Building Design Variables Usage as a Tool of Value Engineering During Designing

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Abstract. The deployment of construction economics has become more desirable today, mainly due to need to establish how building costs are spent, and be able to come up with the most optimum alternatives. This research article therefore, explored 1) the various costs inputs called design variables used by design consultants, plus their underlying factors, 2) how the practice of value engineering (VE) impacts on projects in Indonesia. A qualitative methodology, was used inform of a questionnaire, designed based on a 5 pointer liker scale approach, and distributed among 30 respondents consisting of consultants and clients in areas of Surakarta. The collected data was processed using statistical method of relative importance index, followed by descriptive analysis inform of bar and pie charts. The results obtained were that building plane shape (index 83.2), was mostly used, which itself depended on external features of building membrane and shape of building site (80.0 each), then other variables were building complexity (82.1); and building façade (77.9), meanwhile the least used was sharing walls (index 62.1), Lastly, VE was found to benefit the industry by producing designs which meet time, cost and quality targets, on the other hand material wastages and loss of confidence was reported once VE was neglected.

1 Introduction

In more recent studies under design economics, it can be seen that there is an attempt to represent as closely as possible how costs are actually spent [1]. In line with that, it was established by [2] and [3] that the level of influence on these building costs goes on declining as project develops through the various stages of its life cycle. These economic studies have led to new phenomena such as building design variables, which have generally been viewed as an attempt to have a representation or form of geometry of a building, project how this form of geometry impacts on costs, as early as possible i.e. before most of the decisions are spent. They have been generally organized in form of a list of alternative design proposals, and quality specifications. Hence in one way or the other helping the building client by making him aware of the likely financial commitments before extensive work is undertaken.

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This whole process or movement towards construction economics has bread into two concepts but which are merely similar i.e. Value management (VM), being about getting the right project, and Value Engineering (VE) as what is done to get the project right.

According to the research that was made in United States of America (USA) by [4], it was indicated that with this application of VE on construction project, a great deal of savings amounting up to between 34-36 % of total costs of a project could be realized. Furthermore, this concept has been greatly viewed to be in line with the famous quote of John Ruskin's (1819–1900), who said, 'It is not the cheaper things in life that we want to possess, but the expensive things that cost less' [5].

In Indonesian perspective development of this VE begun to be realized when *Departemen Pekerjaan Umum (DPU)* released National Standard competence of works *(Standar Kompetensi Kerja Nasional Indonesia) (SKKNI)* to the value engineering professionals. However, this was followed with establishment that this VE concept is not fully realized, that's why from their report in 2008 it led to issuance of bye law *06/PRT/M/2008* on 27 June 2008. The law decreed that in case of discovery of existence of inefficiencies or wastages resulting from unnecessary construction costs, poor type of form of construction, poor cost estimates, and even the method of construction itself, then it becomes incumbent on owners and service providers to do VE. Therefore, it's upon this background that the author sought to undertake study survey so as to achieve the following objectives: 1) firstly to establish the various design variables used by architect consultants in Indonesia, plus underlying factors for their selection, then 2) seeks to find out how the practice of VE impacts of project in Indonesia.

2 Related literature study

2.1 Design variables theory

In trying to meet client requirements and external constraints brought about by matters like statutory requirements, environmental factors and construction process among others, the architects have started to model their designs using parameters called design variables. The building design variables have been suggested as part of the solution by helping in the field of economics especially during modelling on the constraints of cost analysis and forecasts of the project under the concept of providing value for money products or VE. Therefore, from these design variables, design decisions are normally established, as they give solutions of challenges to do with form, time and economy for buildings [6]. According to [7], also it's these variables which form designers' forecasts, because they give the information for forecasting and determining whether value can be achieved at an acceptable cost [8]. The practice is so important in that, clients are able to get reliable cost advice to enable them assess and choose viability of a project when it is still early [9], by indicating how they impact on costs hence enable clients whether to incur that cost or not. The following have been established in previous studies:

2.1.1 Building plan shape

This is generally defined to stand for the spatial feature which defines the outline of the building. It impacts on the areas and sizes of the vertical members like walls their accompanying finishes, windows, partitions and the finishes used, etc, plus the perimeter details which include ground beams, fascias, and the eaves of roofs.

Over the years, studies focusing on the problems of plan shapes and construction cost have been on the increase, resulting in large number of publications. They have generally established that the cost of building construction increased due to increases in external walls, ceilings, floors or the roof [10-14]. Therefore, the various previous researchers all have concluded that, perimeter-to-floor ratio unit construction cost and overall project costs vary with plan shape complexity or irregularity. This being attributed to the fact that a particular shape of the building affects significantly costs of a great number of building elements like foundations, walls, building structure frame, finishes and decorations, roofing, electrical and mechanical services, which later alone also impact on costs of operating and maintaining the building hence overall life cycle costs affected.

