Structure value engineering using ETABS for midrise building

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Abstract. Value Engineering is a creative, planned, structured approach and has the goal of identifying and optimizing the cost efficiency of a job. This research aims are to find some innovations or alternative ideas that will be used with the aim of lowering the cost efficiency than the cost before the application of value engineering by prioritizing the quality and quality of work. To support the results, ETABS modeling application is used to design alternatives that will be calculated. As a result, after applying the value engineering to the Employees Mess Building project, the total saving cost that can be done as a whole is Rp2,092,778,048, - with a percentage saving cost of 39.4% for upper structure costs. Based on the results obtained, the most efficient beam and column structure uses Alternative 1, reinforced concrete and the floor slab structure uses Alternative 2, Half Slab Precast.

Keyword: concrete, optimum water content, slump value, compressive strength, wet mix, dry mix

1. Introduction

A construction project is a series of activities that are interrelated to achieve certain goals (building/construction) with the consideration of one of which is the aspects of cost and quality. 70% cost of the building construction is being committed in design stage including construction method; hence integration of multidiciplinary expertise is important throughout the building construction process [1]. The limited budget is also one of the considerations for the use of materials that can be used in building construction work. Therefore, construction service providers must think creatively to choose the materials used to get as cost-effective as possible without neglecting engineering principles [2].

Currently, there are many alternative materials that are often used in construction, especially structures, including steel, reinforced concrete, composites, half slab precast and other materials. However, the selection of this material is highly dependent on certain factors, including volume, method, and ease of obtaining building construction materials. Reflecting on these conditions, to analyze cost efficiency on quality so as to determine the material in building project construction, there are many ways that can be done and one of them is Value Engineering [3].

Value Engineering is a creative, planned, structured approach that has the goal of identifying and optimizing the cost efficiency of a job. Value engineering is used to innovate alternatives or ideas with the aim of reducing the amount of costs used from the previously planned cost planning but without reducing the quality and functional limitations of a job, especially construction [4].
This Value Engineering analysis is carried out after the project planning stage and in general reviewing the structural components. This is because the structural components have the greatest item value or weight so that they are less effective and efficient, which causes a waste of construction costs. The Value Engineering process includes the structural planning stage, construction work methods and material / material selection [3].

To support the selection of materials / materials, a tool is needed that can be used especially in calculating volume and also for analyzing with a faster process. This is of course a concern because it makes the analysis process with alternative results that are more subjective in nature so that the use of the chosen alternative is not the best. So, in this study, an assistive tool was used, namely the ETABS application because it has advantages in designing high-rise buildings and is able to analyze buildings with a large number of joints [5]. In addition, 20-40% of failures in construction occur during the implementation stage and most of that risk depends on the performance of the contractor. The use of ETABS is also intended to ensure the quality of construction. Quality aspects can be said to be quality if they meet several elements, one of which is meeting security requirements. The ETABS application is then used as a reference for checking the quality of buildings that have been designed using other alternative materials so that they remain in a safety condition in accordance with the building construction design [6].

2. Literature Review
Value engineering (value engineering) is an effort to make cost savings (efficiency costs) so as to reduce the occurrence of cost overruns due to unnecessary costs when planning costs on the condition that adhering to the engineering principles of maintaining performance, strength, reliability, quality, function, benefits, aesthetics and other aspects that are considered vital in all work activities. This value engineering process generally requires a stage of innovation and creativity, so that a cost-saving process can be carried out which has the potential to experience swelling. These stages can be studied based on basic knowledge, discussions with experienced parties and information based on surveys via the internet [7]. The application of value engineering is more focused on its use for construction projects, especially on construction costs and quality. In order to carry out the process of applying value engineering, an initial stage is first carried out, namely the planning stage so that it can be known at an early stage about the cost components that need efficiency. Analysis of the application of value engineering should be carried out before entering the construction implementation stage so that there is no delay in the execution of the work, the incurring of additional costs, so that it can save time until construction work is carried out in the field [8].

