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Cost-Saving Strategy Employing Value Engineering Analysis on Basement Construction Work

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Abstract. The increasing infrastructure development in Indonesia requires efficient project management to address cost, time, and quality challenges. This study examines the basement construction at the BRI Gatot Subroto Tower Project in South Jakarta, which had a budget of USD 54,021,493.20. Changes in construction methods, from ground anchors to island-type strutting and eventually to a steel platform, were analyzed using value engineering techniques. The study employed a combination of quantitative and qualitative methods, using **Pareto Analysis** and **Analytical Hierarchy Process (AHP)** to evaluate alternative construction methods for cost efficiency. The **steel platform** method was found to be the most effective, achieving **cost savings of USD 257,010.56** (26.7% reduction) and a lower total **Life Cycle Cost (LCC)** compared to island-type strutting. The findings highlight the value of **Value Engineering (VE)** in optimizing project costs and improving overall efficiency.

Keywords: Analytical Hierarchy Process; Life Cycle Cost; Steel Platform; Value Engineering; Island-Type Strutting

1. Introduction

Infrastructure development in Indonesia continues to increase. Ministry's APBN of PUPR from 2017 to 2022 continues to grow with a nominal value of USD 6.13 Billion up to USD 9.8 Billion, a realization of more than 90% (Prihapsari et al., 2022). Budget and increased realization due to very supportive infrastructure need nation's economy. Good project management needs to accompany the increasing number of development projects. Project management is a series of efforts starting from planning to execution construction with an organizational system and control of all elements in the project to ensure that the planned targets can be achieved at an efficient cost (Hosaini et al., 2021).

One method in project management related to efficiency cost is value engineering (VE). VE is an approach closely related to the function and value of a job with cost efficiency (Sheikh et al., 2022). Value Engineering has several advantages, such as the more systematic approach to keep the analysis according to the topic problems to produce optimal final results (Diputera et al., 2018). It is suggested to apply the VE analysis at the pre-construction phase, to avoid potential major redesigns, and more opportunities for improvement can be implemented. Many academics and researchers from

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Indonesian institutions regularly publish their work in VE studies since they believe in the benefits of VE in public and private project practice. (Miraj et al, 2019).

Gatot Subroto BRI Tower, South Jakarta, is the object of the study in this research. The Gatot Subroto BRI Tower was chosen as the object of this paper because it involved significant basement construction work, which provided an ideal case to apply and evaluate Value Engineering (VE) techniques. The project experienced changes in construction methods, from ground anchors to island-type strutting and finally to a steel platform, making it suitable for analyzing cost efficiency and construction optimization through VE. Additionally, the project's large budget allowed for a thorough investigation of cost-saving strategies construction budget for this project is USD 54,021,493.20. In addition, this project utilizes a method of replacement on work for the basement area starting from the ground anchor method, island-type strutting, and finally, the steel platform. The method change is based on the existing condition, where a development project is on the side of the basement work area. Therefore, the ground anchor method was changed to island-type struttings. However, because the strutting work requires a longer time, especially in excavating and installing steel strutting, changes are made to design a steel platform.

There are many changes in work methods in the basement work area. Therefore, the authors are interested in performing research on the basement work area of Gatot Subroto BRI Tower, South Jakarta, using the VE method. The research will focus on each approach of VE steps to identify the most appropriate method.

This study aims to figure out the amount of efficiency that could be generated from the cost of existing design of the basement area job of BRI Tower located on Jl. Gatot Subroto - South Jakarta, by making a selection of alternative designs from the ground anchor, island-type strutting, up to the steel platform, with the implementation of Value Engineering Analysis.

1.1 Value Engineering

Value engineering is a method that has been devised to obtain increased value. Various extensive researches have been conducted to figure out the supremacy of Value Engineering. Among the other values, the most highlighted advantage is cost savings. For example, the implementation of value engineering (VE) during school development in Libya led to cost reduction in the overall project for about between 20% and 30% (Youssef et al., 2023). While it was clearly shown that the basic benefits are acceptable to stakeholders and customers from the application of value engineering and the material return from it, it enhances the role of consulting firms in the construction industry in Egypt (Abdelalim et al., 2021). Particularly when it comes to the development of underground construction, value engineering improves product costs by reducing the unnecessary costs associated with the product (Abdelfatah et al., 2020). Introducing a systematic VE approach for major sewer projects in Egypt was proven to reduce costs and improve sustainability. The implementation of Value Engineering (VE) also successfully reduced the cost by approximately 27% and the value of the project increased after the process (Usman et al., 2018). Integrating risk management, value management, and quality management would assist clients in utilizing resources more effectively, in addition to saving time and money (Abdelalim et al., 2021). Cost efficiency at 9.8% savings had also been obtained for clean and dirty water installation work (Rahayu, 2023). Even, a ship designer who emphasizes cost reductions and profit maximization during the design process applies Multi-Criteria Analysis, which includes VE Analysis (Buana et al, 2022). With some variations in the implementation, such as plug-in utilities, value-engineering processes can be developed as catalyst tools for facilitating project-based solutions by producing new plugins for time-saving and quantity management (Kabaca and Yalnız, 2022).

