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Prioritization of Trans-Sumatra Toll Road Segment Phase II Using The Analytical Hierarchy Process

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Abstract
The construction of the Trans-Sumatra Toll Road (JTTS) is a national strategic project aimed at strengthening regional connectivity and boosting economic growth in Sumatra. PT Hutama Karya (Persero) is tasked with building over 2,700 kilometres of toll roads in Sumatra, as mandated by the Indonesian government. However, the implementation of Phase II has faced challenges such as delays in land acquisition, limited budgets, complex geographical conditions. These issues led to deviations from the planned time and budget, which could hinder the achievement of the project's national goals. This study aims to assist PT Hutama Karya, particularly the Toll Road Planning Division (RJT), in prioritizing toll road segments for Phase II. To address this, study employs the Analytical Hierarchy Process (AHP), a multi-criteria decision-making method. A hierarchical structure based on key objectives, evaluation criteria, and segment alternatives is developed, with expert-based weighting. Interviews with four subject matter experts (SMEs) identified four main criteria: traffic volume, land readiness, investment costs, and geographical conditions. The three segments evaluated were Betung–Tempino–Jambi, Jambi–Rengat, and Rengat–Pekanbaru. The analysis, using a pairwise comparison questionnaire processed with SuperDecision software, revealed that the Betung–Tempino–Jambi segment is the best to prioritize due to its high traffic volume, better land readiness, lower investment costs (Rp21.01 trillion), and more favorable geographical conditions. Rengat–Pekanbaru ranked second, while Jambi–Rengat ranked third due to higher costs and more challenging conditions. This study contributes practical insights for PT Hutama Karya and suggests future research directions in infrastructure management.

INTRODUCTION

Infrastructure plays a vital role in supporting national economic growth, particularly in reducing logistics costs, improving transportation efficiency, and promoting regional development equity (Firdaus et al., 2019; Wibisono & Yani, 2020; Rasyid et al., 2021; Suprayitno et al., 2022; Santosa & Permana, 2023). The Trans-Sumatra Toll Road Project is designed not only to support connectivity but also as a catalyst for long-term economic growth on the island of Sumatra, by strengthening the integration of the industrial and financial sectors (Kurniawan et al., 2020; Hidayat et al., 2022; Lestari & Yuliana, 2023; Rinaldi et al., 2021; Saputra & Marwan, 2020).

The Indonesian government, through Presidential Regulation No. 100 of 2014 and its amendment via Presidential Regulation No. 117 of 2015, has tasked PT Hutama Karya (Persero), a strategic state-owned construction company, to build and manage 24 toll road sections in Sumatra, eight of which were targeted to be operational by 2019 (Azhari & Azizah, 2020; Prasetyo & Hapsari, 2021; Damayanti & Siregar, 2023). The largest economic contributions in Sumatra come from North Sumatra and Riau provinces, each contributing over 22% to Sumatra's regional domestic product (RDP), while provinces like Bengkulu and Aceh have smaller contributions but still show positive growth above 4% (BPS, 2023; Sari & Hidayah, 2021; Putri et al., 2022).

In 2014, Hutama Karya officially accepted the national strategic project to develop the Trans-Sumatra Toll Road. Through Presidential Regulation No. 100 of 2014, later updated to Presidential Regulation No. 117 of 2015, Hutama Karya was mandated to establish 2,770 kilometres of toll roads in Sumatra, prioritising the first eight sections until 2019, along 650 kilometres. At this time also, PT. Hutama Karya (Persero) re-established a new Toll and Bridge Infrastructure Construction subsidiary to support the national strategic project.

Vision: Indonesia's Most Valuable Infrastructure Developer Mission:

1. Succeeding the government's mandate to build and operate the TransSumatra Toll Road.
2. Develop infrastructure-based multi-businesses through service investment, construction, and manufacturing businesses that can provide premium value-added to corporations while accelerating Indonesia's economic growth.
3. Build sustainable corporate capacity and capability by strengthening human and financial capital and creating a safety culture within the company to build sustainable corporate capacity and capability.

PT Hutama Karya (Persero) has a hierarchical organizational structure to manage its operations efficiently. The President Director leads the structure. The company also operates subsidiaries and business units, such as PT Hakaaston, PT Hutama Karya Infrastruktur, and PT HK Realtindo, to support its infrastructure development goals.

