Investigating The Impact Of Architectural Design Variables On Reducing Construction Costs And Providing Solutions In Value Engineering

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Abstract: Accurate cost estimation during the design phase of a project is crucial for ensuring the quality of architectural design and the ability to start and complete construction on schedule. To address the challenges related to performance, form, time, and economy in building design, this study aims to identify inefficient elements or costs resulting from unnecessary construction by utilizing value engineering techniques. To achieve this objective, a list of main design variables that impact construction costs was compiled through library research on the design process. These variables include the shape and complexity of the design, building size, building height, number of floors, building coverage, circulation space, integration, percentage of wall, mechanical and electrical services, column spacing, floor spacing, and compatibility. Subsequently, interviews and case samples were used to explore these variables using a Likert scale. The collected data was then subjected to statistical analysis using SPSS software, including a one-sample t-test to determine the accuracy of the variables and Friedman's test to rank them. The research findings revealed that the shape and complexity of the design and the height of the building are among the most critical variables posing threats to the quality and cost of architectural projects.

Keywords: architectural design variables, reducing construction costs, value engineering

1- Introduction

The success or failure of a construction project depends on the reliability of the cost estimates prepared, especially in the early stages of its development. In recent studies in the field of design economics, it can be seen that the architectural design of the building has a great impact on the total costs of the building's life cycle and a high capability in applying value engineering processes. [1]

Cost studies are usually done in the first stage of project design and when the architect considers different design options. At this stage, studies are usually done using approximate quantities and cost models will be most effective. [2]

In this process, the architect's decisions may be overshadowed by cost constraints, so he must be aware of the approximate cost limits for each design and specification choice he makes. [3] (Ston, 1983)

Value engineering is a management solution and a creative perspective that seeks to find the best functional balance between cost, validity and reliability in products or projects using a device approach. [4] (Zimmerman, 1982)

On the other hand, architectural design is a repetitive process through which a set of requirements such as physical, aesthetic, functional, etc. are creatively changed and designed as a result. In addition, design decisions are solutions to problems of function, form, and economy for construction. [5] (Pena and Parshell, 2001)

In an effort to find solutions to all the constraints encountered during the design process, the design team always tries to consider its settings in a wide range of issues. Especially how the best building project can be done without compromising performance and quality. Evaluating different design options provides better solutions to achieve a specific project. [6] (Ashworth, 2004) [Economic studies have led to new phenomena such as the identification of design variables, which have generally been considered as an effort to decide or shape the design of a building, in projects where design parameters affect costs. Most of the decisions made are usually organized as a list of alternative design proposals and quality specifications. Therefore, in one or more ways to inform about possible financial obligations before doing extensive work. (Sahid, 2017) [7] As a result, researchers in the field of design process have identified a large number of design variables as models that include construction costs. They have also stated that knowing the design variables helps to reduce unnecessary costs as one of the valuation methods. Therefore, the need for more studies in this field is very necessary. They include the following:

the shape of the plan; building size; circulation space; grouping of buildings; The height of the floor and the total height or the number of floors of the building. [6]

In this research, we aim to identify the design parameters that describe the form of the building, and if they are realized in the design of architectural engineering projects, the quality of the designs and consequently the value of the projects will increase.

2- Research background

The first Persian sources of value engineering were compiled by Mahab Quds Company and the country's

planning management organization in 1379. Based on the results obtained from the research conducted by Ahad Nazari, Jamali Harsini and Goldost Joybari under the title "Application of value engineering in improving the design of construction projects" in 1389 and Saleh Mohammadi's research in 1387 under the title "Necessity of applying value studies in the design phase" we found that the design phase has the best capacity for value studies. [1] (Mohammadi, 1389) It is also the only project in the field of design economy and key decisions that are made by architects in the early stages. In 1382, with the title "reducing the costs of construction and architectural design of residential buildings" with the aim of investigating the factors affecting the cost of construction of residential buildings, it was carried out by Jaleh Talebi. [2] (Talebi, 1382) General design variables have been identified by various studies of many authors and the relationship between different building design variables and construction cost has been investigated. Keskolas and Cohen 1 argue that the construction cost is a function of many design variables, which include the location of the building, price index, building type, building height, building quality, and construction technology. [8]