Research Purposes
This research on the application of value engineering aims to:

a. Knowing the dominant cost components that value engineering needs to be applied;
b. Knowing the material components used in order to obtain savings after applying value engineering;
c. Knowing the comparison of the initial design costs against the cost of alternative materials after applying Value Engineering;
d. Knowing the alternative materials used and meeting the safety requirements in building construction

3. Methodology
3.1 Research Stage
The methodology research is a quantitative research and the stages of research follow (Figure 1):

- **Problem Identification**: The research begins by identifying the problem which is then used as the object of the thesis research;
- **Literature Study**: The results of problem identification are then developed through appropriate studies based on science in books, journals (national / international), and other reference sources;
- **Data Collection**: The data taken are primary data and secondary data in the form of technical drawings and project RAB;
- **Primary Data**: Data in the form of field observations and interviews with related parties;
- **Secondary Data**: Data in the form of technical drawings and project RAB;
- **Analysis Stages**: Analyze project data in accordance with the object of research and provide the best alternative results;
• **Conclusions and Suggestions:** Researchers provide conclusions and input for the next research step.

![Research Flow Diagram](image)

**Figure 1. Research Flow Diagram**

### 3.2. Data Retrieval

**Location Survey**
The position of the project location is right on Jl. KH. Wadid Hasyim No. 96A, Central Jakarta. It is known that the ongoing project has only reached the foundation work stage. The owner of this project is PT. Nusantara Sejahtera Raya. The function of this building is as a residence for employees. The building consists of 4 floors using a steel structure. The contractor for this project is PT Andal Rekacipta Pratama, structural planner, namely Mr. Andreas Arianto Pramudya, S.T. and the architectural planner in this project is Mrs. Anila Pramesti, S.T., M. Ars.

**Interview**
In this interview session, it was carried out with the parties involved in the building construction project in this case, namely as follows:
- Project Manager to obtain technical data and RAB;
- Structural expert to validate research results.

### 4. Analysis and discussion

**Information Phase**
The following is project data that will be analyzed for the application of value engineering, as follows
- Building area : 2,253 m²
- Number of Floors : 5 floors (including basement)
- Technical Specifications : HWF and IWF steel (BJ41)
- Project Value : Rp9,625,000,000
- BOQ Upper Structure : Rp7,064,479,038

At this stage, the data that has been collected is in the form of project technical drawings and the project structure RAB as the basis for the analysis stage which is described in the Table 1-3 below:
Table 1. BOQ Building Structure Work

| No | Description                  | Total               |
|----|------------------------------|---------------------|
| 1  | Preliminaries + Structure Work | Rp9,625,000,000,- |

Table 2. Details of Total BOQ for Foundation and Ground Floor Works

| No | Description Work Structure | Total               |
|----|----------------------------|---------------------|
| 1  | Pile Foundation Work       | Rp873,405,217,-     |
| 2  | Pile Cap Work, Tie Beam, etc. | Rp285,369,746,-  |
| 3  | Ground Floor Work          | Rp2,206,723,680,-  |

Table 3. Details of Total BOQ Floors 2-5 and Lift Floor + Roof

| No | Description Work Structure | Total               |
|----|----------------------------|---------------------|
| 1  | 2nd floor                  | Rp807,874,842,-     |
| 2  | 3rd floor                  | Rp807,874,842,-     |
| 3  | 4th floor                  | Rp807,874,842,-     |
| 4  | 5th floor                  | Rp807,874,842,-     |
| 5  | Lift Floor + Roof          | Rp467,481,021,-     |

Furthermore, the following data are project technical data which are described in Figure 2-5, which are as follows:

Figure 2. Column Plan Floor 1- Floor 4
Figure 3. Floor Plan LMR Columns

Figure 4. Floor Beam Plan 2-4

Figure 5. Floor Plan 5 Beams, LMR Floor, and Machine Roof Floor
Selection of Work Items for Value Engineering Application