2.1.2 Average storey height

This is defined as height from finished floor to next finished floor or from finished floor to ceiling or head room height (bungalow. Generally the following items may experience increases as a result of changes i.e. decrease or an increase in storey height: 1). The amount of heat energy may increase due to volume of building increasing plus the length which supply cables have to run it may also be increased. 2) Longer service and waste pipes may be required. 3) Chances of having expensive roof costs due to cost of hoisting are high. 4) The costs for circulation elements like staircases and lifts also increase as they are vertical elements whose quantity depend on headroom height. 5) Chances are high of cost increases in applying finishes and decorations due to very high heights of ceilings, sometimes calling for additional scaffolding.

2.1.3 Number of storey

This is much related to the average storey height of a building, however its self refers to how high or the number of levels in terms of vertical construction. In reference to this constructing of tall buildings, it generally affects four major building elements significantly because of the number of storeys of high-rise building i.e. frame structure construction, external wall (curtain walling in most case for office buildings), lift installation and fire protection (as in services), all mainly vertical elements of the building.

Previous studies like [15] pointed out that construction cost generally falls as the number of storeys increases. In the United States, for [16], on the elements comprising of eight office buildings from 8 to 75 storeys on a hypothetical site. It was found out that generally unit building cost tended to rise moderately with building height. Meanwhile for [18], he found out that, minus the lower floors, the unit office building cost was almost constant building height was varied.

In addition to the ones stated above, other designs identified in the previous studies over the years included: Mechanical and Electrical Services; Circulation Space; Grouping of Buildings; Column Spacing; Building Size; Sharing walls; Floor spans and Constructability.

In summary, with this discovery of these design tools called design variables in use during design modelling and modification, this was handy in current survey study of Indonesian construction industry. This was put to a research questionnaire survey to establish among the available design variables which were in use in Indonesia. This was highly viewed as basis for further development to solve problem of inefficient and poor designs identified by department PU.

2.2 Theory of construction costs

The term cost in general terms can be defined as the value of any currency given in to obtain a product, or service, to expend labour and use equipment and tools or to operate a business. For the case of construction it was defined by [17] in their book titled, 'Cost Modelling', as; the cost of the contract incurred by the client. Meanwhile, the source for construction costs were generally grouped into two basic sources according to [18] and [19], i.e. the owner-designer costs i.e. ones that come up as a result of, owner's requirements and the design, and the contractors' and subcontractors' costs, through the competitive market and their own organizations.

3 Methodology

This research study took an approach of exploring the literature of previous studies; and then later surveyed of the practices by consultants and views of clients in the building industry. It should be noted that, this research was developed as an extension of the previous studies like [11, 20], hence, it was mainly focused on enhancing on these previous studies, basing on their discoveries about design variables, helping to establish if it was the same conditions that exist within the Indonesian industry. In line with that, sample study area was Surakarta and areas around it.

Thirty participants (30), consisting of 23 design consultants and 7 clients were sampled, basing on Roscoe in his book Research Methods for Business [21] about determination of sample respondents. The research data collection tool used i.e. questionnaire was designed basing on objectives of the research, hence, it was divided into two sections, firstly being about the practice of design variables and the second one about value engineering in the industry. Meanwhile, the sampling technique applied was stratified purposeful sampling, which enabled to use information rich cases for in depth study depending on their characteristics [22].

The data collected from the questionnaire for easy analysis, was done using Microsoft excel. This stated with data validity and reliability test using descriptive analysis technique i.e. formula of Product Moment r*xy*, which was then compared with 5 % error standard table. This descriptive analysis statistics method, analyses data by using descriptions or illustrations of the data collected from the questionnaire [23].

Furthermore, under analysis it included the responses that were received from the survey participants being tabulated and analyzed individually. This was done with usage of the following formula as suggested by [24]:

$$\text{Relative importance Index} = \left\{\frac{\sum_{i=1}^{5} a_i\, x_i}{5\sum_{i=1}^{5} x_i}\ x\ 100\%\right\} \quad (1)$$

Where a_i = constant expressing the weight given to i;
x_i = variable expressing the frequency of each response for; i= 1, 2,3,4,5.

Finally, the findings were displayed by tabulation or using bar charts and pie charts, etc.