The RJT (Toll Road Planning) Division of PT Hutama Karya has an essential role in the planning and development of toll road projects. This division is led by the EVP and is divided into three main sections: Supervision & Quality, Planning & Engineering, and Planning, Funding & Investment. Sub-sections such as technical, BIM, contracts, and financial systems. In addition, there are also supporting teams such as secretaries, QHSSE, and expert staff. This structure is designed to support complex teamwork and ensure that every aspect of the toll road project can effectively coordinate.

The development of the Trans Sumatra project is divided into four phases. Each phase has its specific time. The total length of this project is 2836 km. The constructed toll road is 1.235 km, with 987,45 kilometres entirely operated toll road.

From January 2025, the Trans-Sumatra Toll Road project will enter Phase 2, which is strategically planned to support regional connectivity and economic equality throughout Sumatra. The construction of these sections is targeted for completion in 2029, in line with the government's long-term infrastructure roadmap to improve logistics efficiency and accelerate each province’s mobility

PT Hutama Karya (Persero) is experiencing significant delays in constructing the Trans-Sumatra Toll Road project due to multiple challenges, including incomplete land acquisition, stalled funding, and complex technical obstacles on site. Extreme weather conditions and difficult geographic landscapes have further impeded construction activities. Additionally, increasing material and labour costs have added pressure on project timelines and budgets. These delays have resulted in operational schedules deviating substantially from initial targets, potentially leading to reduced revenue and substantial cost overruns.

By 2023, the Company had successfully constructed 67.8 kilometres of the Trans-Sumatra Toll Road with a total investment of Rp17,938 billion. The actual construction length fell short of the RKAP’s target of 99 kilometers, with an investment allocation of Rp24,059 billion for 2023. There were two main reasons for this shortfall: land acquisition challenges and delays in issuing the Toll Road Concession Agreement (PPJT). Most of the delays in land acquisition were caused by administrative bottlenecks at the National Land Agency (BPN) and delays in clearing customary lands. A further obstacle to construction progress was the absence of a finalized PPJTs document for the Betung-Tempino-Jambi segment and the Pekanbaru ring road. In the BUJT segment, these deviations significantly underperformed revenue targets.

In the fourth quarter of 2023, certain sections of the JTTS toll road that have been in operation did not meet their toll revenue targets. The discrepancies observed in the Terbanggi Besar - Pematang Panggang - Kayu Agung and Pekanbaru-Dumai sections were attributed to the expectation that tariff adjustments would be applied from the start of Quarter 1; however, these adjustments have not yet taken place. Additionally, the deviation in the Binjai-Stabat section is linked to a drop in traffic volume resulting from a 10% tariff reduction on the Medan-Binjai Toll Road and the commencement of operations on the Stabat-Tanjung Pura section at the start of Quarter III, which has also not yet been realized. The deviation in the Pekanbaru-Bangkinang section assumes a 12% decline in traffic at the beginning of Ramadan, but the actual traffic reduction was 21%. Another deviation happened in the Taba Penanjung-Bengkulu section, which assumes an 11% decrease in traffic volume at the start of the Ramadhan month, but the actual traffic volume reduction was 19%.

The acceleration of infrastructure development, particularly the Trans-Sumatra Toll Road (JTTS), is crucial to achieving Indonesia's long-term vision of equitable economic growth across regions. Despite its status as a National Strategic Project, Phase II of the JTTS continues to face persistent delays caused by challenges in land acquisition, limited budget allocations, and complex geographical conditions. Previous studies (e.g., Raharjo et al., 2021; Putri et al., 2023) have investigated risk factors and financing feasibility in toll road construction but have yet to provide a structured prioritization framework that guides project segmentation in constrained environments. This research addresses that gap by introducing a decision-support model using the Analytical Hierarchy Process (AHP), which integrates multiple expert-weighted criteria—traffic volume, land readiness, investment cost, and geographical conditions. The novelty of this study lies in the application of AHP for segment prioritization in a real-world megaproject context, incorporating both qualitative and quantitative assessments from key stakeholders. The objective is to assist PT Hutama Karya's Toll Road Planning Division (RJT) in systematically identifying the most feasible segment to prioritize for development. The findings are expected to not only contribute to more strategic project implementation but also to offer practical guidance for optimizing public investment and minimizing project delays.

I.1 Research Question & Objective

1. What criteria affect the priority selection of toll road segments?
2. Which toll road segment is the best to prioritize?
3. What is the improvement plan for the future?

