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Design Alternatives Selection for Cost and Time Efficiency Using Value Engineering Method: Case Study of Ramp 5 Wringinanom Junction Krian – Gresik Toll Road

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Abstract

The Surabaya Raya toll network encompasses two critical sections connected by the Wringinanom Junction and links the Trans Java Toll Road Surabaya – Mojokerto at KM 723 with the Krian – Gresik Toll Road at KM 3+300 in Wringinanom District, Gresik Regency. This junction includes four ramps to facilitate connectivity, with Ramp 5 intersecting the Surabaya – Mojokerto Toll Road Rest Area at KM 725A and serves traffic from Gresik to Surabaya. This intersection necessitates a design adjustment to enhance traffic flow and safety. There are several problems that will be resolved, including what alternative designs can be implemented, wheter alternative designs affect efficiency in terms of costs and time, which alternative designs are more efficient. Accordingly from these problems, the aim of this research is to analyse several design alternative, calculate and analyse time and cost comparison, analyse factors that can influence potential delays in construction completion and decide on the most efficient design alternative in terms of time and cost. The value engineering process comprised information gathering, creative ideation, analysis using the paired comparison method, and recommendation. In the creative phase, three design alternatives were proposed. The paired comparison analysis revealed that the third design alternative that features the tunnel construction under the rest area, is the most efficient, with an estimated cost of IDR 126,236,641,897.46, a duration of 98 days, and a more practical construction aspect. Consequently, the third design alternative was recommended for implementation in this study.

1. Introduction

The Surabaya Raya toll network plays a critical role in facilitating transportation and connectivity across the region. The Wringinanom Junction, a key intersection in this network, connects the Trans Java Toll Road Surabaya – Mojokerto at KM 723 with the Krian – Gresik Toll Road at KM 3+300. This junction is crucial for seamless vehicular movement between these major toll roads. Among the four ramps at this junction, Ramp 5, which intersects with the rest area on the Surabaya – Mojokerto Toll Road at KM 725A, requires a design adjustment to enhance traffic flow and safety.

Value Engineering (VE) is an essential methodology in optimizing project designs for cost and time efficiency while maintaining or enhancing performance and quality [1]. It is a systematic approach that involves a professional team focusing on the functions of a project, aiming to achieve desired outcomes at the lowest possible cost [2]. By analysing existing problems and developing creative solutions, VE seeks to maximize value through design improvements.

Several case studies have demonstrated the effectiveness of value engineering across various projects. For example, a value engineering analysis on the multi-story parking project at UNAIR Campus B in Surabaya led to significant design changes, including the reduction in the thickness of roof and floor slabs, resizing of beams and columns, and shortening of pile lengths. These modifications resulted in a cost reduction of IDR 14,514,456,000, which represents an 18.24% savings from the original budget [3]. Another example is the South-South Trans Java Road Network project, where value engineering suggested using a 4 cm thick asphalt concrete wearing course (AC-WC) for gradients above 4% to optimize the compliance with regulations and achieving cost efficiency [4]. Similarly, for the Kali Cengger Bridge construction on the Semarang-Solo Toll Road, value engineering proposed replacing the original 150 cm diameter bored pile foundation with two alternatives: a 100 cm diameter bored pile at 8 m depth or a 100 cm driven pile at 10 m depth. This adjustment offered savings of IDR 268,978,574 and IDR 1,335,083,971, respectively [5].

In this study, the value engineering method was applied to analyse and propose design alternatives for Ramp 5 at the Wringinanom Junction. The goal was to identify the most cost-effective and time-efficient design that also ensures ease of construction. The VE process was divided into four phases: information, creative, analysis, and recommendation. Each phase contributed to a comprehensive evaluation of the design alternatives, ensuring that the selected solution meets the objectives of the project. By leveraging value engineering principles, a robust framework is expected to be generated, particularly in enhancing the decision-making process for the construction of Ramp 5, which will also enhance the overall efficiency and functionality of the Wringinanom Junction within the Surabaya Raya toll network.

2. Methodology

The methodology of this study employs a structured Value Engineering (VE) approach to analyse and select the most efficient design alternative for Ramp 5 at the Wringinanom Junction. The process is divided into four distinct phases: Information, Creativity, Analysis, and Recommendation. Each phase is strategically designed to systematically evaluate the project, aiming to identify the optimal solution based on cost, time, and ease of implementation.

2.1 Value Engineering Approach

2.1.1 Information Phase

In the initial phase of this study, comprehensive data collection was undertaken to gather all relevant information about the project. This included current design specifications, site conditions, traffic data, and any specific constraints or requirements associated with the construction of Ramp 5.

2.1.2 Creative Phase

During the creative phase, alternative design solutions were developed through brainstorming and innovative thinking. Three design alternatives for Ramp 5 were proposed:

- **Alternative 1:** Implement a dedicated lane for vehicles transitioning from the Trans Java toll road to the rest area at KM 725A.
- **Alternative 2:** Relocate the rest area from KM 725A to KM 727A.
- **Alternative 3:** Construct a tunnel underneath the rest area at KM 725A.

2.1.3 Analysis Phase

The analysis phase involved a detailed evaluation of the proposed design alternatives using cost, time, and ease of implementation as criteria. The paired comparison method and evaluation matrix were employed to quantitatively assess each alternative [6]. Table 1 shows the Paired Comparison Method Index employed in this study. This method facilitated the determination of the relative importance of various criteria by comparing them in pairs. The outcomes were then utilized to assign weights to each criterion.