Brandon identifies the shape of the design as the main variable. The number of floors, the average height of the building and the complexity of the design are suitable descriptions of the building form. (Brandon, 1978) [9]

Swaffield and Pasquier identified 3% of wall thickness and overall building height as descriptors that can be useful in determining mechanical and electrical service costs. [10] (Swaffield and Pasquire, 1996) Seeley 4 showed that for comparing buildings with equal floor area, reducing the ratio of wall area to floor area is suggested for more cost efficiency. And although the circle shape has the smallest perimeter, it is usually not the cheapest. (Seeley, 1996) [11]

Frey and Brandon suggest that the measurement factor be used in setting the cost estimate. The ratio of the wall area to the floor area, which is perhaps the most famous and familiar efficiency coefficient, but is only used to compare buildings with equal floor area. [12] (Ferry and Brandon, 1999) [Then Chao5 critically pointed out that most of the existing design shape indices are based on design geometry without reference to experimental data. He proposed a new approach to convert any shape into a square that has an area equal to that shape using Cox's box cost model estimation. His results show that it is better to create a regression model that is considered as a basis for determining the efficiency of the shape. However, the use of different types of projects with very diverse features in terms of size and specifications is the shortcoming of this research. [13] (Chau, 1999, p17) [Ebrahim used regression analysis to develop predictive models to evaluate the effect of changes in building design on unit construction cost. However, unlike Chao's results, Ibrahim's results confirmed the ability to predict the shape indicators of the existing plan and use some building parameters, especially the building perimeter and floor area and the ratio of wall area to floor area. [14] (Ibrahim, 2004) [He also argued that the size of the building is also an important variable that determines the cost of construction. (Ibrahim, 2003) [15] (Table 1) the variables are shown along with some of the authors who have been studied:

Table 1: Identification of building design variables and previous authors (source: research results)

refrence	Design variables
Seely 1983, Ashworth [7] 6 [2004], Keskolas and Cohen [8] 1974, Seely [11] 1996, Studman et al .Brandon [12] 1999, Zima 2008, Zima and Plebankevich 2012	The shape and complexity of the plan
Sili 1997	The size of the building
Sili 1996, Ebrahim 2003	building height
Flanagan and Norman 1999, Clarke and Kingston 1930, Stone [3] 1963, Sealy 1996, Ministry of Environment Thomson 1966, Frey and Brandon 1991, Esculler 1986, Trigenza ,1971 ,1972, Stirrett 1972, Tan 1999 ‘	Number of floors
Sili1997	Covering the building
Sili [11] 1996	circulation space
Ashworth 1994, Abuza 2010, Sealy 1996	to be integrated

3- Literature of the subject

1-3- Theory of construction costs

The term cost in general can be defined as all the amounts that must be paid during the life of a product, project or service, including acquisition, production, operation, maintenance and access costs from the beginning of the project to the end of the operation period. Most of these costs are hidden and are not paid attention to. In his book entitled "Cost Models", Skitmore 8 defined the cost as the contract borne by the customer. [16 (Skitmore and Marston, 1999)] Design economy means reducing costs without reducing standards and qualities. The key to influencing project construction costs is in the hands of the owner or contractor, because any decision made at the beginning of a project's life cycle has a greater impact than decisions made at later stages of the project. [17] (Hendrickson, Kress 1388) The features of the design, the technical specifications of the building and its execution plans in different construction systems and methods are the basis of estimating the cost of the building. To calculate the amount of materials used, the number of workers and technical staff, values are proposed, all of which are a function of the architectural design of the building.