The following is a summary of the BOQ details of the structure for the 1st floor - the roof floor as described in the Table 4 below:

| Ranking | Work Type                | Cost          | Cost Percentage | Cumulative Percentage |
|---------|--------------------------|---------------|-----------------|-----------------------|
| 1       | Beam Work                | Rp2,333,041,900.- | 33%             | 33%                   |
| 2       | Column Work              | Rp1,922,578,645.- | 27%             | 60%                   |
| 3       | Floor Slab Work          | Rp1,055,828,222.- | 15%             | 75%                   |
| 4       | Foundation Work          | Rp873,405,217.- | 12%             | 87%                   |
| 5       | Lift and Roof Work       | Rp467,481,021.- | 7%              | 94%                   |
| 6       | Pile Cap+Tie Beam Work   | Rp285,369,746.- | 4%              | 98%                   |
| 7       | Pedestal Work            | Rp126,774,287.- | 2%              | 100%                  |
| Total   |                          | Rp7,064,479,038 |                 | 100%                  |

Based on the data above, an item analysis can be made based on Pareto Law which states that only the cumulative costs of up to 80% of the total work items will be analyzed. Figure 6 shows a chart of item selection analysis based on Pareto law.

From Figure 6 above, based on the analysis of the Pareto law graphic, it can be stated that the work that is worth doing the application of value engineering is the work of beams, columns, and floor plates and this result is in accordance with the method pattern in the journal [4].

Function Analysis Stage

At this stage, a value search is carried out based on costs and the functions that will be created using the FAST diagram, then from the diagram, the functions of the subcomponents that form a structure will appear. This function will be divided into 2, namely primary function and secondary function. After classifying by function, a cost analysis of the function or Cost / Worth (C / W) is carried out with the condition that if the value is > 1, it is necessary to apply value engineering. The following Table 5 is the C / W calculation, which is as follows:

| No. | Component | Function | Type | Cost (Rp) | Worth (Rp) | C/W Ratio |
|-----|-----------|----------|------|-----------|------------|-----------|
| 1   | Beam      | Resist   | Load | 2,333,041,900 | 2,092,362,652 | 1.12      |
| 2   | Column    | Resist   | Load | 1,922,578,645 | 1,586,165,097 | 1.21      |
| 3   | Floor Slab| Resist   | Load | 1,055,828,222 | 1,009,230,692 | 1.05      |

From the recapitulation Table 5 above, the value of C / W > 1 so that analysis can be done using value engineering. The next step will be modeling for alternatives that will be used to perform value engineering. These results are based on the method pattern in the journal [9].
Creativity and Innovation Phase

- **Alternative Materials for Columns and Beams**
  - Existing: HWF and IWF steel
  - Alternative 1: Reinforced concrete
  - Alternative 2: Composite

- **Alternative Floor Plate Materials**
  - Existing: Metal deck
  - Alternative 1: Reinforced concrete
  - Alternative 2: Half slab precast

Analysis Phase

**Beam and Column**

| Column/Beam Type | Dimension | Reinforcement Detail | Total Length (m) |
|------------------|-----------|----------------------|------------------|
| K1               | 40 x 40 cm| Longitudinal: 10D22, Confinement: D12-150 | 71               |
|                  |           |                      | 281              |
| K2               | 30 x 30 cm| Longitudinal: 8D16, Confinement: D10-150 | 40               |
|                  |           |                      | 131.5            |
| K3               | 45 x 45 cm| Longitudinal: 10D22, Confinement: D12-150 | 2                |
|                  |           |                      | 8                |
| K4               | 50 x 50 cm| Longitudinal: 14D22, Confinement: D12-150 | 1                |
|                  |           |                      | 4                |
| B1               | 30 x 50 cm| Longitudinal: 8D22, Confinement: D8-200 | 153              |
|                  |           |                      | 758.7            |
| B2               | 30 x 40 cm| Longitudinal: 8D22, Confinement: D8-150 | 170              |
|                  |           |                      | 779.3            |
| B3               | 40 x 60 cm| Longitudinal: 8D22, Confinement: D8-150 | 14               |
|                  |           |                      | 57.8625          |
| B4               | 40 x 75 cm| Longitudinal: 8D22, Confinement: D8-150 | 3                |
|                  |           |                      | 13.0875          |