Table 1 *Paired comparison method index*

	B	C	Score	Perecentage (%)	Decription
A	A2	C2	2	33	A
	B	C2	0	0	B
		C	4	67	C
Total			**6**	**100**	

The evaluation matrix integrated both qualitative and quantitative criteria to ensure a comprehensive decision-making process. Each design alternative was assessed and scored based on cost, time, and ease of implementation, with weights assigned according to the results from the paired comparison method. Table 2 shows the evaluation matrix used in this study. Each design alternative for work items A, B, and C analysed in Value Engineering was assessed based on cost, time, and ease of implementation. The weights for these criteria were derived from the paired comparison method table. Specifically, the weight (W) and index (I) values were used to calculate the score (Y) for each criterion by multiplying the weight by the index. The total score for each alternative (∑Y) was then computed as the sum of all weighted scores. The alternative with the highest total score was selected as the optimal work item. Column 1 to 9 represent the assumed criteria for evaluating these work items, ensuring that each design alternative was scored comprehensively and weights were assigned appropriately based on the paired comparison results.

Table 2 *Evaluation matrix*

No	Function Weight	Criteria									Total
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
		W	**W**	**W**	**W**	**W**	**W**	**W**	**W**	**W**	
1	**A**	I	I	I	I	I	I	I	I	I	∑Y
		Y	Y	Y	Y	Y	Y	Y	Y	Y	
2	**B**	I	I	I	I	I	I	I	I	I	∑Y
		Y	Y	Y	Y	Y	Y	Y	Y	Y	
3	**C**	I	I	I	I	I	I	I	I	I	∑Y
		Y	Y	Y	Y	Y	Y	Y	Y	Y	
										Total	

2.1.4 Recommendation Phase

In the final phase, the results from the analysis phase were synthesized to recommend the optimal design alternative. This involved presenting a detailed justification for the chosen design and emphasizing its advantages in terms of cost savings, time efficiency, and ease of implementation. This methodology provides a thorough and systematic evaluation of design alternatives, ensuring that the most efficient and effective solution is selected for the Ramp 5 construction project at Wringinanom Junction. The recommendation was supported by comprehensive data analysis, ensuring that the decision was well-informed and aligned with project goals. Table 3 shows the template of recommendation that would be generated from this study.

Table 3 *Template recommendation table*

Recommendation Phase	
Project	....
Location	....
Design Alternatives	....
Proposed Design	....
Savings	....
Basic of Consideration	....

3. Result Analysis and Discussion

3.1 Information Phase

Based on comprehensive data collection during the initial phase, the existing design of the intersection on the Krian Gresik Toll Road and Surabaya Mojokerto Toll Road is depicted in Figure 1. This intersection features four ramps, including Ramp 5, which is uniquely positioned at the Rest Area on the Surabaya – Mojokerto Toll Road at KM 725. Given that this rest area serves traffic from Gresik to Surabaya, a strategic redesign of Ramp 5 is essential to ensure smooth and safe vehicle transitions without disrupting the functionality of rest area. Considering the high vehicle traffic on this route, developing alternative designs is important to enhance traffic efficiency and improve user comfort.

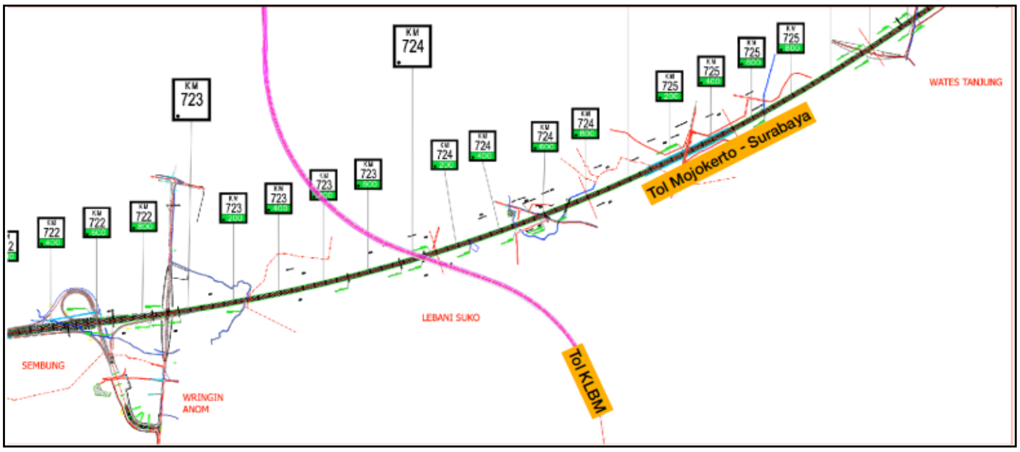


Fig. 1 *Initial design intersection of Krian Gresik toll road and Surabaya Mojokerto toll road*

3.2 Creative Phase

The Creative Phase is a pivotal stage in the Value Engineering (VE) process where innovative design alternatives are generated to address the identified problems and enhance the value of the project. During this phase, the project team brainstorms and explores various design solutions for Ramp 5 at the Wringinanom Junction. Three alternative designs were proposed, each offering distinct approaches to improve the functionality, cost efficiency, and time efficiency of the ramp.