Value Engineering (VE) enhances construction efficiency by integrating Risk Management, reducing work duplication, and improving project outcomes (Masengesho et al., 2021). Combining VE with BIM can cut project costs and duration by 10% (Li, Wang, and Alshwal, 2021). VE helps evaluate material use efficiency (MUE), closing gaps in project performance (Choi et al., 2023), and optimizes small-scale LNG carrier designs by reducing hull shell area by 1.57% (Wibisana and Budiyanto, 2021).

Research over the last decade has shown VE improves productivity and cost efficiency (Chen et al., 2022; Janani et al., 2018). In today's digital era, VE integrates measurable and immeasurable concepts, leading to mathematical models that support AI-based systems (Woodhead and Berawi, 2022). VE has been used to develop multi-story buildings and optimize residential projects, such as choosing cost-effective flat slabs (Hosam Elhegazy, 2022; Albasyouni, 2021). BIM and VE combined enhance green building designs and balance owner requirements (Wei et al., 2020).

VE's environmental impact is evident in reducing embodied carbon by 8% and cutting costs by 10% in post-tensioned concrete structures (Robati et al., 2021). VE also brings environmental benefits (Adnan et al., 2018) and helps optimize green building envelopes for energy savings and lifecycle costs (Yuan et al., 2020). Integrating BIM with VE promotes sustainable designs (Baarimah et al., 2021), improving customer loyalty by minimizing waste and unnecessary expenses (Elfargani, 2023). VE and life cycle costing in the oil and gas sector ensure quality at the lowest cost, considering sustainability (Al-Yafei et al., 2017).

VE applies a functional approach across various scientific fields to enhance project value (SAVE International, 2007). VE stages are 6, namely (see Figure 1):

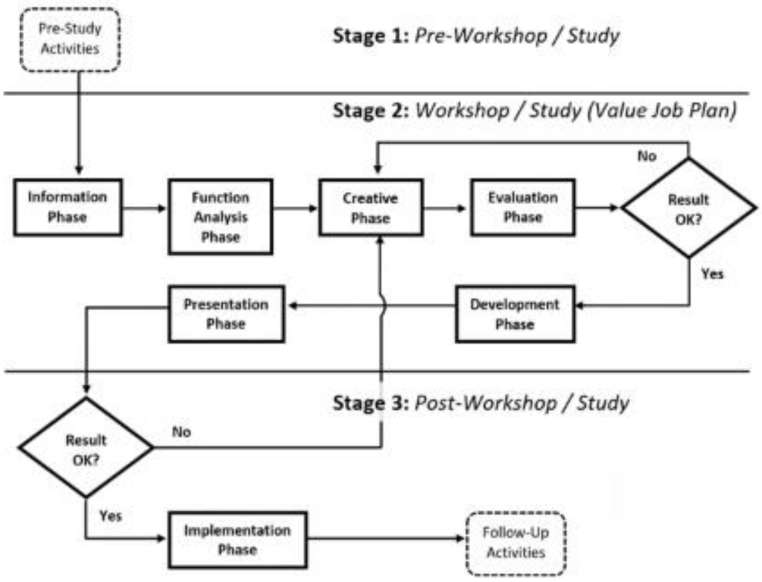

Figure 1 Value Engineering Stages

1) Information Stage

The information stage is the initial stage in conducting value engineering (SAVE International, 2007). Tools used at the information stage include Pareto Analysis, Tear Down Analysis, and SWOT Analysis.

2) Function Analysis Stage

Analysis function is an activity to define and evaluate the work identified during the information stage. The tools used include Function Analysis System Technique (FAST) and Function Tree.

3) Creative Stage

Goal of the creative stage is to find ideas and solutions as much as possible based on the understanding obtained at the information stage and stage function analysis and remain function-oriented. Tools used to obtain ideas and solutions include Brainstorming, TRIZ, and the Gordon Technique. While a developed BIM-based VE Idea Bank enables the systematic retrieval of past VE data from over 23 industry professionals ((Park et al., 2016).

4) Evaluation Stage

The fourth stage of VE is the evaluation stage. The purpose of the evaluation phase is to eliminate ideas collected based on the creative Stage. Tools used at the evaluation stage are the Analytical Hierarchy Process (AHP), Pugh Analysis, and T-Charts.

5) Development Stage

The development stage is to gain a deeper understanding of the selected ideas, especially cost analysis (SAVE International, 2007). The tools used are Life Cycle Cost (LCC).

6) Presentation stage

The presentation stage is to give conclusions based on the analysis carried out and made as best as possible so that the interested parties easily understand the reports and easy to make decisions.

Further presentation development using technologies like VR/AR, BIM (Building Information Modelling), AI (Artificial Intelligence), IoT, and automation can stimulate innovation, collaboration, and growth among researchers and industry experts (Shihata et al, 2023). The future of Value Engineering (VE) will involve advanced digital technologies such as AI and the Internet of Things (IoT).

Research from the Far East and Europe highlights AI integration in high-production industries. Lithuanian and Iranian researchers applied VE in supply chain cost management using the gray multi-criteria decision-making method, demonstrating model stability in actual cases (Heidary et al., 2020). South Korean studies showed generative design can improve productivity by automating design alternatives (Lee, J. et al., 2023).