2-3- The theory of design variables

Building costs are affected by various factors, some of them are interrelated. It is essential that architectural engineers are fully aware of the consequences of changes in shape, size, floor height, overall height, erosion and other building characteristics. [11] (Seeley, 1996) [Architects have started to model using parameters called design variables in an effort to comply with customer requirements and external restrictions caused by issues such as legal requirements, environmental factors and the construction process. Building design variables with help in the field of economics, especially when modeling the constraints of cost analysis and project forecasts under the concept of valuation for the cost of products or value engineering, have been proposed as part of the solution. They are also a basis for decision-making, as a solution to the problems of performance, form, time and economy for buildings. [5] (Pena and Parshell, 2001) [Parameters of a building that can vary between designs while offering the same quality and location. Morphological factors that affect the cost of construction. In fact, they form the form of designers. [18] (Ashworth and Skitmore, 1983) [provide information to predict and determine whether value is obtained at an acceptable cost. [19] (Morton and Jaggar, 1995) [This practice is very important for clients to be able to show reliable costs to evaluate and project viability in early times and how they affect the cost. [20] Fortune and Lees, 1944) [Swafield and Pasquier believe that a cost modeling system that includes the performance of the building, the level of services provided, and the parameters that describe the building form, improves the accuracy of the initial cost consultation of construction services. [21] (Swaffield and Pasquire, 1995)

3-3- Effects of design variables on building cost 1-3-3- Building plan

The shape of the building plan has a major impact on the dimensions of its external vertical elements such as walls, windows and external doors, as well as internal vertical elements such as separators and elements of the heating and piping system, as well as on the surrounding details, such as plinths, skirting boards, It has roof ridges and... (Tables 2, 3 and 4). In addition, the skeleton of the building and its vertical and horizontal structural elements are also affected by the shape of the plan. The dimensions of all the mentioned elements affect the cost of the building. The closer the length and width of the rectangle are to each other, the smaller the perimeter is, in other words, the closer the rectangle is to the square, the smaller the perimeter. Using the circle shape as the general form of the building has features that increase the cost. The reasons for the high cost of the circular shape include: creating problems for the contractor in the implementation of the building; high cost of achieving curved surfaces; Standard joints that are produced based on right angles, for example in woodwork, curved surfaces or corners with acute angles create problems and inefficient use of site space. [19] (Morton and Jaggar, 1995) [Seeley compares two buildings of rectangular and irregular shapes, each of which has a similar floor. In the building with an irregular shape, the cost of drilling increases by about 20% and the cost of drainage increases by about 25%. Due to the complexity of the work, brickwork and roofing will cost more. (Seeley, 1996) [11]

2-3-3- Building height and number of floors

A change in the height of the floor causes a change in the cost of the building without changing the ground level, and when there is a wide variation in the height of the floor between the building, it causes problems in the approximate method of estimation, and between the main items of the building that are affected by the variation in The height of the floor is placed, a comparison is made. The height of the floor (height of the floor to the floor) is determined according to the needs of the users of the building. A height higher than what is necessary to provide comfort conditions causes additional costs such as large machinery or equipment. The height of the floor affects the cost of the vertical elements of the building, both internal and external, it increases the cost of the structure, and due to the increase in the volume of the spaces, it affects the cost of facilities, especially heating. In a building with high floors, the price per square meter of its floor area, if other factors are equal, is more than a building with a lower floor height. Also, the ratio of the outer shell to the floor area will be higher. [22] (Bathurst and Butter, 1980) [Tall buildings should never be considered cost-effective unless the land price savings achieved by occupying a smaller site can offset the significant additional costs of construction. slow The reason why two- or three-story buildings are relatively economical compared to one-story buildings is that a roof and a series of foundations respond to two or three times the substructure and the walls and columns carry the additional load without or with little change. .