I.2 Research Scope and Limitations

Scopes:

This research aims to identify the best alternative segment for prioritization within Stage II of the Trans-Sumatra Toll Road project, focusing specifically on Segments 14, 15, and 16 under the responsibility of PT Hutama Karya's Toll Road Planning Division (Division RJT). The study involves discussions with subject matter experts (SMEs) within the division to determine viable alternative segments for further evaluation. The selection process employs the Analytical Hierarchy Process (AHP) methodology, which enables structured, multi-criteria decision-making based on expert judgment. Pairwise comparison questionnaires are distributed to selected respondents who possess relevant knowledge and are directly involved in the decision-making process within Division RJT. However, the study is limited in scope to prioritization analysis only; it does not include detailed planning, scheduling, or technical feasibility studies for the implementation of the selected segment. These exclusions define the boundaries of the research and highlight areas for future investigation.

RESEARCH METHOD

This chapter discusses and explains how the researcher designed the study, collected and analyzed the data to achieve the research goal. This chapter begins with the research design, which outlines the framework of the research flow. After the research design, the data collection method is explained. The researcher determines the data sources used for this study. The data is collected through tools such as questionnaires distributed to Highway toll.

Research Design

The research design of this final project is structured into five systematic stages aimed at addressing business problems related to prioritizing segments of the Trans-Sumatra Toll Road. Stage 1 begins by identifying the core business issues, formulating research questions and objectives, and defining the scope and limitations of the study. Stage 2 involves conducting a literature review, incorporating theoretical frameworks and findings from previous case studies to establish a solid academic foundation. In Stage 3, data collection is carried out through two channels: primary data obtained via pairwise comparison questionnaires, and secondary data gathered through non-structured interviews and company documentation. Stage 4 centers on data analysis using the Analytical Hierarchy Process (AHP) method, with the assistance of Super Decisions software to process and interpret the primary data, while secondary data is used to enrich and validate the analysis. Finally, Stage 5 formulates business solutions and strategic recommendations based on the results, concluding the research with actionable insights. This structured design ensures that the research remains methodical, objective, and aligned with its core purpose—delivering a reliable decision-making framework for toll road segment prioritization.

Data Collection Method

The data will be divided into 2, namely primary data and secondary data

1. Interview

The data will be collected through interviews with key Toll Road Planning Division personnel. These interviews aim to obtain detailed information about the conditions, challenges, and important factors that influence the prioritization of highway segments. Interviews are helpful because they allow deeper exploration of issues. By interviewing directly with 4 SME Toll Road Planning Division can capture practical insights and understand the real considerations behind project decisions. The interview method used a semi-structured approach, where the interviewer followed a list of guiding questions but still provided free space for further exploration or clarification during the discussion. This approach balances consistency between interview sessions and the depth of information obtained. Interviews were conducted with four subject matter experts (SMEs) to obtain diverse and applicable perspectives on toll road projects' planning and decision-making process.

Table 1. SME Respondent

No	Initial Name	Position
1	DAP	Junior Project Director, Supervision and Quality
2	DN	VP Planning & Engineering
3	HPW	VP Planning, Funding & Investment
4	IH	EVP Toll Road Planning Division

Source : Data by Researcher

Table 2. Quesiton Objective

No	Question Objective	Position
1	Company General Information	Head Subdivision Planning and Engineering
2	Trans-Sumatra Project condition	Sub-Section Planning and Engineering
3	Challenge in Project	Head Supervision and Quality
4	Criteria supporting decision making	Head Subdivision Planning, Funding & Investment

Source : Data by Researcher

Table 3. Quesiton Objective

Topic	No.	Main Question	Probes
Priority Criteria for Toll Road Segment	1	In your opinion, what are the key factors influencing the selection of toll road segments to prioritize?	Why are these factors considered important? Are there any real project examples you have been involved in?
	2	How does land acquisition readiness affect the smooth implementation of toll road construction?	Does land ownership status (government, community, private) affect the process? Are there any social or technical obstacles?
	3	How important is traffic volume or demand potential in determining the segment priority?	What data or indicators are usually used? Are segments near industrial zones more likely to be prioritized?
	4	To what extent does the required investment cost influence toll road segment prioritization?	Do segments with higher investment needs tend to be delayed? What are the typical cost components that drive investment differences?
	5	What geographical factors are usually considered before deciding to develop a toll road segment?	Does the topography (e.g., soft soil, highlands, swamps) affect construction time and cost? Do high rainfall or disaster risks like flooding/landslides become major obstacles? How about logistics access for heavy equipment to the project site?