AI and optimization techniques, combined with BIM data, provide energy-efficient solutions while balancing cost and functionality (Kiavarz, H et al., 2024). AI and IoT are also crucial for sustainability, with new ecological indicators proposed to assess construction project sustainability (Kulejewski and Rosłon, 2023).

1.2 Pareto Analysis

According to Sunarto & WN (2020) in Juran & Godfrey (1999), the Pareto analysis law states that 80% of work results come from 20% of the main causes. In the construction industry, generally, 20% of these causes come from high-cost work. The Pareto principle, also known as the 80/20 rule, states that 80% of results or problems are often caused by 20% of the factors. In the construction context, 20% of the costly work usually explains about 80% of the issues or challenges that arise (Alkaiyat, 2021). This principle is often visualized in the form of a diagram that illustrates the comparison between a small portion of significant causes (20%) and most of the less significant causes (80%). This diagram makes it easier to identify critical factors that need to be considered to achieve maximum improvement (Pareto Analysis Pocketbook, 2020) while also helping to allocate resources more effectively.

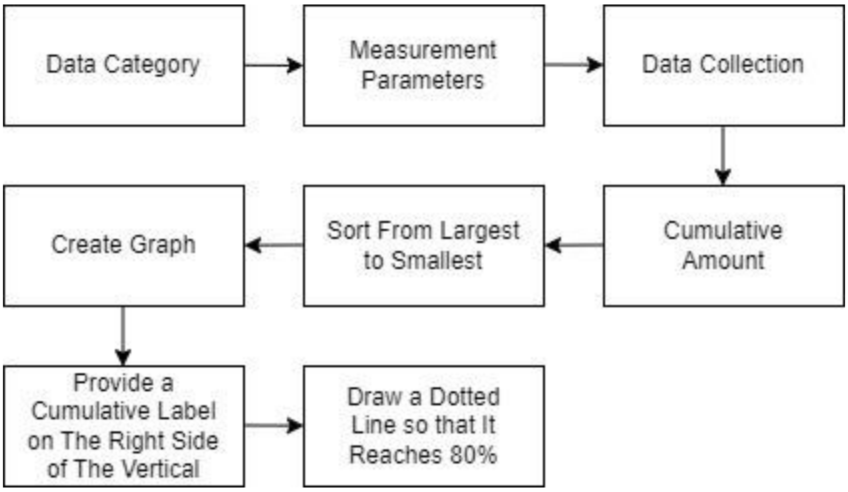

Figure 2 Steps to Create a Pareto Diagram

1.3 Function Analysis System Technique (FAST)

The FAST Diagram is one of the tools used in the function analysis stage in Value Engineering (VE). In Silviana et al. (2020), Charles Bytheway developed FAST diagrams to determine linkages among different functions in a job. Key Definitions of FAST According to Silviana (2020), the basic terms in the FAST Diagram include:

1) **Higher Order Function**
   This is the function shown all the way to your left side on the diagram, and it is what you actually want, which will be done in less than a second. It is a lower-order function that depends on this higher-level function.
2) **Lower Order Function**
   This function is the input of a FAST Diagram positioned just to the right of it on a diagram.
3) **Basic Function**
   The primary function of the higher-order function, which is the basis for other functions.
4) **Secondary Function**
   Additional functions that explain and support the primary function.
5) **Design Objective**
   Parameters or goals to be achieved in the design.
6) **All The Time Function**
   A function that is the result of a higher order function and applies all the time.
7) **At The Same Time Function**
   Functions that only occur at specific moments or conditions.

According to Berawi (2014), the FAST Diagram has several essential functions, namely helping to understand the work being analyzed so as not to make mistakes in determining the functions involved, finding functions that may not be directly visible, simplifying and explaining the problems faced, and improving technical skills. In making a FAST Diagram, according to Silviana (2020), several things need to be considered. The two main keywords used are "How" and "Why." PrimaryThe essential function to secondary function is the scope of the problem that must be identified based on higher-order function and lower-order function. The process begins with the question, "How can the basic function be achieved?" The answer will be placed on the right side as a secondary function, and this process continues until all functions are identified. After that, the question "Why does this function need to be done?" is answered on the left side as a further explanation until all functions can be understood in depth.

1.4 Analytical Hierarchy Process (AHP)

AHP (Analytic Hierarchy Process) was a decision-making tool and method created by Thomas L. Satty. It is commonly applied in decision support for business, engineering, and public policy planning. This technique dissects grand challenges into small sub-challenges and prioritizes each criterion in terms of contribution-enabled resources to consume distributed solutions for the best result (Supriadi et al., 2018).

The steps in AHP include:

1) **Determining the Problem**
   The problem faced must be clearly described to facilitate the creation of a hierarchical structure.
2) **Constructing a Hierarchy**
   That hierarchy will start with the primary goal at the top and then the criteria and solutions we need to evaluate.
3) **Making a Pairwise Comparison Matrix,** comparing criteria and alternative solutions with one another and weighing each to finally determine which one is the most important.
4) **Scale,** all comparisons are rated by weight, from 1 to 9, wherein each number represents an increasing level of significance.

