Value engineering application in a high rise building (a case study in Bali)

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Abstract. Finding affordable alternatives material to replace the initial design of the architecture work of a commercial high rise building project without reducing the value of the material itself. Then analysing the cost saved from applying the value engineering in the architecture work of a high rise building. Calculation through the value engineering process was conducted. A commercial high rise building in Bali was chosen as a case study to implement the value engineering process in the design stage. The value engineering stages included calculating the cost/worth function, analysing through Function Analysis System Technique (FAST), innovation and creativity stage, evaluation of the life cycle cost, decision analysis and last the decision making. The research found that by applying value engineering through several items of work in a commercial high rise building it could save up to up to 8% of the total cost of the architecture work. The architecture work that was analysed through value engineering were the wall work, the door work, the floor work and the sanitary work. These were found to be the most effecting result from the Pareto calculation. The application of value engineering is this research was only done in one commercial high rise building in Bali. The work analysed was also only the architecture work. Therefore other types of construction project might result in different value of cost saving. This research identifies the cost saved through the application of value engineering in a commercial high rise building in Bali, which emphasizes on high quality materials in the architecture work. This research will contribute to the study literature of value engineering with a case study of commercial high rise building.

Keywords: value engineering, architecture work, cost saving, high rise building, Bali, construction

1. Introduction

In building a construction project, controlling the cost of the project is one of the important process in project management. One of the technique used is through the process of value engineering (VE) [1]. VE is a process to help make decision based on a systematic multidiscipline and measured by analyzing the function to achieve the best value of a project. The best value of a project is achieved by defining the functions needed to achieve the target value desired. VE also provides those function with the optimum cost, quality consistency and the required performance [2].
The ability of VE in increasing the construction industry’s competitiveness in several countries is due to the fact that there are a lot of benefits that VE has brought to construction projects. The ability of VE to help make decision in the design phase is one of its advantages so that the cost saving result is more optimal [3]. The architecture work in a project cost around 28% – 43% of the total cost of the project [4]. Hence VE can be applied to the architecture work of a construction project to obtain the optimal cost.

In building construction project it is found that there is a lot of over spent budget due to the over utilized materials and completion of work that exceed the designed schedule [5]. VE can be used to overcome those problems to minimized cost without reducing the value and quality of the substitute item. Therefore the total cost of the project can be more efficient. The earlier the application of VE in the stages of construction, the more optimum the result of the cost saving [6].

2. Overview of the Application of Value Engineering

Value engineering (VE) was applied in the Bregana-Zagreb-Dubrovnik Motorway construction in Croatia where the cost saved was $43,000,000 and the time saved was up to 12 months [7]. In the Widya Mandala Catholic University project in Pakuwon City, Indonesia, the cost saved through VE analysis was 15.79% from the total cost of the project [8].

The Syaloom Karombasan GMIM Church project in Manado, Indonesia, applied the VE analysis in the wall work and ceiling work. The cost saved through the VE analysis was 24.5% from the initial cost of the project [5]. A mechanical & electrical work in a project was analysis through VE and obtain a cost saving result of 10.8% from the total cost of the project, in assumption that the life span of the building is 10 years [9]. The obstacle in applying VE in Indonesia is that there is still little knowledge on the concept of VE, especially in using the Function Analysis System Technique (FAST) diagram [10].

3. Value Engineering

Value engineering is a value methodology application in a project or services that is design or concept to achieve added value [1]. There are 3 basic elements needed to measure a value those are the function, quality and cost [11]. The relation between the elements can be seen from the equation 1.

\[
\text{Value} = \frac{\text{Function} + \text{Quality}}{\text{Cost}}
\]

The following situation are the alternatives that can be performed in value engineering based on the relation between function, quality, and cost:

- Decreasing the cost, but the function and quality is maintained;
- Increasing the value or quality or both but maintaining the cost;
- Increasing the function and quality, and also reducing the cost;
- Increasing the function and quality by increasing the cost.