3.2.1 Design Alternative 1

In Design Alternative 1, a dedicated line is proposed to facilitate the movement of vehicles from the Trans Java Toll Road directly to the rest area at KM 725A. This design aims to streamline traffic flow and reduce congestion at the junction. Figure 2 illustrates the 1st alternative design from this phase. The key features of this alternative include:

- **Dedicated Line**: A specific lane is constructed to separate traffic heading to the rest area from the main traffic flow, minimizing interference and enhancing safety.
- **At-Grade and Elevated Sections**: The design incorporates both at-grade and elevated sections to ensure a smooth transition for vehicles.
- **Cost Considerations**: While this design improves traffic flow, it involves significant construction costs due to the combination of at-grade and elevated structures.

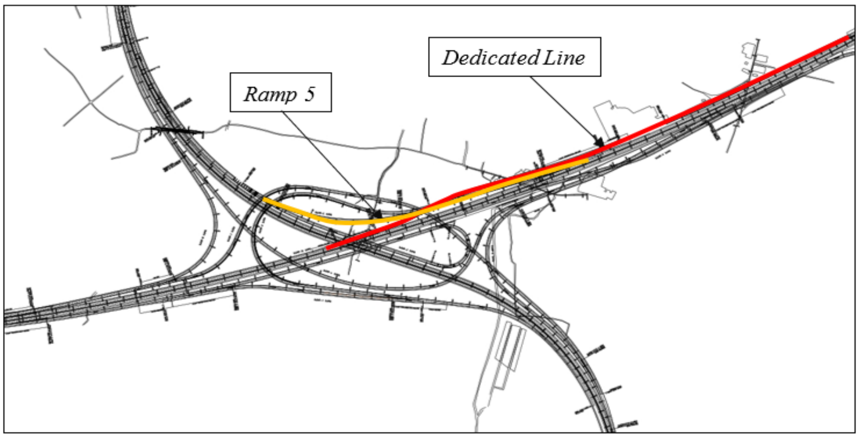


Fig. 2 *Alternative design 1 with dedicated line*

3.2.2 Design Alternative 2

Design Alternative 2 involves relocating the rest area from KM 725A to KM 727A, approximately 2 kilometres away. This alternative aims to eliminate the conflict between Ramp 5 and the rest area by physically separating them. The key features include:

- **Relocated Rest Area**: The rest area is moved to a new location at KM 727A, away from the intersection with Ramp 5.
- **Construction and Demolition**: This design requires the demolition of the existing rest area and construction of a new facility at the relocated site.
- **Land Acquisition**: Additional land acquisition is necessary for the new rest area, which adds to the project cost and complexity.

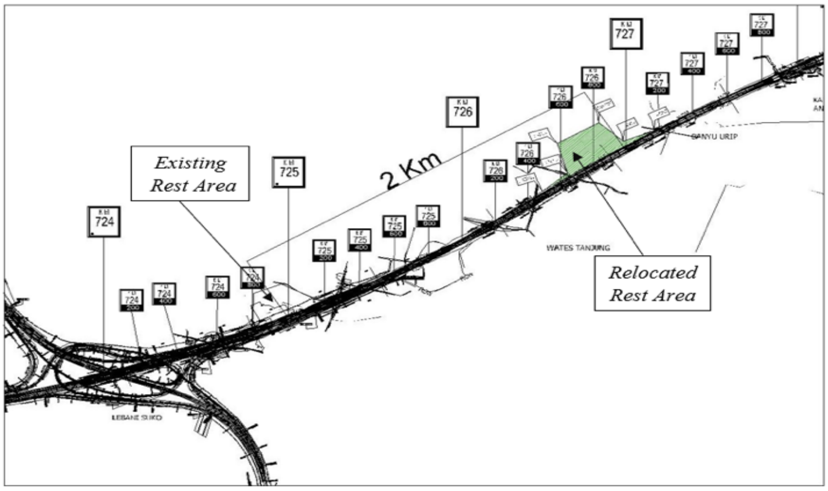


Fig. 3 *Alternative design 2 with relocated rest area to KM 727 A*

3.2.3 Design Alternative 3

Design Alternative 3 proposes constructing a tunnel under the existing rest area at KM 725A. This design seeks to maintain the current location of the rest area while providing an unobstructed route for Ramp 5 traffic. The key features include:

- **Tunnel Construction**: A tunnel is constructed beneath the rest area to allow Ramp 5 traffic to pass without interference.
- **Use of Precast Materials**: The design employs precast corrugated concrete sheet piles (CCSP) and precast bracing to enhance construction efficiency and structural integrity.
- **Cost and Time Efficiency**: This alternative is designed to be cost-effective and quick to implement, utilizing advanced construction techniques.