3-3-3- Covering the building

The protrusions and depressions in the facade of the building affect the value of its environment. Although this effect may be insignificant for a single unit, it is significant and should be considered in mass construction

projects where the construction of a large number of buildings is desired. (Brandon, 1978) [9]

4-3-3- Separating walls

The area of the separating walls is most affected by changes in the shape of the plan. The nature of the effect depends to a large extent on the type of building in question and should be considered independently. [12]Ferry and Brandon, 1999

5-3-3- Circulation space

One of the important design goals is to eliminate unnecessary spaces and this can increase cost efficiency. Interior spaces in most buildings are divided into main functions, circulation spaces, and other auxiliary spaces such as facility rooms and warehouses. Although these spaces are necessary for the proper functioning of the building, but by removing some extra spaces, the cost efficiency may increase. [19] (Morton and Jaggar, 1995) [The effect that the circulation space has on the costs of the whole building is that less space is spent on design and it is more economical and It is possible to reduce the costs related to heating, cooling and maintenance with its optimal design.

4-3- Value engineering

Value methodology is a systematic approach to improve projects, products and processes. Value methodology is used to analyze factory processes and products, design, build projects, and commercial and administrative processes. Value methodology helps balance essential functions, efficiency, quality, customer satisfaction, cost, and resources needed to meet those needs. The right balance increases the value of the project. [23] (SAVE International, 2001) [The concept of the word "value" in value engineering is very prominent and basic, it requires understanding concepts. "Price", "quality", "function" and "cost" are among the most important concepts. Based on the specific needs of the project, the definition of value can include: functional development, flexibility, expandability, product maintenance, or even beauty along with cost reduction. [24] (Value Engineering Guide in Design and Construction, 2010) Every construction project has four stages of feasibility, design, construction and operation. The design stage is about 1% of the total costs of each project and can affect up to 70% of the costs of the building's lifetime. Always to meet the needs of the employer, consultants or designers can provide various designs, and it can impose a lot of cost on the design. In order to help designers, we identified the variables that potentially have the most value saving potential.

4- Research Method

The purpose of the present research is to conduct a comprehensive review of the studies conducted in the field of architectural design parameters, in order to identify and then rank the most important factors affecting the reduction of construction costs with the value engineering approach. This research is practical in terms of purpose, so that while presenting how to use design variables in the building, it tries to reduce construction costs. Also, according to the method of data collection, the present research is a descriptive survey research. By means of purposeful sampling and a questionnaire, which was given to 10 people active in construction projects in Tehran and having expertise in project management, design, civil engineering. To achieve the research goals, first, by using library studies and literature review, the main variables of architectural design and the background factors of measurement have been extracted. And in order to statistically check and verify these variables with the opinion of the target community, a questionnaire was used. The graphic status shows the expertise of the experts. The opinions of relevant experts and professors were used to check the validity of the questionnaire. In order to ensure the evaluation of different design options based on the mentioned variables, we examined case projects.

Descriptive and inferential statistics were also used to analyze the obtained data. Extracting relevant results using SPSS software version 19, so that descriptive analysis was done by calculating the mean and standard deviation of the data and inferential analysis was done by t-test and Friedman's test. A one-sample t-test was used to compare the theoretical mean (theoretical mean considered 3) and the experimental mean (mean Likert scores).

5- Brief Introduction of Case Examples

The projects studied in this research have been successfully carried out by the consulting engineers of Crit Kara Company, with the value engineering approach. We evaluated the ideas and suggestions that were recommended to improve the efficiency and quality of the plans in the final reports. The description of the details is not within the scope of this article.

6- Analysis of findings

6-1- Kolmogorov-Smirnov test results:

The result of this test shows the normal distribution of all research variables (significance level greater than 0.05), therefore, parametric tests are used to test variables and for inferential analysis.

6-2- The first hypothesis

In order to investigate the first hypothesis of the research (it seems that the factors that show the characteristics of the project have the most influence on the selection of the initial cost estimation method and the design variables that have a greater effect on the cost are not given enough attention.) was used from Amon T.Tek sample and Friedman.

1-2-6-one-sample t-test of factors affecting the cost estimation method from the point of view of experts

The results of the single-sample t test of this hypothesis show that the significance level obtained for the variables of project size, owner and available information is less than the alpha error level of 0.05 and the t statistic is more than 1.96, so at the confidence level of 99 Percentage, there is a positive significant difference between the mean of variables of project size, owner and available information and the mean value (3) Therefore, these 3 variables were confirmed as effective factors on the cost estimation method.