3.1. Value

In value engineering, the economic value is priorities and comprises of 4 categories as followed:

- Cost value which is the total cost to produce an item, comprises of the total amount of workers, materials, equipment and overhead;
- Exchange value is the worth that is exchange. Worth is a term used for buyer that is motivated to buy a product. This value is based on the market value at a specific time;
- Esteem value is a value that cause the owner or user to be willing to pay for a prestige. This value is related to the needs and wants of the user;
3.2. Function

Function is the main element in value engineering (VE) analysis. The purpose of VE is to achieve the functions needed from a system with the total efficient cost. The functions in VE is important because the function is the main object linking it to the cost. Function can be divided into 2 categories, which are:

- Basic function is the main reason a specific system existed, a basis or reason for the existence of a product and has a use value;
- Secondary function is a function not directly used to accommodate the basic needs, however needed to support the basic needs [1].

3.3. Cost

Cost is the sum of all of the income and outcome made to develop and produce a project/product. The income of a project/product always analyses the effect of the decision made towards the quality, reliability and maintenance of the project/product because this will affect the cost of the project/product. Based on the relation between function, quality and cost, one of the reason of a low value is that there is unnecessary cost [11].

3.4. Law of Pareto

Law of Pareto of the 80/20 law is found by an Italian economist, Vilfredo Pareto. Pareto stated that 80% outcome is the result from 20% income. 80% reaction is caused from 20% action, or 80% result comes from 20% effort. Pareto analysis is the method used to analyze the highest cost of the item of work which has the potential to be analyzed in value engineering. Only the cumulative cost of 80% will be further analyzed through value engineering.

3.5. Cost-to-Worth (C/W)

Cost-to-worth is the basic theory of value which is the relation between cost and worth [1]. The ratio of cost-to-worth is obtain from the following equation:

\[
\text{Cost to Worth} = \frac{\text{Cost}}{\text{Worth}}
\]

The high ratio of cost-to-worth ratio indicates the area where cost saving in a system can be high. A cost-to-worth ratio larger than 1 indicate a potential of cost saving [13].

3.6. Life Cycle Cost (LCC)

The LCC is the overall cost starting from the planning phase until the facility is utilised [11]. The element in an LCC calculation is the investment cost, financing cost, operational cost, maintenance cost, replacement/repair cost, tax and salvage value. In calculating the LCC, all of the values of each elements are converted into the present value. LCC can be calculated using the following equation:

\[
\text{Life Cycle Cost (LCC)} = (\text{Initial Cost} + \text{Replacement/Repair Cost} + \text{Maintenance Cost} + \text{Operational Cost} + \text{Salvage})
\]
3.7. Function Analysis System Technique (FAST) Diagram

FAST diagram is a diagram related to all of the function in a system of component which shows the specific relation between each function and clearly show what the system are able to do. FAST diagram is needed to model a function to determine the area that needs to be improved. Improvement of value can create innovation because creative ideas are made during this process. Question of “HOW-WHY” need to be asked when developing a FAST diagram [1].

4. Methodology

The state of the art of this research is that this research is based on a case study on a 5 stars hotel project located in Bali. Only the architecture work will be analyzed through the value engineering analysis. The methodology of the research can be seen in Figure 1.

Figure 1. Methodology Study of the Research
5. Application of Value Engineering

The analysis in each phases of the value engineering process describe in Figure is explained below [11]:

5.1. Information phase

The information phase is the first step in value engineering. Information such as project design, project background, obstacles in the project and project cost is obtain.

The architecture work of the object study, which is a 5 stars hotel project cost 40% of the total cost of the hotel. Based on the law of Pareto which stated that only cumulative cost up to 80% will be further analyzed, the works that can be further analyzed using value engineering is the wall work, door work, floor work and the sanitary work. The details of the architecture budget of the hotel and the Pareto analysis can be seen in Table 1.