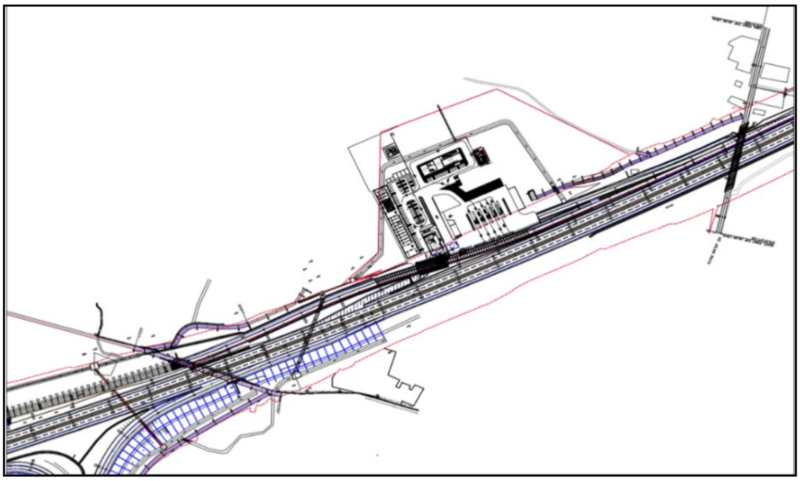


Fig. 4 *Alternative design 3 with tunnel under the rest area at KM 727 A*

Each of the three design alternatives presents unique advantages and challenges. The dedicated line in Alternative 1 offers a straightforward solution but at a higher cost. Relocating the rest area in Alternative 2 eliminates the conflict but involves significant demolition, construction, and land acquisition expenses. The tunnel in Alternative 3 provides a balance of cost, time, and ease of implementation, making it a strong contender for the final recommendation. By systematically evaluating these design alternatives, the Creative Phase sets the stage for the Analysis Phase, where the feasibility and efficiency of each option are rigorously assessed to determine the optimal solution for Ramp 5 at the Wringinanom Junction.

3.3 Analysis Phase

3.3.1 Cost Analysis of Design Alternatives

The cost analysis phase evaluates the financial implications of each proposed design alternative for Ramp 5 at the Wringinanom Junction. This analysis provides a detailed breakdown of the construction costs associated with each design, allowing for a comprehensive comparison to identify the most cost-effective solution. Table 4, 5, and 6 displays the cost estimation for the construction of Design Alterative 1, 2 and 3, respectively. The cost estimation for Design Alternative 1 involves constructing a dedicated line for vehicles from the Trans Java Toll Road to the rest area at KM 725A. This includes both at-grade and elevated sections. While the cost estimation for Design Alternative 2 includes the relocation of the rest area from KM 725A to KM 727A. This involves demolition, land acquisition, and new construction. Lastly, The cost estimation for Design Alternative 3 involves constructing a tunnel under the existing rest area at KM 725A. This design seeks to maintain the current location of the rest area while providing an unobstructed route for Ramp 5 traffic:

Table 4 *Design alternative 1 construction cost estimate*

I. Dedicated Line						
Construction Type	**Length (m)**	**Area (m^2)**	**Price/m^2 (IDR)**	**Price/Km (IDR)**	**Total Price/m^2 (IDR)**	**Total Price/KM (IDR)**
At Grade	1,540.73	12,325.83	4,335,719	34,685,754,872.74	53,441,348,419.33	53,441,348,419.33
Bridge	152.82	1,375.37	19,623,997	176,615,973,150.37	26,990,276,400.87	26,990,276,400.87
				Total Price (IDR)	**80,431,624,820.19**	**80,431,624,820.19**
II. Ramp 5						
Construction Type	**Length (m)**	**Area (m^2)**	**Price/m^2 (IDR)**	**Price/Km (IDR)**	**Total Price/m^2 (IDR)**	**Total Price/KM (IDR)**

At Grade	407.80	3,262.41	4,335,719	34,685,754,872.74	14,144,885,522.86	14,144,885,522.86
Piled Slab	328.00	2,952.00	6,250,233	56,252,093,412.33	18,450,686,639.24	18,450,686,639.24
Bridge	250.00	2,250.00	19,623,997	176,615,973,150.37	44,153,993,287.59	44,153,993,287.59
				Total Price (IDR)	**76,749,565,449.70**	**76,749,565,449.70**
				Grand Total I + II (IDR)	**157,181,190,269.89**	**157,181,190,269.89**

Table 5 *Design alternative 2 construction cost estimate*

I. Ramp 5

Construction Type	Length (m)	Area (m^2)	Price/m^2 (IDR)	Price/Km (IDR)	Total Price/m^2 (IDR)	Total Price/KM (IDR)
At Grade	707.80	5,662.41	4,335,719	34,685,754,872.74	24,550,611,984.68	24,550,611,984.68
Piled Slab	278.00	2,502.00	6,250,233	56,252,093,412.33	15,638,081,968.63	15,638,081,968.63
				Total Price (IDR)	**40,188,693,953.31**	**40,188,693,953.31**

II. Relocation of Rest Area KM 725A

Work Item	Volume	Area (m^2)	Price (IDR)	Unit	Total Price (IDR)
Demolition of Rest Area Building	-	21,034.16	546,500.00	m^2	11,495,168,440.00
Land Acquisition	-	60,896.64	500,000.00	m^2	30,448,322,000.00
Rest Area Construction	-	21,034.16	5,500,000.00	m^2	115,687,880,000.00
Gas Station Construction	-	3,500.00	4,377,460.17	m^2	15,321,110,600.00
500 Kva Electricity Connection	1	-	325,000,000.00	Ls	325,000,000.00
Existing Tenang Relocation Compensation	1	-	15,000,000.00	Tenant	630,000,000.00
				Total Price (IDR)	**173,907,481,040.00**
				Grand Total I + II (IDR)	**214,096,174,993.31**