1.5 Life Cycle Cost (LCC)

Life Cycle Cost (LCC) is the calculation of the total cost of an asset throughout its life cycle, starting from the planning stage, construction, operation, maintenance, to demolition. LCC depends on the planned service life (RICS, 2016). By calculating LCC, we can determine the most efficient alternative in terms of cost. Here are the main components in LCC:

1) **Initial Cost**
   This is the cost incurred to start a project or produce a product, often considered an investment. Initial costs include four main components: building costs, development costs, implementation costs, and other additional costs (Berawi, 2014).
2) **Annual Cost**
   This cost is incurred routinely during the life of the asset, such as operational costs, maintenance costs, and other recurring costs (Berawi, 2014).
3) **Nonrecurring Costs** are those that arise at the end of the period, such as demolition costs and the residual value of the asset (Berawi, 2014).

2. Methods

This form of research is a combination of quantitative and qualitative research. Quantitative research is based on the data and analysis used. There are several stages to focus on calculations tested using certain instruments. Furthermore, the form of qualitative research in this study is focused on understanding the project problems and alternative solutions in depth. The research flow chart can be seen in Figure 2 below:

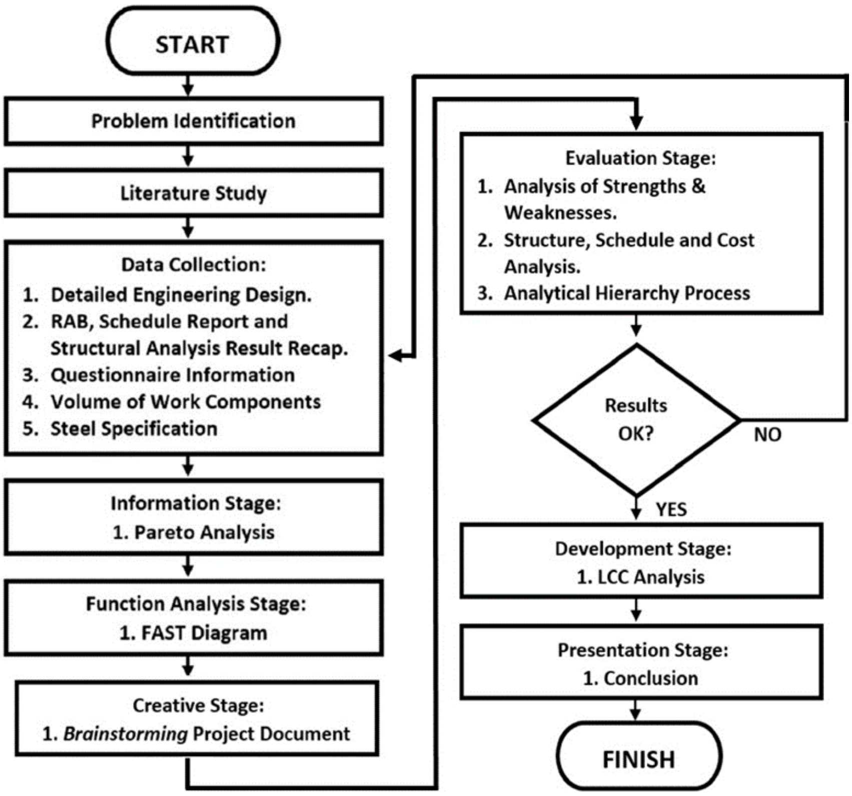

Figure 3 Flow Diagram

2.1. Data Collection

The data collection techniques used are questionnaire techniques and statistical datasets. The questionnaire will only be given to 3 respondents. The selected respondents are employees involved while the project is ongoing. Each respondent will receive 1 questionnaire containing personal identification and will fill in values for the 3 provided parameters, which include implementation time, ease of implementation, and construction costs. This data will later be used for AHP analysis.

The questionnaire technique involved distributing intensity assessment questionnaires to stakeholders or experts to compare different construction methods (ground anchors, island-type strutting, and steel platforms) based on criteria such as cost, implementation time, and ease of use. The responses were then used to populate the comparison matrices in the Analytical Hierarchy Process (AHP).

2.2. Pareto Analysis

Pareto analysis is a statistical decision-making technique that identifies a limited number of input factors as having a greater impact on outcomes, whether they are positive or negative. Within this study, the Pareto analyses will be carried out twice. At first, a Pareto analysis will be carried out based on the Budget Estimate Plan of the work structure. Secondly, a Pareto Analysis will be carried out based on the Budget Estimate Plan of the selected jobs during the first Pareto Analysis.

2.3. FAST Diagram

Function Analysis System Technique (FAST) Diagram is a technique to develop a graphical representation showing the logical relationships between the functions of a project, product, process, or service based on the questions “how” and “why”.

2.4. The Strengths and Weaknesses Analysis

The strengths and weaknesses analysis helps us in analyzing our strengths and weaknesses within a competitive environment. The approach focuses more on a company's strengths and weaknesses. The method is similar to ones used in the SWOT analysis but merely focuses on the first two of the four aspects.

2.5. Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a process that uses hierarchical decomposition to deal with complex information for achieving decision-making, such as information technology vendor and product evaluation.