4 Results and discussion

The data reliability and validity test as seen in Table 1 obtained a product moment r_{xy} of 0.531 which lies in between 0.40 and 0.60 according to [21] guide, this meant that the connection between the responses given is enough.

Meanwhile, the test for correlation significance of product moment for N = 19 respondents, at a significance level of 5% shows that obtained r_{xy} 0.531 is greater than standard one from table i.e. r_t = 0.456, hence H_o is rejected and alternative H_1 is accepted.

Hence, the data collected was reliable as validity the test showed correlation between many answers obtained.

Table 1. Product moment r_{xy} computation.

N	r_{xy} Product Moment	Condition	Level of Connection	Product Moment r_t	Conclusion
19	0.531	0.40 -0.60	Connection is Enough	for 5% = 0.456	Ho rejected alternative H1 accepted

4.1 Building design variables used for modification in application of VE

On the building design variables as applied in decision making to modify designs so as to have value for money, the findings as shown in Fig. 1, were that in the Indonesian construction, building shape and its complexity is mostly as indicated by importance index of 83.2 and 82.1 respectively, this means design consultants in Indonesian like any other building industry ought to pay to much attention on the determinants of these parameters and their impact of any on costs. Therefore, this affirms findings in previous researches under review like [7, 25, 26] among others, who also said building shape variable with its complexity as the most influential design variables.

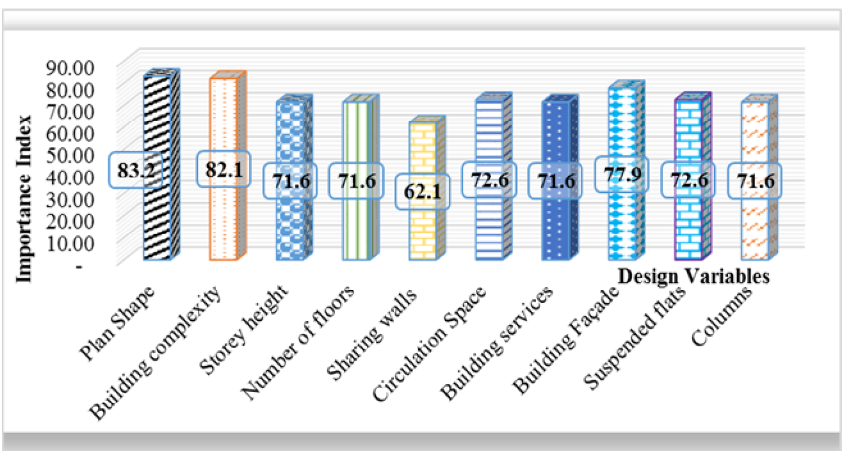

Fig. 1. Variables/parameters used for modifying designs.

This basically explains why these two parameters on construction costs i.e. plan shape layout and complexity are also becoming popular of recent, with the fact that many building projects, especially hotels and commercial buildings having a big portion of its their outer walls as glazed area or aluminium cladding. Hence, attention increasing, optimizing the shape. As it may go a long way in saving a great deal of these new expensive building materials.

4.1.1 Underling factors considered while adjusting designs

Thereafter, their factor considerations underlying application of some were also sought for. The findings obtained were as indicated in proceeding Tables 2 and 3 plus in Fig. 2.

For the building plan shape**,** however much as it may be and its complexity as seen in figure1, as the most common used design parameters during modelling and adjustments of designs to save costs, they did not work in isolation but had other factors influencing them i.e. which shape to use also depended on the following as seen in Table 2.

Table 2. Factors affecting choice of shape of a building.

	Factors	Importance Index	Ranking
A	Shape of building site	85,3	2
B	External characteristics of building membrane and building structure	86,3	1
C	Building Function	80,0	3
D	Symbolism	68,4	6
E	Structure in relation to light control	75,8	4
F	Cost saving of the building shape	72,9	5

As can be seen in Table 2, the building plan layout mainly depended on how external characteristics of a building membrane are and the shape of the available building site where it was to be constructed, as represented by importance index of 86.3 and 85.3 respectively. This means that the design architect should make through survey of the building site so as to make a design which is buildable on the available plan lay out and fits with in resultant shape membrane.

Meanwhile, with the underling factors for a particular building height, it's mainly ease of excess with in the building spaces and function use of a building by importance index of 82.1 and 80.1 respectively where most influential.

Table 3. Factors affecting choice of building height.