2-2-6-Friedman's test of factors affecting the cost estimation method from the point of view of experts

Also, based on Friedman's test, it was found that the obtained significance level is equal to zero and is less than the alpha error level of 0.05. The variables "owner" with an average rating of 2.15, "project size" with an average rating of 1.95 and "available information" with an average rating of 1.90 have the highest importance and there is no significant difference between them.

6-3- The second hypothesis

To investigate the second hypothesis (variables of architectural design have a significant effect on cost reduction) the mean and Friedman descriptive test of two target populations were used.

1-3-6- Descriptive study of design variables in case examples

According to the obtained results (Tables 14, 15, 16), the variable shape, height and circulation space of the building have a larger average and equal to the estimated average value. According to the Friedman test, "shape and complexity of the plan" with an average rating of 2.92, "circulation space of the building" with an average rating of 1.92 and "building height" with an average rating of 1.17 have the highest importance and in the first priorities to They are third.

Finally, based on the results obtained from among these 10 variables, "shape and complexity of the plan" and "building height" in both target communities (case sample and experts) are the most effective variables with more priority in this field and can be It should be noted that the variable "combination" has the least importance.

6-4- Background factors affecting architects' decisions about the shape and complexity of the design

To investigate the background factors affecting architects' decisions regarding the most important variable, "design shape and complexity" and how close they are to saving in projects. A sample t-test of two target communities was used.

1-4-6-one-sample t-test of building plan shape variables in case samples

The results of the single-sample t test show that the significance level obtained for the variables of site shape and building performance is less than the alpha error level of 0.05 and the t statistic is greater than 1.96, so at the 99% confidence level, the difference There is a positive significance between the mean of "site shape" and "building performance" and the mean value (3). Therefore, these 2 variables were confirmed as background factors affecting architects' decisions about the design's shape and complexity. Also, since the average of the "building performance" variable is equal to 5, so its standard deviation is zero, and the sample TT statistic is not applicable.

This variable has a 100% influence on the decision making regarding building design variables (plan shape).

7- Discussion and conclusion

In general, the findings of the research indicate that from the point of view of experts, there is a significant difference between the variables of project size, owner and available information, and the results of the t-test also confirm their influence on the selection of the initial cost estimation method. Meanwhile, the design variables have a greater effect on the cost and are not given enough attention.

In an effort to find solutions to problems of building performance, form and economy, we tried to consider building plans in a wide range of options called design variables. The variables of design shape and complexity, building size, building height, number of floors, building cover, circulation space, integration, wall percentage, mechanical and electrical services (facilities) and structure system were identified through deep investigation and the relationship between these variables and construction cost was evaluated. .

In order to statistically check and confirm these variables from the point of view of experts, and also to ensure the evaluation of different design options based on the mentioned variables, we examined the proposed ideas to improve the efficiency and quality of the projects studied by value engineering. The most changes that were made in these projects were ranked among them using Friedman's test. From the comparison of the average opinions of experts and the examination of case examples, it can be seen that the variables "design shape and complexity" and "building height" are more prioritized.

Due to the fact that today, the decisions of architects during the design process are overshadowed by limitations. Therefore, the background factors affecting their decisions about the most important variable, the shape and complexity of the plan and how close they are to saving in the projects were investigated. According to the comparison of the t-test in the two target communities, the factors of "site shape" and "performance" in case examples and from the point of view of experts, in addition to these two variables, "shell features" and "requirements" also influence the decision of the plan shape. .

It is important to mention that almost all experts in the field of value engineering know that the best time to apply the techniques of this method is in the early stages of design and before entering the design phase. However, considering the massive amount of projects currently being implemented in the country, as well as the high capabilities of the country's architects and the points mentioned in the research, it seems that the architectural design parameters can be a basis for making decisions in this field.

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