The following are the steps in the Analytical Hierarchy Process:

The First Step is to make a 3x3 matrix from the results of the intensity assessment questionnaire for comparisons between criteria according to the number of criteria and analyze it for each comparison. The author used a 3x3 matrix in the Analytical Hierarchy Process (AHP) because the matrix size corresponds to the number of criteria being compared. The 3x3 matrix simplifies the process of calculating eigenvalues and ensuring the consistency of the judgments made in the comparisons. The green color is given when the comparison is done homogeneously. The blue color is given according to the assessment of comparison intensity between criteria.

The Second Step is the calculation of the eigenvalues based on the values of the Criteria Comparison Matrix by dividing the values in certain matrix columns by the total value in each criterion column. When all the values are ready, do the sum of the values per row. If the total value per row has been obtained, then each value is divided by three because the matrix used is 3 x 3, so the average eigenvalue per row is generated.

The Third Step is to calculate the value of λmax. The calculation is done by multiplying the total value in the comparison matrix multiplied by the average value (see Equation 1).

The Fourth Step is the calculation of index consistency (see equation 2)

The Fifth Step calculates the ratio consistency (see equation 3).

$$\lambda maks = \Sigma \text{ Value of the Comparison Matrix } \times \text{ the Average Value} \quad (1)$$

$$CI = (\lambda maks - n) / (n-1) \quad (2)$$

$$CR = CI / IR \quad (3)$$

Consistency Index (CI) is a parameter used to measure the consistency of the values provided by each respondent in the pairwise comparison of criteria. A lower CI value indicates greater consistency in the judgments. The use of CI is crucial to ensure that the data is reliable and valid for further analysis.

Random Index (IR) is a benchmark value determined based on the number of parameters or criteria used in the comparison. It is derived from a standard table and serves as a reference point in consistency calculations.

Consistency Ratio (CR) is the result of dividing CI by IR. This ratio indicates the overall level of consistency in the assessments. If the CR value is less than 0.1, the given judgments are considered reasonable and acceptable. If the CR exceeds 0.1, the judgments are considered inconsistent and may require further review.

3. Results and Discussion

3.1 Results of Pareto Analysis

Pareto analyses are carried out two times. First, a Pareto analysis was carried out based on the work structure budget estimate plan. Then, a Pareto Analysis is performed based on the Budget Estimate Plan of the selected jobs in the first Pareto Analysis. The ultimate goal of applying Pareto analysis during the process control in construction is the identification of the priorities, which functions as a measuring method to verify the efficacy of the model (Moon et al., 2015).

Based on Figure 3, the work that reaches more than 80% in tower work and basement structure work with a percentage of 81/50. However, due to basement structure work related to steel structure work, two jobs were chosen based on the availability of analysis data: basement structure work and steel structure work. While, in Figure 4, with steps, the same percentage of Pareto analysis was obtained by 94/66.

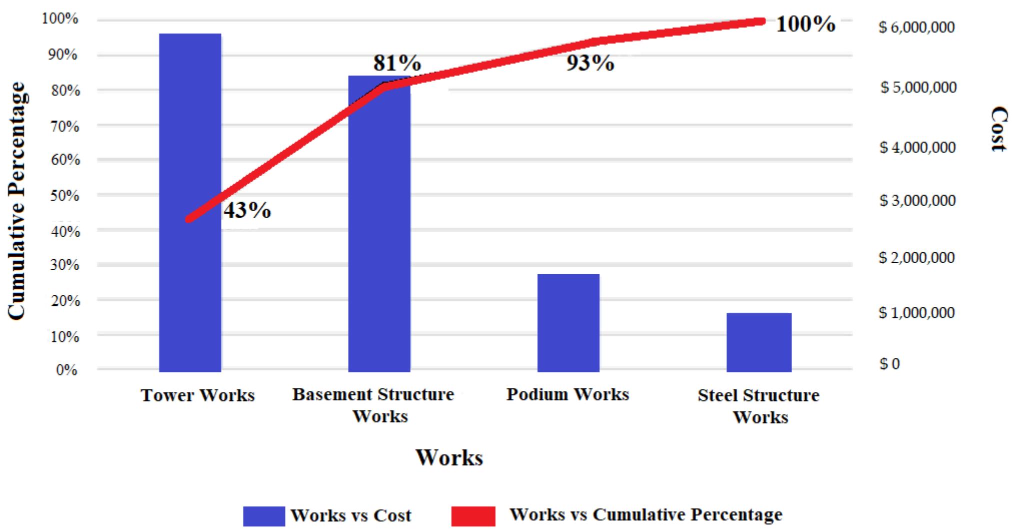

Figure 4 Pareto Analysis of Total Work Distribution in the BRI Tower Basement Construction Project