2. Pairwise Comparison Matrix

The Analytic Hierarchy Process uses a comparative analysis approach, which makes the questionnaire format different from general survey forms. In AHP, participants are asked to compare criteria and alternatives in pairs to determine their relative importance. The questionnaire will be processed using the Super Decision Analysis software to facilitate this process.

The questionnaires will be distributed to the heads of subdivisions within the Tol Road Planning Division who are directly involved in the Trans-Sumatra project. Their judgments and preferences will be used to calculate each criterion's weights and prioritize the toll road segments. This method ensures that the decision-making process is based on structured expert input and reflects the actual priorities within the project environment.

Data Analysis Methods

1. **Analytical Hierarchy Process**

The Analytical Hierarchy Process decomposes a complex decision problem into a hierarchical structure, starting from the overall goal, down to criteria and sub-criteria, and finally to the decision alternatives. Saaty (2008) outlined the structured process of AHP in several stages:

1. Define the problem and determine the kind of knowledge required.
2. Structure the decision hierarchy, starting from the goal at the top, then criteria and sub-criteria at the middle level, and ending with decision alternatives at the bottom.
3. Construct pairwise comparison matrices for the criteria and alternatives, comparing elements at each level with respect to their importance toward the element above.
4. Synthesize the results by calculating the priority weights and aggregating them to determine the ranking of alternatives.
5. Check the consistency ratio to ensure the judgments made are reasonably consistent.

In the context of this study, AHP is employed to prioritize highway segments of the Trans-Sumatra Toll Road based on multiple evaluation criteria. The structure of the AHP model in this case includes:

1. Goal (Top Level):
   To determine the priority ranking of highway segments for development based on strategic and technical factors.

2. Criteria (Middle Level):
   - Traffic Volume: Evaluates current or projected traffic levels to assess demand.
   - Land Acquisition Readiness: Measures of land required for the toll road segment, including legal status, administrative progress, and potential for conflict or delay.
   - Cost of Investment: Refers to how much funding is needed to build the toll road, including land costs, construction, and necessary facilities.
   - Geographical Condition: Includes technical aspects such as terrain type, soil condition, flood risk, and overall construction difficulty.
     Each criterion reflects different dimensions of urgency and value, forming a comprehensive basis for strategic decision-making.
3. Alternatives (Bottom Level):
   The decision alternatives consist of candidate highway segments being evaluated:
   - Segment 14: Bentung – Tempino – Jambi
   - Segment 15: Jambi – Rengat
   - Segment 16: Rengat – Pekanbaru
     Each segment will be assessed against the defined criteria using pairwise comparisons and priority calculations as part of the AHP methodology.
4. Framework Connections:
   Connections Between Criteria and Alternatives:
   The lines connecting each criterion to every alternative represent evaluating each highway segment against each criterion. This reflects that every segment is assessed for its alignment and performance relative to all key factors (criteria).

Here is the process to conduct AHP analysis (Taherdoost, 2017).:

1. Collecting data using questionnaires: To perform pairwise comparisons, a questionnaire should be distributed to respondents, such as managers, experts, or users, to gather their opinions. Each decision-maker assigns their preferred value for each element, and

individual judgments are then aggregated into group judgments for each pairwise comparison using their geometric mean. The scale ranges from one to nine, where one indicates that the two elements are equally important. At the same time, nine signifies that one element is significantly more important than the other in the pairwise matrix. The scale and the corresponding importance values for each number are outlined in the table.

Importance Scale	Definition of Importance Scale
1	Equally Important Preferred
2	Equally to Moderately Important Preferred
3	Moderately Important Preferred
4	Moderately to Strongly Important Preferred
5	Strongly Important Preferred
6	Strongly to Very Strongly Important Preferred
7	Very Strongly Important Preferred
8	Very Strongly to Extremely Important Preferred
9	Extremely Important Preferred

Figure 1. Importance Scale
Source : Data by Researcher

Which of the following criteria do you think is more critical for selecting best alterantive for road segment selection prioritize.

Criteria Scoring																			NAMA RESPONDEN:	JABATAN:
No	Criteria	Rating																	Criteria	Gomean Data
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		
1	A																		B	
2	A																		C	
3	A																		D	
4	A																		E	
5	B																		C	
6	B																		D	
7	B																		E	
8	C																		D	
9	C																		E	
10	D																		E	

Figure 2. Criteria Scoring
Source : Data by Researcher

"Criteria A"
Which road segments have better "Criteria A"?

