, floor wall**and**ceiling,painting and decoration, recorded costs of ₦1,325,440, ₦264,600, ₦566,440, ₦733,246, ₦224,246, ₦260,000, ₦137,730 respectively.

DISCUSSION OF RESULTS

The comparison of cost between the square and rectangular shape classroom establish the following results:

(a) The shape building indicate the higher overall cost ₦3,781,792, whilst the rectangular shaped recovered a sum of ₦3,044,464
(b) The square and rectangular shaped building therefore indicated cost per square meter of N35.68 million/m2 and N28.72 million/m2 respectively.
(c) A total percentage differential of (12.56)% is established to exist between the square and rectangular shaped building.
(d) The elemental cost percentage differential rage between (0.53 to 17.77%) for the various elements studied for the two plan shapes.
(e) The square shape building established an external perimeter wall and floor area ratio (index) of (1.10). Whilst the perimeter wall and floor area ratio rectangular building is (1.54).

IMPLICATIONS OF THE CASE STUDY RESULTS

(i) Shape as design variable, has impact on the building having same floor area and same specification as shown by the outcome of the research. (ii) The result is in tandem with the expectations from theoretical background, where the impact of shape of simple building forms, on cost is minimal, even though, it is generally expected that the further the plan shape moves away from square, the more expensive the cost would have been. (iii) This research has specifically indicated that the square and rectangular shaped building have established perimeter wall area ratios (indices) of (1.10) and (1.54) respectively.

SUMARY OF RESEARCH FINDINGS

The result of this case is in tandem with the generic expectation of the impact of plan shape as design variable on building cost. Seeley (1983) has established that plan shape of a domestic structure have little or no effect on cost, this arises because of the high density of internal portioning wall in a domestic building. Factory building however because of their small amount of internal portions, the perimeter floor area will have its maximum effect. Cost also increases as the building perimeter moves further from the square.

Research finding emanating from the extensive review of related literature from other authors, like Seeley (1983), has established that plan shape a "key" design variable on building cost asserting further that there exist an interplay. Between design and specification, which makes it impracticable to consider the effect of plan shape as an isolated variable that affect building cost as that the configuration of door and windows are manifestation of how plan shape impact on building cost. Sakifi et-al (2015), has also discovered from reviews that the highest number of researchers picking interest, in mainly plan shape, total height of building and services. This is because of the extent of effect, they have on the costs and individual elements. Furthermore, Sakifi et-al (2015) provide a summary of table on research findings from previous researchers, showing the cost implications of various design variables. The table provides relevant headings as basis for discussion on highlighted design variables and their impact on building cost.

Table II cost implication of building design plans. A literature review analysis.
Source: Ainomugisha Safiki, Mohammad Solikin and M. Nursahid (2015).
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Table II
COST IMPLICATIONS OF BUILDING DESIGN PLANS: A LITERATURE REVIEW ANALYSIS.

No.	Design Variable	General cost Implication	Accounting for the Probable cost implication
1	Plane shape	High perimeter- to – floor unit construction costs (square is cheapest of all)1	1.1 high quantities of Decorations like paints and plaster. 1.2 Increased volume of external enclosing block walling. 1.3 Increased heat surface area. 1.4 change in foundation quantities 1.5 longer service and waste pipes 1.6 chances of extra doors & window
2	Shape complexity	Irregular and Complex shapes Have higher the costs	2.1 high roof costs due to corners and Material cutting wastages. 2.2 setting out costs and time increase. 2.3 excavation costs increased 2.4 drainage costs high due to extra manholes and longer pipes
3	Size of Buildings	Unit construction Cost, such as cost Per square meter reduce	3.1 economical preliminaries (as site offices, water supply temporary Roads costs etc.) are fixed 3.2 on cost and overheads form a smaller proportion of total costs 3.3 greater economy In using lifts, bathrooms.
4	Average store height	High construction Costs for heights	4.1 increased Volume of Heating and Longer length Off pipes or cable 4.2 longer service and waste pipes to supply sanitary appliances 4.3 higher roof costs due to increased hoisting 4.4 increased Staircases and lifts costs 4.5 cost in applying finishes & decorations High working at high levels.
5	Number of Story	Generally there are cost items which fall as the number of story increases , those which fall initially And then rise and those unaffected by height	5.1 foundation costs Decreasing

			5.2 beyond a certain number of Stores the form Of construction of the change and Costs rise. 5.3 cost varies with type form construction of building. 5.4 Air conditioning Costs likely fall. 5.5 Sophisticated equipment (wet).
6	Building Envelope	Simple envelop Adopted (square shape) the more economical design is.	6.1 lowest Perimeter/ floor hence cost expended on the wall & finishes plans the roofing plus.
7	Circulation Space	lower space expended of Circulation elements the more economical design is	7.1 associated costs on heating cooling light and maintenance yet no profanation use, low.
8	Grouping of Buildings	{8}, {9} {11}, {12}niter-liking building often Results in saving in cost	8.1 Reduction in the quantities of foundations. External walling.
9	Percentage of Glazed wall	High wall to floor Ratio results in Higher cost	9.1 Due to glazing and cladding being a very expensive element of building.
10	Mechanical & Electrical services	Great proportion result building Becoming costly	10.1 Since they costly elements 10.2 They are Biggest consumer of energy Between up to 30% and 40%.
11	Floor spans	Floor Increase Considerably with Larger spans.	11.1 floors and roof are the most Expensive Parts of a building Structure
12	construability	The more Constructability of Any design plan Becomes difficult The higher the cost Implication.	12.1 the complicated Structure need Specialized expertise 12.2 construction time increases where Construct ability is a problem 2.3 Ease of compatibility of different elements once its well planned

Source: Ainomugisha Safiki, Mohammad Solikin and M. Nursahid (2015).

CONCLUSION

The research draws the following conclusions as it relates to the case study on the impact of plan shape as a building design variable. Differences exist between the initial total costs of the square and rectangular shaped buildings. (ii) on an accommodation having same size, the square building is more economic than the rectangular shape. (iii) the perimeter wall area to gross floor area (wall/floor area ratio), is an important index in the determination of economic shapes. Admittedly, it would appear not prudent to over generalize the outcome of the relationship drawn from the results of the case study, principally due to the numbers of designs, never the less they do serve to establish the broad trend, the influence of plan shape (of simple buildings) on cost is minimal. Furthermore, the research from the outcome of extensive reviews of previous studies concludes that design variables form the basis for the formulation of alternative building design, each of which impacts on cost of buildings in different ways.

RECOMMENDATIONS

The research advocates the following recommendations: During the early stages of design, the ratio of perimeter wall area to gross floor area should be a good basis for determining economic plan shapes of building of a given accommodation size. However since this singular consideration or variable cannot lead to an effective cost appraisal in isolation, amidst competing variables, the research further recommends studies on building design variables and their cost implications. Cost models that input a wider range of design variables for similar accommodation will provide a more viable option, in future researches with necessary adjustments for size, other design variables and specifications.

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