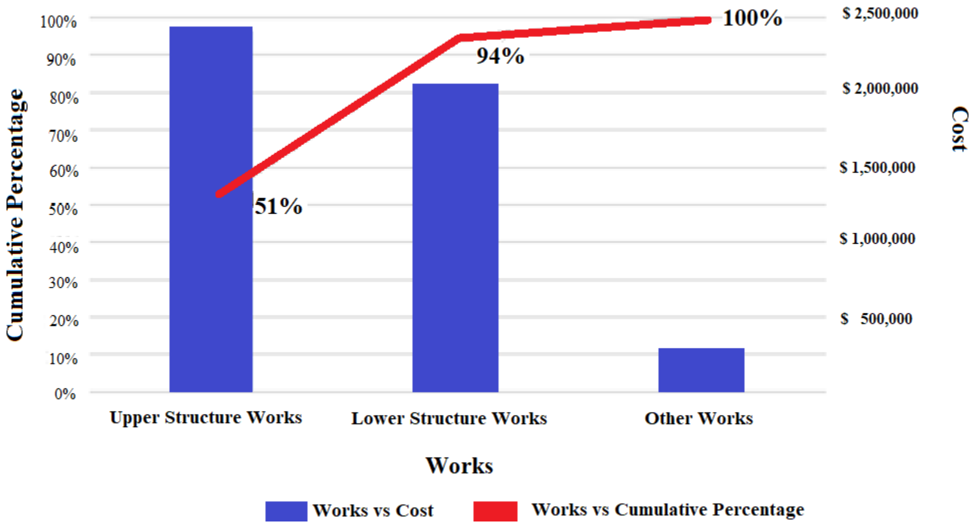

Figure 5 Pareto Analysis Focused on the Basement Structure Work in the BRI Tower Project.

3.2 Results of FAST Diagram

FAST Diagram creation based on function. All functions follow the principle of basement work in general. Figure 5 describes the scope of basement work, starting from basic functions to secondary functions.

Figure 5 explains that the higher-order thinking basement is to add room. The basic function of building the basement structure is to create a structural framework. Next function: the base is followed by a secondary function describing how to generate the function base. Then, the objective is to accelerate the structure and produce innovation. The overtime function of basement work is to increase stability and access. This is defining the sets of transformation processes applicable to different groups of benchmarking data classified according to their attributes. (Choi et al., 2020).

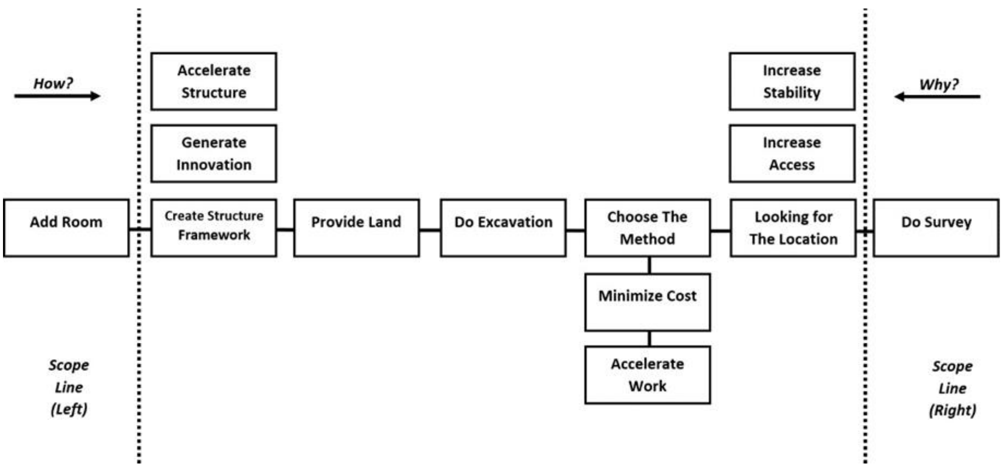

Figure 6 FAST Diagram of Basement Structure

3.3 Alternative Method

1) A Ground Anchor is a structural component mounted on a retaining wall to move the tensile load applied to the ground to withstand lateral loads (Aldo and Susilo, 2018). The installation of ground anchors is also divided into two systems: active and passive. The active system is the pulling given to the anchor. While the active system is the force that occurs when the load begins to be given.
2) Strutting is one of the soil reinforcement methods arranged sequentially according to the excavation elevation. At the end of the side, it will be connected to a sheet pile to resist lateral forces caused by the soil.
3) Using a steel plate
   WF 588x300x12x20
   with specifications: h = 588 mm, b = 300 mm, tf = 20 mm, tw = 12 mm, fy = 240 MPa, fu = 370 MPa, and E = 200,000 MPa.

3.4 Result of Analytical Hierarchy Process (AHP)

AHP was developed by Thomas L. Saaty in 1980 (Haddad et al., 2015). It allows decision-makers to consider quantitative and qualitative criteria based on pair-wise comparisons, showing the relationship between objectives, evaluation criteria, sub-criteria, and alternatives hierarchically. Hierarchy structure The first step in applying AHP is to define the decision problem, identify the criteria, and establish the structural hierarchy. Pair-wise Comparisons: Decision-makers or experts conduct pair-wise comparisons using a scale ranging from 1 to 9 to evaluate the importance of each criterion relative to the other Cambridge, et al. l.2012). Weightage Calculation: The relative weights of each criterion are calculated using the eigenvector method. These weights are then used to prioritize the alternatives based on their performance about each criterion. This process helps determine the relative weights of each criterion. This includes defining the main objectives (e.g., minimizing costs, ensuring quality), evaluation criteria (e.g., material costs, labor costs, project duration), and sub-criteria (e.g., specific types of materials, labor efficiency) AHP is used to identify, analyze and reduce construction risks by organizing complex problems into a structured hierarchical model.