Scoring Alternatif	A1																	NAMA RESPONDEN: 0	JABATAN: 0
Alternative	Rating																	Alternative	Gomean Data
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		
A1																		A2	

Scoring Alternatif	A2																	NAMA RESPONDEN: 0	JABATAN: 0
Alternative	Rating																	Alternative	Gomean Data
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		
A1																		A3	

Scoring Alternatif	A3																	NAMA RESPONDEN: 0	JABATAN: 0
Alternative	Rating																	Alternative	Gomean Data
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		
A2																		A3	

Figure 3. Alternative Scoring
Source : Data by Researcher

2. Synthesis Criteria Process

To achieve convergence within a set of answers through successive iterations, the process should be repeated multiple times to facilitate decision-making when dealing with an incompatible matrix. Subsequently, the raw data is converted into meaningful absolute values using the following formula to normalize the weights.

$$Aw = \lambda_{max}\, w\,, \lambda_{max} \geq n \text{ x}$$

$$\lambda_{max} = \frac{\sum aijwj - n}{w1}$$

$$\lambda_{max} = \{a_{ij}\}\ with\ a_{ij} = 1/a_{ij}$$

where:
A = pair wise comparison
W = normalized weight vector
λ_{max} = maximum eigenvalue of matrix A
a_{ij} =numerical comparison between the values i and j

Calculating their eigenvalue in each criterion, then proceeding with the average from this case, results in the most important criteria.

3. Find the consistency index (CI) is calculated using the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where:
CI = consistency index
λ_{max} = maximum eigen value of matrix A
n = number of compared elements

4. After the CI value is provided, continue to find the value of Random Consistency Index (RI).

: The value of Random Consistency Index,
Source: Golden and Wang (1990)

Dimension	*RI*
1	0
2	0
3	0.5799
4	0.8921
5	1.1159
6	1.2358
7	1.3322
8	1.3952
9	1.4537
10	1.4882

Figure 4. Random Consistency Index
Source : Data by Researcher

The RI value depends on the matrix size and is obtained from the table above. It is important to note that a consistency ratio below 0.10 indicates that the comparison results are acceptable.

5. To assess the consistency of the pairwise comparisons, the Consistency Ratio (CR) is calculated using the following formula:

$$CR = \frac{CI}{RI}$$

Where:
CR = Consistency Ratio
CI = Consistency Index
RI= Random Index (based on matrix size, retrieved from Saaty's RI table)

6. Perform Alternative Comparisons for Each Criterion
   Repeat the process for comparing alternatives with respect to each criterion.
7. Then find the total value of each Alternative
   For example:
   The score for Alternative 1 is calculated as:
   $$Alternative\ 1\ Score\ = (Average\ comparison\ of\ Alternative\ 1\ with\ Criterion\ 1\ \times Synthesis\ value\ of\ Criterion\ 1) + (Average\ comparison\ of\ Alternative\ 1\ with\ Criterion\ 2\ \times Synthesis\ value\ of\ Criterion\ 2) + (Average\ comparison\ of\ Alternative\ 1\ with\ Criterion\ 3\ \times Synthesis\ value\ of\ Criterion\ 3) + (Average\ comparison\ of\ Alternative\ 1\ with\ Criterion\ 4\ \times Synthesis\ value\ of\ Criterion\ 4)$$
8. Then ranking up to provide the highest score represents the best choice of the alternative. Confirm that the ranking aligns with the decision-making objectives.

RESULTS AND DISCUSSIONS

This chapter analyzes determining which toll road segments should be prioritized for development in the Trans Sumatra Toll Road phase II. The method used is the Analytical Hierarchy Process (AHP), which helps to develop a structured decision-making model. The analysis begins by reviewing several significant problems that arise in the early stages of the project, such as delays in implementation, obstacles in land acquisition, and declining revenue between sections. Based on the results of discussions with experts and references from literature, the main criteria were determined as the basis for the assessment: traffic volume, investment costs, land readiness, and geographical and operational conditions. The AHP method generates the best alternative toll road segment to be prioritized.