Table 6 *Design alternative 3 construction cost estimate*

I. Ramp 5						
Construction Type	**Length (m)**	**Area (m^2)**	**Price/m^2 (IDR)**	**Price/Km (IDR)**	**Total Price/m^2 (IDR)**	**Total Price/KM (IDR)**
At Grade	1,646.00	13,168.00	5,103,412	40,827,296,928.64	67,201,730,744.54	67,201,730,744.54
Piled Slab	365.00	3,285.00	6,250,233	56,252,093,412.33	20,532,014,095.50	20,532,014,095.50
				Total Price (IDR)	**87,733,744,840.04**	**87,733,744,840.04**
II. Box Tunnel						
Construction Type	**Length (m)**	**Area (m^2)**	**Price/m^2 (IDR)**	**Price/Km (IDR)**	**Total Price/m^2 (IDR)**	**Total Price/KM (IDR)**
Box Tunnel	144.00	1,296.00	29,709,025.51	267,381,229,565.42	38,502,897,057.42	38,502,897,057.42
				Total Price (IDR)	**38,502,897,057.42**	**38,502,897,057.42**
				Grand Total I + II (IDR)	**126,236,641,897.46**	**126,236,641,897.46**

The cost analysis reveals that Design Alternative 3, involving the construction of a tunnel under the rest area at KM 725A, is the most cost-effective solution, with a total cost of IDR 126,236,641,897.46. Design Alternative 1, which includes a dedicated line, is the second most economical option at IDR 157,181,190,269.89. Design Alternative 2, which involves relocating the rest area, is the most expensive, with a total cost of IDR 214,096,174,993.31. This comprehensive cost analysis forms the basis for further evaluation and decision-making in the Value Engineering process.

3.3.2 Time Schedule Analysis of Design Alternatives

The time schedule analysis evaluates the duration required to complete each proposed design alternative for Ramp 5 at the Wringinanom Junction. This analysis provides a detailed breakdown of the construction timelines associated with each design, allowing for a comprehensive comparison to identify the most time-efficient solution. Figure 5, 6, and 7 illustrates the time schedule needed to construct the Design Alternative 1, 2, and 3, respectively.

The construction timeline for Design Alternative 1, which includes a dedicated line for vehicles from the Trans Java Toll Road to the rest area at KM 725A, is estimated to be 102 days. The key milestones for the construction of this design alternative is as follows:

- **Site Preparation**: Initial site preparation and mobilization activities are expected to take approximately 10 days.
- **At-Grade Section Construction**: Building the at-grade sections is projected to take around 50 days.
- **Bridge Construction**: The construction of the elevated sections (bridge) is estimated to take 42 days.

This timeline reflects the need for both at-grade and elevated construction, which contributes to a relatively moderate overall duration.

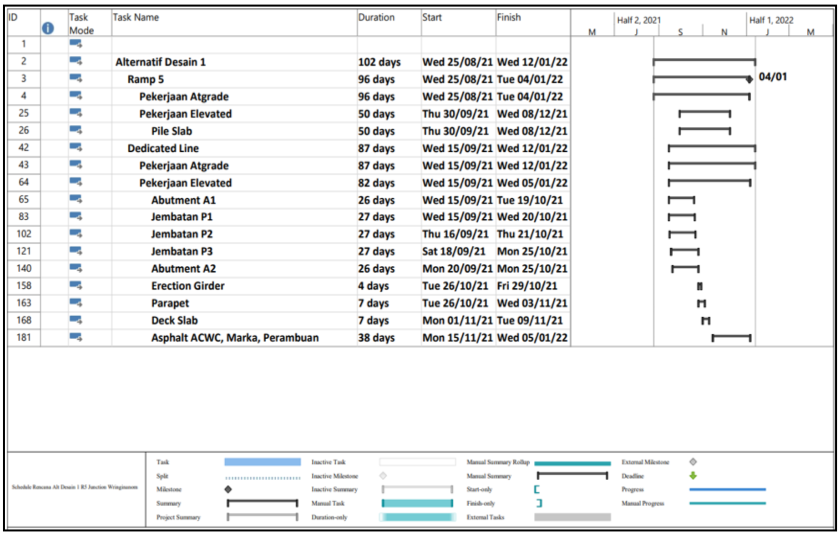


Fig. 5 *Design alternative 1 time schedule*

The construction timeline for Design Alternative 2, which involves relocating the rest area from KM 725A to KM 727A, is estimated to be 402 days. The key milestones for the construction of this design alternative is as follows:

- **Demolition and Land Acquisition**: Demolition of the existing rest area and acquisition of new land is expected to take about 90 days.
- **New Rest Area Construction**: Constructing the new rest area facilities at KM 727A is projected to take approximately 180 days.
- **Ramp 5 Construction**: Building Ramp 5 with the new alignment, including at-grade and piled slab sections, is estimated to take around 132 days.

The extended duration for this alternative is primarily due to the additional tasks of demolition, land acquisition, and new construction, which significantly increase the overall project timeline.