| Table 1. Recapitulation of the Hotel’s Architecture Budget and Pareto Analysis |
|--------------------------|----------------|----------------|-----------------|-----------------|----------------|
| No. | Detail Work | Budget | Percentage Cost | Cumulative Percentage |
|-----|-------------|--------|-----------------|-----------------------|
| 1   | Wall Work   | Rp 10,616,900,040.00 | 27% | 27% |
| 2   | Door Work   | Rp 9,589,460,100.00 | 25% | 52% |
| 3   | Floor Work  | Rp 6,063,009,700.00 | 16% | 68% |
| 4   | Sanitary Work | Rp 3,955,560,000.00 | 11% | 79% |
| 5   | Equipment Work and etc. | Rp 3,834,051,000.00 | 10% | 88% |
| 6   | Paint Work  | Rp 2,689,147,025.00 | 7% | 95% |
| 7   | Ceiling Work | Rp 1,780,600,250.00 | 5% | 100% |
| TOTAL |                  | Rp 38,528,728,115.00 |                  | 100.00% |

A second Pareto analysis is done to each of the work identified in the first Pareto analysis. The sub-works in the wall work, door work, floor work and sanitary work is analyze. The recapitulation of the second Pareto analysis can be seen in Table 2.

| Table 2. The Pareto Analysis of Sub-Works |
|--------------------------|----------------|----------------|-----------------|-----------------|----------------|
| No. | Detail Work | Cumulative Percentage | No. | Detail Work | Cumulative Percentage |
|-----|-------------|-----------------------|-----|-------------|-----------------------|
|     | Wall Work   |                       |     | Floor Work  |                       |
| 1   | Inner brick work | 39% | 1   | Parquet floor work | 40% |
| 2   | Inner plastering work | 69% | 2   | 60x60 ceramic floor work | 73% |
| 3   | Toilet wall ceramics work | 93% | 3   | Skirting parquet work | 83% |
|     | Door Work   |                       |     | Sanitary Work |                       |
| 1   | Glass of the sliding door work | 38% | 1   | Fixed Shower Head | 20% |
| 2   | Glass of the single door work | 66% | 2   | Closet | 38% |
| 3   | Glass wall work | 78% | 3   | Single Lever Bath & Shower | 52% |
|     | Floor Work  |                       |     |               |                       |
| 1   | Parquet floor work | 40% | 5   | Double Towel bar | 71% |
| 2   | 60x60 ceramic floor work | 73% | 6   | Wastafel | 79% |
| 3   | Skirting parquet work | 83% |     |               |                       |
5.2. Function analysing phase

The function of each element of work in a construction project is analyzed to find out which work have the highest potential to contribute the most to the total cost of the project. In figuring out which item of work has the highest potential in contributing the most to the total cost of the project, a cost-to-worth analysis need to be carried out for each item of work. A value of C/W > 1 means that the item of work can be analyzed through value engineering. The C/W result of each item of work can be seen in Table 3. Based on Table 3, the 4 items of work identified earlier through the Pareto analysis also has the result of C/W larger than 1. This means that those item of works that can be analyze through value engineering.

| No. | Detail Work      | C/W |
|-----|------------------|-----|
| 1   | Wall Work        | 2.33|
| 2   | Door Work        | 1.07|
| 3   | Floor Work       | 1.26|
| 4   | Sanitary Work    | 1.28|

A FAST diagram is made to identify the basic function and the secondary function of the item of work analyzed through VE. The FAST diagram for this research can be seen in Figure 2.

5.3. Creativity phase

A couple of alternative ideas are proposed in this step to substitute to the original design. The alternative material proposed need to accommodate the function identified through the FAST diagram in Figure 2. The points that to be considered in choosing an alternative are:

- Initial cost;
- Maintenance cost;
- Quality [1].
3 alternatives materials are chosen to be evaluated for each of the work item. The alternative chosen in regard to the original design has the same quality but some have different dimension or different shape.

5.4. Evaluation phase

The alternative ideas chosen will be further analyzed through life cycle cost (LCC) analyses to calculate the value of money of the chosen alternative ideas based on the estimated interest rate and the duration of the building age. In LCC analyses the total cost of the project through its life span and the amount of cost saved due to the alternative material is calculated.

The LCC analysis was done up to 35 years, assuming that the life span of the hotel is 35 years. There are several components that needs to be calculated in the LCC analysis as followed:

- **Initial cost**
  
  The initial cost of the item of work is calculated by calculating the unit price analysis based on the Ministerial of Public Work Regulation No. 11/2013. The unit price will then be multiplied the volume of the item of sub-work according to the shop drawing given from the owner.