- **Alternative 2: Composite**
The following is a detail of reinforcement and details of the composite structure in the ETABS modeling used as follows:
  - Column K1 = HWF Steel 250 x 250 x 9 x 14 (50 x 50 cm), 8D16, D8-150;
  - Column K2 = Steel HWF 150 x 150 x 7 x 10 (40 x 40 cm), 8D16, D8-150;
  - B1 / B2 beam = IWF Steel 250 x 125 x 6 x 9 (30 x 45 cm), 8D16, D8-150;
  - B3 beam = 200 x 100 x 5.5 x 8 (30 x 40 cm) IWF steel, 8D16, D8-150;
  - B4 beam = IWF steel 150 x 75 x 5 x 7 (25 x 35 cm), 8D16, D8-150;
  - B5 beam = 100 x 100 x 6 x 8 (25 x 35 cm) HWF steel, 8D16, D8-150;
  - Floor plate = 12 cm

**Floor Slab**

- **Alternative 1: Reinforced Concrete**
  For floor slabs, the reinforcement specifications used and the dimensions of the floor slabs used are the same as the original design, but in this alternative, the formwork used is wood, while the initial design uses metal decks so that the efficiency comparison between conventional and metal deck methods will be compared. For the thickness of the floor slabs used is 12 cm and the quality of the concrete f'c 30 MPa or K-350 based on the modeling design that has been made previously.

- **Alternative 2: Half Slab Precast**
In this alternative, based on the results of discussions with the planning team, M6-150 + D8-250 = 188.4 + 200.96 = 389.36 mm$^2$ > 334.93 mm$^2$ (correct assumption) is used. For details on the concrete used in the half slab, it is shown in Figure 7.

![Figure 7. Details of Half Slab Concrete](image)

From Figure 7, it can be seen that the thickness of the slab used for the precast half slab is 8 cm which serves as a substitute for formwork / scaffolding and is cast with 5 cm thick concrete. For the quality of the concrete used, following the results of the modeling that has been made, namely f'c 30 MPa. The reason for using a precast half slab with a thickness of 8 cm is that this number is the optimal number for lifting or moving the precast so that it does not occur. However, if the thickness exceeds 8 cm, the size of the overtopping concrete will decrease, causing the possibility of the concrete to crack. The calculation is based on the method pattern in the journal [10].

### Estimated Costs of Alternative Design

#### Beam and Column

**a. Alternative 1: Reinforced Concrete**

| No | Description               | Qty  | Unit | Unit Price (Rp) | Subtotal (Rp) | Total (Rp) |
|----|----------------------------|------|------|-----------------|---------------|------------|
| 1  | Casting Concrete Ready Mix f’c 30 MPa | 225,15 | m$^3$ | 1.095.639       | 246.683.121   |            |
| 2  | Reinforcing                | 43.747 | kg   | 10.291          | 450.204.354   |            |
| 3  | Formwork                   | 1.962 | m$^2$ | 164.093         | 321.950.466   |            |
|    | Total                       |     |      |                 | 1.018.837.941 |            |

| No | Description               | Qty  | Unit | Unit Price (Rp) | Subtotal (Rp) | Total (Rp) |
|----|----------------------------|------|------|-----------------|---------------|------------|
| 1  | Casting Concrete Ready Mix f’c 30 MPa | 59.42 | m$^3$ | 1.095.639       | 65.102.869    |            |
| 2  | Reinforcing                | 13.762 | kg   | 10.224          | 140.707.455   |            |
| 3  | Formwork                   | 629.8 | m$^2$ | 162.293         | 102.212.131   |            |
|    | Total                       |     |      |                 | 308.022.455   |            |