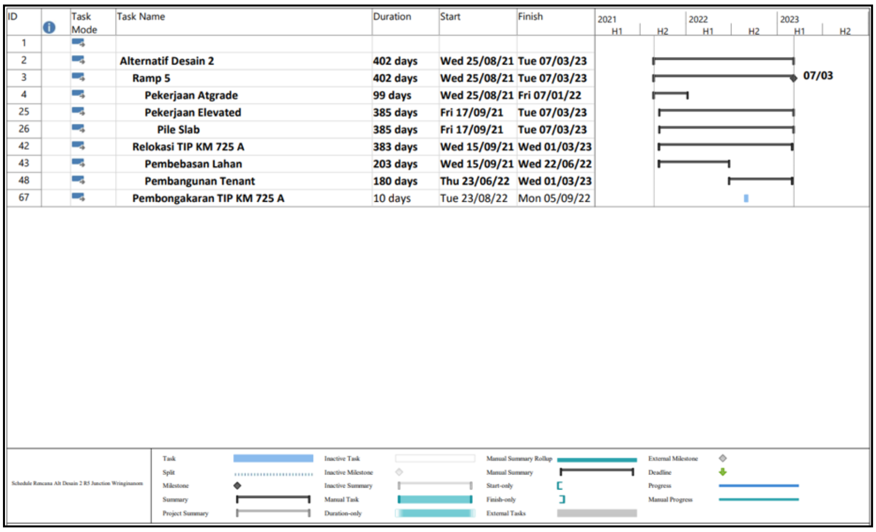


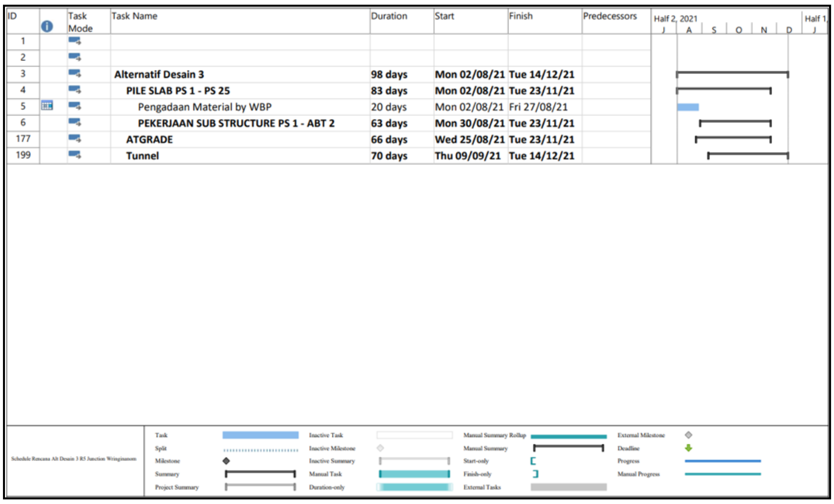
Fig. 6 *Design alternative 2 time schedule*

The construction timeline for Design Alternative 3, which proposes constructing a tunnel under the existing rest area at KM 725A, is estimated to be 98 days. The key milestones for the construction of this design alternative is as follows:

- **Site Preparation**: Initial site preparation and mobilization activities are expected to take approximately 10 days.

- **Tunnel Construction**: Building the tunnel under the rest area, including excavation and installation of precast materials, is projected to take around 70 days.
- **Final Works**: Additional construction activities, such as finishing and site restoration, are estimated to take 18 days.

This timeline demonstrates the efficiency of using precast materials and advanced construction techniques, which contribute to the shortest overall duration among the three alternatives.



ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1						
2						
3		**Alternatif Desain 3**	**98 days**	**Mon 02/08/21**	**Tue 14/12/21**	
4		**PILE SLAB PS 1 - PS 25**	**83 days**	**Mon 02/08/21**	**Tue 23/11/21**	
5		Pengadaan Material by WBP	20 days	Mon 02/08/21	Fri 27/08/21	
6		**PEKERJAAN SUB STRUCTURE PS 1 - ABT 2**	**63 days**	**Mon 30/08/21**	**Tue 23/11/21**	
177		**ATGRADE**	**66 days**	**Wed 25/08/21**	**Tue 23/11/21**	
199		**Tunnel**	**70 days**	**Thu 09/09/21**	**Tue 14/12/21**	

Fig. 7 *Design alternative 3 time schedule*

The time schedule analysis indicates that Design Alternative 3, which involves constructing a tunnel under the rest area at KM 725A, is the most time-efficient solution with a total duration of 98 days. Design Alternative 1, featuring a dedicated line, follows with an estimated duration of 102 days. Design Alternative 2, which involves relocating the rest area, is the least time-efficient with a total duration of 402 days. This comprehensive time schedule analysis informs the decision-making process by highlighting the relative time efficiency of each design alternative.

3.3.3 Ease of Implementation Analysis

The ease of implementation analysis evaluates the practical aspects and challenges associated with constructing each proposed design alternative for Ramp 5 at the Wringinanom Junction. This analysis considers factors such as construction complexity, the need for specialized equipment or techniques, and potential disruptions to the surrounding area.

For Design Alternative 1, which involves the construction of a dedicated line to the rest area at KM 725A, there are several implementation features to consider. The construction process requires the relocation of residents' graves, a task that necessitates sensitive handling and community engagement. Building the dedicated line, which includes both at-grade and elevated sections, requires significant coordination and integration with the existing infrastructure. However, the implementation is somewhat facilitated by previous similar constructions, providing a reference point that could reduce complexity. Despite these advantages, the combination of at-grade and elevated sections still poses considerable construction challenges.

Design Alternative 2 proposes relocating the rest area from KM 725A to KM 727A, which presents substantial logistical challenges. Similar to Alternative 1, it necessitates the relocation of residents' graves. Additionally, acquiring the new land for the rest area is a time-consuming and costly process. This alternative also involves the demolition of the existing rest area and the construction of a new one, which requires extensive planning and coordination. Moreover, the relocation and compensation of existing tenants add another layer of complexity to the project. Consequently, this design alternative is the most complex and potentially disruptive due to the extensive requirements for demolition, land acquisition, and tenant relocation.