1) AHP Comparison Between Criteria

The following are the results of the intensity assessment questionnaire for comparisons between criteria:

Table 1 Comparison Intensity Between Criteria

Comparison	Intensity
Implementation Time vs Ease Implementation	1
Construction Cost vs Implementation Time	4
Construction Cost vs Ease of Implementation	8

The First Step is to make a 3x3 matrix according to the number of criteria and analyze it for each comparison. In Table 1, the intensity values provided by the respondents are shown based on the questionnaire that was given. The intensity values provided by the respondents are subjective or reflect real events experienced by the respondents.

Table 2 Criteria Comparison Matrix

Criteria	Implementation Time	Construction Time	Ease Implementation
Implementation Time	1	0.25	1
Construction Time	4	1	8
Ease Implementation	1	0.125	1
Total	6	1,375	10

As seen in Table 2, the green color is given because the comparison is done homogeneously. The blue color is given according to the assessment in Table 1. For values that are not given color, the distribution value of the assessment is in Table 1.

Step 2 is the calculation of the eigenvalues based on the values in Table 2 by dividing the values in certain matrix columns by the total value in each criterion column. If you have all the values, do the sum of the values per row. If the total value per row has been obtained, then each value is divided by three because the matrix used is 3 x 3, so the average eigenvalue per row is generated.

Table 3 Eigen Value Criteria

Eigen Value Criteria			Total	Average
0.167	0.182	0.1	0.448	0.149
0.667	0.727	0.8	2,194	0.731
0.167	0.091	0.1	0.358	0.119

Step 3 is to calculate the value of λmax. The calculation is performed by multiplying the total values in the comparison matrix with their respective average values. The purpose of calculating the eigenvalue is to make more realistic decisions based on subjective assessments. This is represented mathematically as follows in Equation (1):

λmaks = Σ Value of the Comparison Matrix x the Average Value

For Example, when we substitute the corresponding values, we get:

$$(6\text{x}0.149) + (1{,}375\text{x}0.731) + (10\text{x}0.119) = 3{,}094$$

Step 4 is the calculation of index consistency (see equation 2)

$$CI = (\lambda maks\text{-}n)/(n\text{-}1) = (3{,}094\text{-}3)/(3\text{-}1) = 0.047$$

Step 5 calculates the consistency ratio (CR), which is the ratio between the consistency index (CI) and the random index (IR). This is calculated using Equation (3):

For this example, substituting the values gives:

CR = CI/IR = 0.047/0.58 = 0.0814 < 0.1 (OK)

2) AHP Comparison of Methods to Implementation Time

The following is the result of the intensity assessment questionnaire for comparison of methods based on implementation time:

As seen in Table 5, the green color indicates that the comparison is done homogeneously. While the blue color indicates the assessment in Table 4. For values that are colorless, they are the distribution values in the assessment from Table 4.

Table 4 Intensity Comparison of Execution Time, Construction Time, and Ease Implementation

Intensity Comparison	Comparison	Time
Execution Time	Steel Platform vs Island-Type Strutting	6
	Steel Platform vs Ground Anchor	9
	Island-Type Strutting vs Ground Anchor	3
ConstructionTime	Steel Platform vs Island-Type Strutting	5
	Steel Platform vs Ground Anchor	3
	Island-Type Strutting vs Ground Anchor	1
Ease Implementation	Steel Platform vs Island-Type Strutting	1
	Steel Platform vs Ground Anchor	0.5
	Island-Type Strutting vs Ground Anchor	0.333

Table 5 Comparison Matrix against Execution Time, Construction Time, and Ease Implementation

mparisonMatrix	:mentationTime	Steel Platform	:land-Type Strutting	Ground Anchor
Against Execution Time	Steel Platform	1	6	9
	:land-Type Strutting	0.167	1	3
	Ground Anchor	0.111	0.333	1
	Total	1.278	7,333	13
Against Construction Cost	Steel Platform	1	5	3
	Island-Type Strutting	0.2	1	1
	Ground Anchor	0.333	1	1
	Total	1,533	7	5
Against Ease Implementation	Steel Platform	1	1	0.5
	Island-Type Strutting	1	1	0.333
	Ground Anchor	2	3	1
	Total	4	5	1,833

Table 5 shows the measurement matrix for analyzing the implementation time, construction cost, and ease of implementation of three structures: Steel Platform, Island-Type Structuring, and Ground Anchor. Step 2 calculates the eigenvalues based on the values in Table 5. This is done by dividing the values in certain matrix columns by the total value in each criterion column. If you have all the values, do the sum of the values per row. If the total value per row has been obtained, then each value is divided by three because the matrix used is 3x3, so the average eigenvalue per row is generated.