	Factor	Importance Index	Ranking
A	Natural wind circulation control	74,7	6
B	Easy of excess in the building	82,1	1
C	Considerations of standard height	75,8	5
D	Cost saving of height	76,8	4
E	Functional use of space	80,0	2
F	Cooling system to be used	77,9	3

As for the design variable of number of storeys, similar to building height it was established that also non-economic considerations were given more attention as indicated in Fig. 2, i.e. building rules and regulations followed by quality and type of soil at indices of 86.3 and 83.5 respectively were more determinant factors. Under this design variable, when it came aspect of economy i.e. to do with how the raise in height influences cost of construction, it was rated as number 3 with index of 61.1. In this case therefore, there is tendency of interplay of non-economic factors, such as regulations and tendency to follow standards, closely followed by economic factors.

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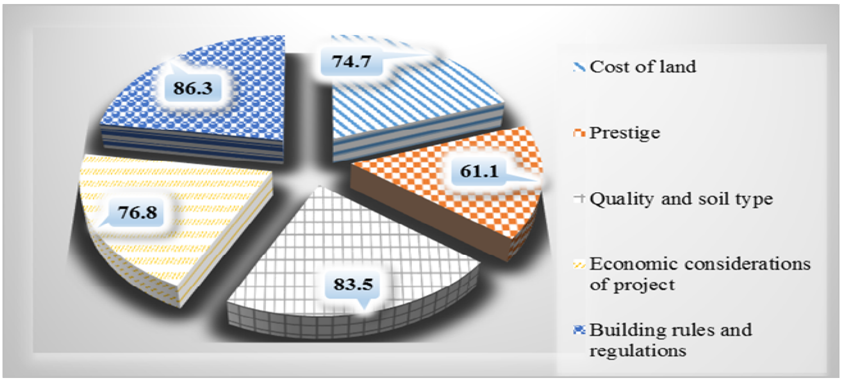

Fig. 2. Factors affecting choice for number of floors to use.

4.2 Consequences of applying design variables as part of VE practice

Basing on the study discoveries on consequences felt are as shown in figure 3 and 4, the concept of applying value engineering is the way to go, because also respondents surveyed agreed with previous researchers like [4] that this practice leads to outputting designs which are cost, and time effective as well as meeting quality specifications represented by 81.1 importance index. Secondly, design cost optimization can be attained with use of this approach during designing represented by index of 80.0.

Meanwhile, on the negative note once this practice is not applied with the growing complexities in designs, it could impact in a way that leads to material wastages and loss of confidence and consequently customers for the design consultant involved as shown by severity index of 80.0 each.

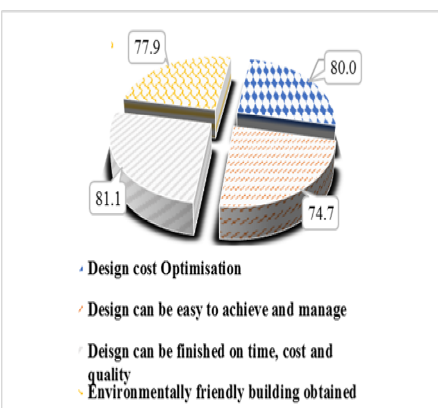

Fig. 3. Positive benefits due use of design variables.

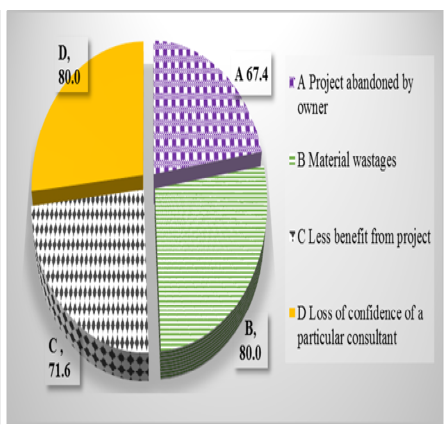

Fig. 4. Negative consequences due to over designing.

5 Conclusion

i) The top most five design variables often used by the architect consultants to modify building designs to meet client demands on costs identified in the survey were; building plane shape, building complexity, building façade, circulation space, and suspended flats.

ii) On the other hand the decision on which building shape plan to use, as the most common design variable, depended on a number of factors, like external characteristics of building membrane, building site shape.
iii) Value engineering as an approach which when used by building practitioners would increase efficiency and reduce unnecessary costs during designs, by delivering design plans that can be finished on time, cost and on quality, hence enabling smooth delivery of projects and profitability for all parties involved . This would solve challenge of PU which led to issuance of by law*, Nomor: 06/PRT/M/2008*

Lastly, the author recommends further research on the topic focusing on establishing to what extent each of the design variables influence the building costs of any project.

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