**b. Alternative 2: Composite**

| No | Description               | Qty  | Unit | Unit Price (Rp) | Subtotal (Rp) | Total (Rp) |
|----|----------------------------|------|------|-----------------|---------------|------------|
| 1  | Casting Concrete Ready Mix f’c 30 MPa | 184.39 | m$^3$ | 1.095.639       | 202.024.875   |            |
| 2  | Reinforcing                | 21.662 | kg   | 11.157          | 241.674.303   |            |
| 3  | Steel                      | 38.127 | kg   | 30.732          | 1.171.721.885 |            |
| 4  | Formwork                   | 1.778 | m$^2$ | 164.093         | 291.757.354   |            |
|    | Total                       |     |      |                 | 1.907.178.417 |            |
Table 10. Composite Column Cost Estimates

| No | Description                          | Qty       | Unit | Unit Price (Rp) | Subtotal (Rp) | Total (Rp)  |
|----|--------------------------------------|-----------|------|-----------------|---------------|-------------|
| 1  | Casting Concrete Ready Mix f’c 30 MPa| 104,99    | m³   | 1,095,639       | 115,031,139   |             |
| 2  | Reinforcing                          | 8,110     | kg   | 9,893           | 80,230,954    |             |
| 3  | Steel                                | 30,368    | kg   | 31,524          | 957,305,648   |             |
| 4  | Formwork                             | 896       | m²   | 164,093         | 147,027,328   |             |
|    | Total                                |           |      |                 | 1,299,595,069 |             |

Floor Slab

a. Alternative 1: Reinforced Concrete

Table 11. Cost Estimation of Ready Mix Reinforced Concrete Floor Slabs

| No | Description                          | Qty       | Unit | Unit Price (Rp) | Subtotal (Rp) | Total (Rp)  |
|----|--------------------------------------|-----------|------|-----------------|---------------|-------------|
| 1  | Casting Concrete Ready Mix f’c 30 MPa| 346,04    | m³   | 1,095,639       | 379,134,920   |             |
| 2  | Reinforcing                          | 2,601,14  | kg   | 7,400           | 23,398,573    |             |
| 3  | Formwork                             | 2,012,74  | m²   | 393,728,174     |               |             |
|    | Total                                |           |      |                 | 796,261,667   |             |

b. Alternative 2: Halfslab Precast

Table 12. Total Alternative Costs 2

| No | Description                          | Total (Rp) |
|----|--------------------------------------|------------|
| 1  | Half Slab Precast Work               | 285,079,450|
| 2  | Casting Concrete Work for 1st floor and Overtopping | 182,701,983 |
|    | Total                                | 467,781,433 |

Life Cycle Cost (LCC)

Table 13. Calculation Results of LCC Beams and Columns

| No | Work Type       | Alternative 1 (Rp) Reinforced Concrete | Alternative 2 (Rp) Composite |
|----|-----------------|----------------------------------------|----------------------------|
| 1  | Beam Work       | 1,703,613,586                          | 2,829,690,062              |
| 2  | Column Work     | 521,996,431                            | 1,868,367,444              |

Table 14. Calculation Results of LCC Floor Slab

| No | Work Type       | Alternative 1 (Rp) Reinforced Concrete | Alternative 2 (Rp) Half Slab Precast |
|----|-----------------|----------------------------------------|--------------------------------------|
| 1  | Floor Slab Work | 1,422,351,520                         | 993,060,702                          |