Design Alternative 3, which involves constructing a tunnel under the existing rest area at KM 725A, is designed for ease of implementation. This alternative also requires the relocation of residents' graves. The main construction activity involves building a tunnel, which uses advanced techniques and precast materials. The use of Corrugated Concrete Sheet Pile (CCSP) Precast and precast bracing for the tunnel construction enhances efficiency and reduces on-site labour. Additionally, this design minimizes disruption to the rest area and surrounding infrastructure, as the tunnel allows for the continuous use of the rest area during construction.

Therefore, this alternative has better possibility to implement by utilizing advanced construction techniques and materials to minimize disruption and enhance the efficiency.

In summary, the ease of implementation analysis reveals that Design Alternative 3 is the most straightforward to implement due to its use of precast materials and minimal disruption to the existing infrastructure. Design Alternative 1, while benefiting from previous similar constructions, involves a mix of at-grade and elevated sections that present significant challenges. Design Alternative 2 is the most challenging to implement due to its extensive requirements for demolition, land acquisition, and tenant relocation. This analysis provides valuable insights into the feasibility and potential impact of each proposed solution, aiding in the selection of the optimal design for Ramp 5 at the Wringinanom Junction.

3.3.4 Paired Comparison Method

The comparative analysis evaluates the three proposed design alternatives for Ramp 5 at the Wringinanom Junction by integrating the results from cost, time schedule, and ease of implementation analyses. These criteria are assessed using a paired comparison method and an evaluation matrix to assign weights and scores to each alternative. Table 7 shows the paired comparison method weights that are used in this study.

Table 7 *Paired comparison method weights*

	B	C	Score	Percentage (%)	Description
A	B3	A2	2	25.0	A = Cost
	B	C3	3	37.5	B = Time
		C	3	37.5	C = Ease of Implementation
Total			**8**	**100**	

The evaluation involved three key criteria: Cost (A), Time (B), and Ease of Implementation (C). From the paired comparison method, it was determined that Time (B) is more important than Cost (A) with a major level of importance, hence labelled B3. Cost (A) is more important than Ease of Implementation (C) with a moderate level of importance, labelled A2, while Ease of Implementation (C) is more important than Time (B) with a major level of importance, labelled C3. These labels correspond to scores: 1 for slight importance, 2 for moderate importance, and 3 for major importance. Summing these scores, A has a score of 2, B has a score of 3, and C has a score of 3. These scores are then converted into percentages: B = 37.5%, C = 37.5%, and A = 25.0%, and used as weights in the evaluation matrix. Based on the weight assigned to each criterion, index numbers are calculated by multiplying these weights with the corresponding criteria for the work items. These include the cost index, time index, and ease of implementation index, as detailed in Tables 8, 9, and 10.

Table 8 *Paired comparison method cost index*

	B	C	Score	Percentage (%)	Description
A	A2	C3	2	25.0	A = Design Alternative 1
	B	C3	0	0.0	B = Design Alternative 2
		C	6	75.0	C = Design Alternative 3
Total			**8**	**100**	

Table 9 *Paired comparison method time index*

	B	C	Score	Percentage (%)	Description
A	A1	C3	1	14.3	A = Design Alternative 1
	B	C3	0	0.0	B = Design Alternative 2
		C	6	85.7	C = Design Alternative 3
Total			**7**	**100**	

Table 10 *Paired comparison method ease of implementation index*

	B	C	Score	Percentage (%)	Description
A	A2	C2	2	28.6	A = Design Alternative 1
	B	C3	0	0.0	B = Design Alternative 2
		C	5	71.6	C = Design Alternative 3
Total			**7**	**100**	

Design Alternative 1 that involves the construction of a dedicated line to the rest area at KM 725A, has a total cost of IDR 157,181,190,269.89 and an estimated construction duration of 102 days. The scores assigned to cost, time, and ease of implementation for this alternative were 25.0%, 14.3%, and 28.6%, respectively. This design involves moderate complexity due to the mix of at-grade and elevated sections and the need to relocate residents' graves, which influences its overall feasibility score.

Design Alternative 2 proposes relocating the rest area to KM 727A, making it the most expensive option with a total cost of IDR 214,096,174,993.31 and a construction duration of 402 days. The scores assigned to this alternative based on the paired comparison method were 0.0% for cost, time, and ease of implementation, reflecting its high complexity and extended timeline. This alternative involves significant logistical challenges, including demolition, land acquisition, and tenant relocation, making it the least favourable in terms of overall feasibility.

Design Alternative 3 that entails the construction of a tunnel under the existing rest area at KM 725A, emerges as the most favourable option. It is the most cost-effective solution, with a total cost of IDR 126,236,641,897.46 and the shortest construction duration of 98 days. This alternative received the highest scores for cost (75.0%), time (85.7%), and ease of implementation (71.4%) based on the paired comparison method. The use of advanced construction techniques and precast materials minimizes on-site labour and disruptions, allowing for continuous use of the rest area during construction.

The evaluation matrix combines these weighted scores to determine the total feasibility of each alternative. Design Alternative 3, with the highest cumulative score, emerges as the optimal solution, offering a balanced approach in terms of cost efficiency, time efficiency, and ease of implementation. Design Alternative 1, while providing moderate benefits, faces implementation challenges due to its dual construction nature. Design Alternative 2, despite its comprehensive approach, is hindered by high costs and extensive logistical complexities. Therefore, Design Alternative 3 is recommended as the most feasible and effective option for the construction of Ramp 5 at the Wringinanom Junction.