Step 3 is to calculate the value of λmax, which represents the maximum eigenvalue. The calculation is performed by multiplying each value in the comparison matrix by the corresponding average eigenvalue. The formula used to calculate λmaks\lambda_{maks}λmaks is shown in Equation (1):

λmaks = Σ Value of the Comparison Matrix x the Average Value

By applying this formula, we substitute the values from the comparison matrix and their respective average eigenvalues as follows:

λmaks = (1,278 x 0.764) + (7,333 x 0.166) + (13 x 0.070) = 3.1

This gives a result of:

λmaks = 3 . 1

Table 6 Eigen Value of Execution Time, Construction Time, and Ease Implementation

Eigen Value of	Eigen Value Criteria			Total	Average
Execution Time	0.783	0.818	0.692	2,293	0.764
	0.130	0.136	0.231	0.498	0.166
	0.087	0.045	0.077	0.209	0.070
Construction Time	0.652	0.714	0.6	1,966	0.655
	0.130	0.143	0.2	0.473	0.158
	0.217	0.143	0.2	0.560	0.187
Ease Implementation	0.252	0.2	0.273	1,723	0.241
	0.250	0.2	0.182	0.632	0.211
	0.0.5	0.6	0.545	1.645	0.548

Step 4 involves calculating the consistency index (CI), which measures the consistency of the comparison matrix. The formula for calculating CI is given by Equation (2):

CI = (λmaks-n)/(n-1) = (3.1-3)/(3-1) = 0.05

Step 5 calculates the consistency ratio (CR), which is used to assess how consistent the judgments are relative to random consistency. The formula for CR is given by Equation (3):

3) AHP Comparison of Methods to Construction Costs

To compare methods based on construction costs, we use the following formula to calculate λmaks , as shown in Equation (1):

λmaks = Σ Value of the Comparison Matrix x the Average Value (1,533x0.655) + (7x0.158) + (5x0.187) = 3,043

The consistency index (CI) is then calculated using Equation (2):
CI = (λmaks-n)/(n-1) = (3,043-3)/(3-1) = 0.022

The consistency ratio (CR) is computed using Equation (3):
CR = CI/IR = 0.022/0.58 = 0.0372 < 0.1 (OK)

4) AHP Comparison Between Criteria

For the comparison between criteria, λmaka is calculated using the same formula:

λmaks = Σ Value of the Comparison Matrix x the Average Value
(4 x 0.241) + (5 x 0.211) + (1.833 x 0.548) = 3,022

The consistency index (CI) is then calculated using Equation (2):
CI = (λmaks-n)/(n-1) = (3,022-3)/(3-1) = 0.011

The consistency ratio (CR) is computed using Equation (3):
CR = CI/IR = 0.011/0.58 = 0.0192 < 0.1 (OK)

Since CR=0.0192CR = 0.0192CR=0.0192 is less than 0.1, the consistency is acceptable.

5) Ranking of Alternative Methods

Afterward, a rating assessment is performed for each method using the average eigenvalue of the criteria multiplied by the average eigenvalue of the comparison of implementation time, construction cost, and ease of implementation.

The steel platform using Equation (4), strutting and Ground Anchor using Equation (4):
Steel Platform = (ΣEigen Value Criteria x Eigen Value Method)
= (0.149 x 0.764) + (0.731 x 0.655) + (0.119 x 0.241) = 0.6223

Strutting (ΣEigen Value Criteria x Eigen Value Method)
(0.149 x 0.166) + (0.731 x 0.158) + (0.119x0.211)
0.1653

Ground Anchor= (ΣEigen Value Criteria x Eigen Value Method)
= (0.149 x 0.070) + (0.731 x 0.187) + (0.119 x 0.548)
= 0.2124

6) LCC Analysis of Island-Type Strutting

For the LCC calculation of strutting, since new steel strutting is being used and needs to be dismantled, it involves an initial installation cost of USD 488,810.93, plus the present worth of maintenance costs, assuming a 12% interest rate over 30 years, which amounts to USD 472,484.65, and then subtracting the dismantling cost, with the same assumption, which is USD 1,959.15. Therefore, the total LCC obtained is USD 959,336.43.

7) LCC Analysis of Steel Platform

For the LCC calculation of the steel platform, using an initial cost of USD 359,177.36, and assuming a 12% interest rate and a 30-year service life for maintenance costs, the present worth is calculated to be USD 347,180.83. Therefore, the total LCC obtained is USD 706,358.19.

4. Conclusions

This study concludes that implementing Value Engineering (VE) on the basement structure work in the BRI Gatot Subroto Tower project has proven to provide significant cost savings. According to Pareto analysis results, basement and steel structure work account for a dominant percentage of the total project cost, specifically 81/50 and 94/66, respectively. The steel platform method was chosen as the best alternative compared to other methods, such as island-type strutting and ground anchor, based on the Analytic Hierarchy Process (AHP) results, which showed that the steel platform had the highest value of 0.6223 in terms of execution time, construction cost, and ease of implementation. The Life Cycle Cost (LCC) analysis also indicated that the steel platform method resulted in a cost saving of USD 256,827.85, or 26.7%, compared to the initial design using island-type strutting. Therefore, the application of VE in this project provides tangible benefits in terms of cost reduction and efficiency improvement without compromising work quality. Further research is recommended to explore other benefits of applying Value Engineering in a broader construction project context.

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