- **Replacement cost**
  
  The maintenance and replacement plan of the material/component of a building is based on the maintenance and replacement plan from Kirk (1995) [14]. The replacement cost is then converted in the form of present value.

- **Salvage cost**
  
  The salvage value of the material after 35 years of its life span.

- **Operational cost and maintenance cost**
  
  The cost of operational and maintenance is 10% from the initial cost based on the Property, Operation, Maintenance, and Energy Cost (POMEC) [15].

- **Life cycle present worth saving**
  
  The present value worth saved of the alternative material used for each item of work.

The percentage cost saved from the LCC analysis for each alternative material can be seen in Table 4.

| No. | Detail Work                  | Saving (%) | Alternative 1 | Alternative 2 | Alternative 3 |
|-----|------------------------------|------------|---------------|---------------|---------------|
|     |                              |            |               |               |               |
|     | Wall Work                     |            |               |               |               |
| 1   | Inner brick work              | 7          | 10            | 13            |               |
| 2   | Inner plastering work         | -1         | 0,354         | 0,149         |               |
| 3   | Toilet wall ceramics work     | 9          | 18            | 23            |               |
|     | Door Work                     |            |               |               |               |
| 1   | Glass of the sliding door work| 11         | 9             | 13            |               |
| 2   | Glass of the single door work | 3          | 2             | 6             |               |
| 3   | Glass wall work               | 15         | 11            | 19            |               |
|     | Floor Work                    |            |               |               |               |
| 1   | Parquet floor work            | 1          | 3,3           | 4,3           |               |
| 2   | 60x60 ceramic floor work      | 3          | 9             | 12            |               |
| 3   | Skirting parquet work         | 4          | 8             | 16            |               |

Sanitary Work
5.5. Decision analysing phase

Process in analyzing the alternative ideas in the aim to choose the alternative ideas that have the potential to save cost in the project. The alternative material which contribute to the highest cost saving based on the life cycle cost analysis will be chosen as the alternative material to substitute the original design. Based on Table IV, it can be seen which material result in the highest percentage of cost saving.

5.6. Decision making phase

A decision is made to which alternative ideas saved more cost to substitute the original design after a process of analyses. The alternative chosen is the alternative material which has the highest percentage of cost saving. The result of the chosen alternative can be seen in Table 5.

Table 5. The Alternative Material Chosen

| No. | Detail Work                   | Alternative Chosen |
|-----|-------------------------------|--------------------|
|     |                               |                    |
| Wall Work                             |                    |
| 1   | Inner brick work             | Alternative 3      |
| 2   | Inner plastering work        | Alternative 2      |
| 3   | Toilet wall ceramics work    | Alternative 3      |
| Door Work                             |                    |
| 1   | Glass of the sliding door work | Alternative 3    |
| 2   | Glass of the single door work | Alternative 3    |
| 3   | Glass wall work              | Alternative 3      |
| Floor Work                            |                    |
| 1   | Parquet floor work           | Alternative 3      |
| 2   | 60x60 ceramic floor work     | Alternative 3      |
| 3   | Skirting parquet work        | Alternative 3      |
| Sanitary Work                         |                    |
| 1   | Fixed Shower Head            | Alternative 3      |
| 2   | Closet                       | Alternative 1      |
| 3   | Single Lower Bath & Shower   | Alternative 2      |
| 4   | Hand Shower                  | Alternative 2      |
| 5   | Double Tower bar             | Alternative 2      |
| 6   | Wastafel                     | Alternative 3      |
6. Conclusion

Based on the value engineering analysis on the architecture work in the hotel in Bali, it can be concluded that the items of work that can be optimized from the value engineering analysis are wall work, door work, floor work and the sanitary work. Through the value engineering analysis from those items of work identified, the percentage of cost saved is 8% from the architecture work. This saves up to Rp 3,082,298,249.00 from the total cost of the project. The alternative material chosen to substitute the original design is the one that contribute the highest in saving the cost of the each item of work.

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