3.3.5 Evaluation Matrix

After making a paired comparison for the index and weight, the next step is to enter the three indexes into the evaluation matrix as follows.

Table 11 *Evaluation matrix*

No	Design Alternatives		Criteria			Total (∑Y)
			Cost	Time	Ease of Implementation	
	Weight (W)		25.0	37.5	37.5	
1	**1**	I	25.0	14.3	28.6	22.32
		Y	6.3	5.4	10.7	
2	**2**	I	0.0	0.0	0.0	0.0
		Y	0.0	0.0	0.0	
3	**3**	I	75.0	85.7	71.4	77.68
		Y	18.8	32.1	26.8	
					Total	**100**

Description :
W = Weight
I = Index
Y = Weight x Index , example: 25% x 25 = 6.3
∑Y = Total Sum of Row

There are 3 design criteria, each of which has a working weight, namely cost (25.0%), Time (37.5%), Method (37,5%. In this context, design criteria are important aspects that need to be considered when designing a project or product. These three criteria are: cost (25.0%) this indicates that 25% of the overall design assessment or consideration is based on the cost required to complete the project or product; time (37.5%) time has a greater weight of 37.5%. This means that the time required to somplete the project is a very important factor and contributes more to the overall assessment; method (37.5%) the method alsa has a weight of 37.5%. This means that the method or technique used in this project is as important as time and has a major role in determining the overall quality of the design.

Assigning values to weights based on the importance of design criteria through analysis using the paired comparison method. The paired comparison method is used to determine the priority or importance of various different criteria. In this context, this method might be used to determine the working of each design criterion. This is done by comparing each criterion individually against the other criteria to see which is more important. For example, you might compare cost to time, cost to method, and time to method. From these comparisons, you can determine hox important each criterion is relative to the others, which is then used to determine nthe final weight.

From each design, the index is multiplied by its working weight. Once the weights are determined for each criterion. The next step is to multiply these weights by the performance index or score for each criterion. This index might be a value derived from assessing the quality, effectiveness, or how well the criteria are met in the design.

3.4 Recommendation Phase

The Recommendation Phase consolidates the findings from the previous analyses to propose the best design alternative for Ramp 5 at the Wringinanom Junction. Based on the comprehensive evaluation of cost, time, and ease of implementation, Design Alternative 3, which involves constructing a tunnel under the existing rest area at KM 725A, is recommended as the optimal solution. Table 12 shows the recommendation table as the summary of this phase.

Table 12 *Recommendation table*

Recommendation Phase	
Project	Ramp 5
Location	Wringinanom Junction, Krian Gresik Toll Road
Design Alternatives	• Ramp 5 with a dedicated line to Rest Area KM 725A • Ramp 5 with Relocation Rest Area KM 725A to KM 727A
Proposed Design	Ramp 5 with the Tunnel Construction under Rest Area KM 725A
Savings	Rp. 87,859,533,095.85
Basic of Consideration	Based on cost, Ramp 5 with tunnel construction is more economical with a cost difference of Rp. 87,859,533,096.31 compared to Ramp 5 with TIP KM 725A relocation (Design Alternative 2). Based on time, Ramp 5 with tunnel construction is faster with a difference of 304 days compared to Ramp 5 with Relocation of Rest Area KM725A is not necessary additional land acquisition for the relocation of TIP KM 725A Based on ease of implementation, Ramp 5 with tunnel construction is easier because it uses precast CCSP and precast Bracing materials

4. Conclusion

This study applied the Value Engineering (VE) method to evaluate and select the most efficient design alternative for Ramp 5 at the Wringinanom Junction by considering cost, time, and ease of implementation. The analysis identified three design alternatives: a dedicated line, relocation of the rest area, and a tunnel under the existing rest area. Using the paired comparison method and evaluation matrix, Design Alternative 3 that involves the construction of a tunnel, emerged as the most favourable option. It demonstrated the lowest cost at IDR 126,236,641,897.46, the shortest construction duration of 98 days, and the highest scores for ease of implementation. This alternative benefits from advanced construction techniques and precast materials that minimise disruptions and allowing continuous use of the rest area. In contrast, the other alternatives presented higher costs, longer durations, and greater implementation complexities. Therefore, Design Alternative 3 is recommended as the optimal solution, balancing cost efficiency, time efficiency, and ease of implementation for Ramp 5 at the Wringinanom Junction.

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Conflict of Interest

We the authors declare that there are no conflicts of interest that could affect the objectivity or integrity of the research and results published in this paper. We also affirm that we have no personal, financial, or professional interests that could influence the analysis, conclusions, or recommendations presented in this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***project data collection and technical analysis and assisted in writing the methodology section****: Martinur Mubdi Syakurohin;* ***corresponding author, led the research process and development of of the value engineering methodology, contributed the drafting and final editing of the manuscript****: Rizki Astri Apriliani;* ***evaluating the time and cost efficiency of each design alternative and assisted in the analysis****: Rudy Santosa;* ***developed creative design alternatives and reviewed technical aspects****: K. Budi Hastono;* ***supported the analysis of results and final design recommendations and assisted in reviewing literature relevant****: Dayat Indri Yuliastuti.*

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