Analysis

Define the Problem and Objective

PT Hutama Karya faces several challenges in implementing the Phase II project. Some of them are the problem of unprepared land, limited funds, quite difficult geographical conditions, and the uncertainty of the number of vehicles that will pass. These things have a direct impact on toll revenues and have delayed construction on several road sections and not in accordance with the planned schedule. In addition, coordination between the parties involved and regulations that have not been running optimally have also slowed down the process. Therefore, a re-evaluation is needed to determine which segments should be prioritized most so the project can run faster and on target.

To answer this problem, this study aims to assist the team in the Toll Road Planning Division (RJT Division) in determining which toll road sections should be prioritized in JTTS Phase II. The assessment is structured using the Analytical Hierarchy Process (AHP) method, which analyzes several important criteria such as traffic volume, land readiness, investment costs, and geographical conditions. The main objective of this study is to determine the priority among three alternative segments, namely Betung–Tempino–Jambi, Jambi–Rengat, and Rengat–Pekanbaru. The results of this analysis are expected to be strategic recommendations for PT Hutama Karya in optimizing resources and increasing the effectiveness of project implementation.

Structuring the Hierarchy

Once the main objective is determined, the next step is developing a decision hierarchy structure to support the prioritization of the toll road segment. The Analytical Hierarchy Process (AHP) method allows complex problems to be broken down into several levels, from the main objective, assessment criteria, and decision alternatives (Kumar & Pant, 2023; Tavana et al., 2023).

In this study, the AHP hierarchy structure consists of three levels. The first level is the main objective: select the most appropriate toll road segment to be prioritized in Phase II of the JTTS project. The second level is the main criterion that is the basis for the assessment, namely:

1. Traffic Volume: Traffic volume is the primary consideration because it is directly related to the revenue projections from toll road operations. SMEs stated that roads with high traffic potential tend to be more promising in terms of financial feasibility and return on investment.
2. Land Readiness: Based on discussions with several engineering experts from the RJT Division, land unpreparedness significantly affects the engineering design process, even the risk of causing time deviations and cost overruns. The higher the level of land readiness, the lower the risk of administrative and social obstacles, so that development can begin more quickly and efficiently.
3. Investment Cost: Each toll road segment has different designs and technical requirements, ultimately affecting the total construction cost. This factor is important because the study must allocate an efficient budget according to the available funding capacity and fiscal support.
4. Geographical Conditions: All SMEs agreed that geographical conditions greatly contribute to the difficulty level in the construction process. Complex Land contours, such as mountain hills, swamps, and areas prone to flooding or landslides, require more engineering planning difficulties and longer construction times. In addition, logistical access to the project location is also a consideration when determining priorities because it affects the effectiveness of construction implementation in the field.