Development Phase

Table 15. Comparison of Bar and Column Price Data

| No | Work Type       | Initial Cost Design (Rp) | Alternative 1 (Rp) Reinforced Concrete | Alternative 2 (Rp) Composite |
|----|-----------------|--------------------------|----------------------------------------|----------------------------|
| 1  | Beam Work       | 2,333,041,900            | 1,703,613,586                          | 2,829,690,062              |
| 2  | Column Work     | 1,922,578,645            | 521,996,431                            | 1,868,367,444              |
Table 16. Data Comparison of Floor Plates Prices

| No | Work Type         | Initial Cost Design (Rp) | Alternative 1 (Rp) Reinforced Concrete | Alternative 2 (Rp) Half Slab Precast |
|----|-------------------|--------------------------|----------------------------------------|--------------------------------------|
| 1  | Slab Work         | 1,055,828.222           | 1,422,351.520                          | 993,060.702                          |

From the data above (Tables 6-16), the price data for all alternative designs have been presented using alternative design prices based on calculations using the LCC (Life Cycle Cost) method. The data above will be used as a reference at the next recommendation stage.

**Recommendation Phase**

Alternative jobs can be recommended, namely as follows:
- Beam work using Alternative 1, namely reinforced concrete beams with f'c quality 30 MPa or K-350 with a total savings of up to IDR 629,428,314, - or 26.98%;
- Column work using Alternative 1, namely reinforced concrete columns with f'c quality 30 MPa or K-350 with a total savings of up to IDR 1,400,582,214, - or 72.8%;
- Floor plate work uses Alternative 2, namely Precast Half Slab plates with f'c 30 MPa or K-350 quality with a total savings of up to Rp.62,767,520 or 5.94%.

After knowing the material components that have been applied by Value Engineering, then the comparison of the initial design and after the application of Value Engineering will be presented in Table 17.

Table 17. Comparison of Alternative Costs to Initial Design

| No | Work Type         | Initial Design Cost | VE Implementation Cost |
|----|-------------------|---------------------|------------------------|
| 1  | Beam Work         | Rp2,333,041.900,-   | Rp1,703,613.586        |
| 2  | Column Work       | Rp1,922,578.645,-   | Rp521,996.431          |
| 3  | Floor Slab Work   | Rp1,055,828.222,-   | Rp993,060.702          |
|    | Total             | Rp5,311,448.767     | Rp3,218,670.719        |

Total Cost Savings 39.4%

From the data in Table 17 above, after implementing value engineering in this study, it was obtained 39.4% savings for the overall upper structure costs.

5. Conclusion

From the results of value engineering analysis on the upper structure of the building, especially on beams, columns, and floor plates with guidelines on the value engineering work plan so that the following results are obtained:

a. The dominant cost component that Value Engineering needs to apply is structural work, namely beam, column and floor slab work, which each have a weight of 33%, 27%, and 15%. This is indicated by the cost component which weighs almost 80% based on the total construction work so it is necessary to apply Value Engineering.

b. The material components used in order to obtain savings after value engineering are applied are as follows:
   - Beam Work: Alternative 1 - Reinforced Concrete;
   - Column work: Alternative 1 - Reinforced Concrete;
   - Floor Slab Work: Alternative 2 - Half Slab Precast

c. The comparison of the initial design costs against the cost of alternative materials after Value Engineering is applied is as follows:
   - Beam work using Alternative 1, namely reinforced concrete blocks with f'c quality 30 MPa or K-350 at a cost of IDR 1,703,613,586, - and a total savings of up to IDR 629,428,314, - or 26.98%;
   - Column work using Alternative 1, namely reinforced concrete columns with f'c quality 30 MPa or K-350 at a cost of Rp.521,996,431, - and a total savings of up to Rp1,400,582,214, - or 72.8%;
   - Floor plate work using Alternative 2, namely Half Slab Precast plate with f'c 30 MPa or K-
d. The alternative material selected and used in this study is reinforced concrete for beam and column work, then the half-slab precast for floor slab work and the material meets the safety requirements in building construction. This is indicated by the results of Run Analysis using the ETABS application, namely there is no indication of O/S (Over Strength), which means that the quality of the structure is strong to withstand loads designed in accordance with building construction planning.

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