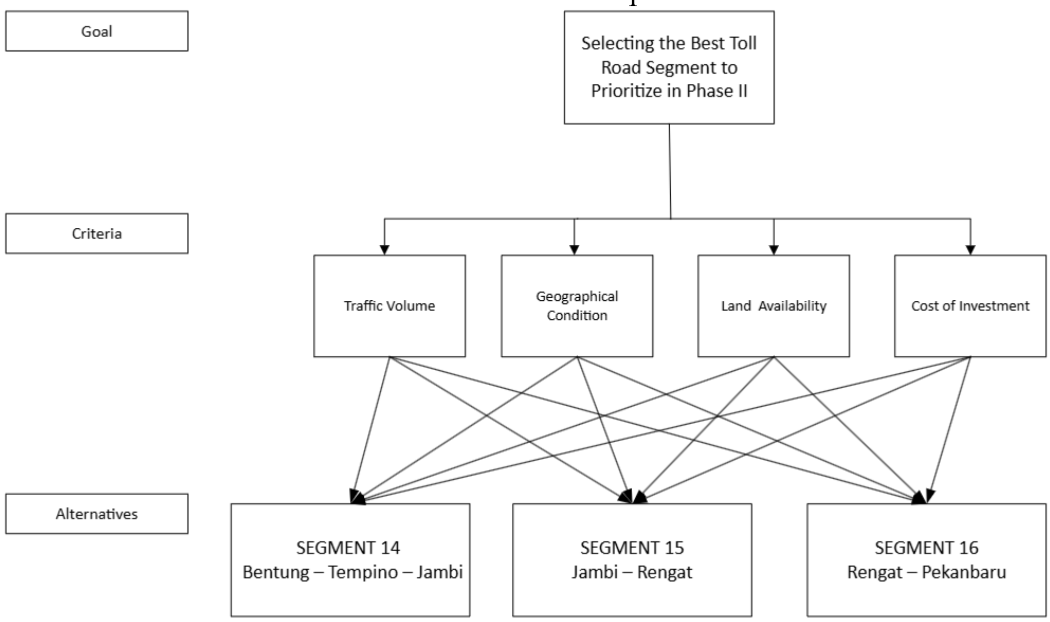


Figure 5. Analytical Hierarchy Process

Overview of the Toll Road Segment

- **Bentung – Tempino – Jambi**

The Betung-Tempino-Jambi toll road segment shows good prospects. Based on available data, this section records the average daily traffic of 7,094 vehicles, consisting of private vehicles, freight vehicles, and heavy vehicles. This volume indicates a real demand for more efficient transportation routes in the region. Operationally, this shows that this section has quite promising toll revenue potential.

This road stretches for ±169 kilometers through an area with dominant land characteristics in the form of plantations and production forests. This geographical challenge involves adjusting the road designs to the contours of the land and dense vegetation. In addition, some roads are located quite far from the city center and main access, which can complicate the logistics process during construction and the initial operational phase.

Meanwhile, the total investment cost for the development of this segment is estimated to reach around Rp 27 trillion, excluding land acquisition costs. This figure includes the toll road's main construction work, interchanges, rest areas, and other supporting facilities.

- **Jambi – Rengat**

The Jambi-Rengat segment is located in the Jambi and Riau Provinces with a route length of 198.1 kilometers and a planned speed of 100 km/hour. This toll road is designed for the initial stage with 2 x 2 lanes and will be increased to 2 x 3 lanes in the final stage of construction. The median used is a double concrete barrier type, with a rigid pavement structure for the main road, access, and intersections.

Geographically, this road route passes through a hilly forest area at the beginning and continues with a flat plantation area in the middle to the end. In the hilly area, expansive soil is found, so special structural handling is needed to avoid soil stability problems. Meanwhile, in the flat area, peat soil is found, which requires soil improvement so that the road construction remains stable and safe for long-term use.

Jambi-Rengat has an average daily traffic volume of 5,407 vehicles, which is considered medium for a provincial toll road. This segment has the highest investment value compared to other segments, around Rp 55.87 trillion. This large investment value is due to the combination of the route's length and the complex soil conditions along it.

- **Rengat – Pekanbaru**

The Rengat-Pekanbaru segment is located in Riau Province with a route length of 176.2 kilometers and a planned speed of 100 km/hour. In the early stages of construction, this section will be built with 2 x 2 lanes and will be increased to 2 x 3 lanes in the final stage. The road median uses a double concrete barrier type, with a combination of rigid and flexible pavement, both for the main route and access and intersections.

Geographically, this route starts from the plantation area and a small part of the forest area with flat to hilly land conditions. Entering the end of the route, the route crosses residential and plantation areas, still with flat to hilly topography. The main technical challenge in this segment is the discovery of peat soil in several locations, so soil improvement is needed to maintain the stability of the road structure.

From an operational perspective, this segment has an average daily traffic volume of 5,736 vehicles per day, which is included in the moderate category for a cross-provincial toll road section. The investment value for the development of this segment is Rp48.73 trillion, which is relatively high and indicates the need for large funds, possibly due to the combination of the length of the track, the type of double pavement, and the need for soil improvement structures in several locations.This section is also equipped with 8 type A rest areas, which are designed to support the comfort of road users on long-distance trips.

Pairwise Comparison

After determining the hierarchical structure, proceed to the next stage, pairwise comparison. The paired comparison process was conducted through direct interviews with respondents to better understand the reasons behind their scores for each criterion. To facilitate this process, the researcher prepared a special questionnaire that helped respondents understand what needed to be compared. The questionnaire is in the Appendix.

The results of this paired comparison are divided into two parts: comparison between criteria and alternatives against each criterion. All data obtained from respondents were then averaged using the geometric method before being used in the weight calculation process.

The following is a summary of the average results of the paired comparisons conducted between criteria and alternatives in this study. The responses were averaged before being used in the weight calculation process.

Table 4. Criteria Mean
Source : Data by Researcher

Criteria	Z				Geometric Mean
	R1	R2	R3	R4	
Geographical-Traffic Volume	0,20	0,17	0,20	0,20	0,19
Geographical Condition -Cost of Investment	0,50	0,50	0,33	0,33	0,41
Geographical Condition -Land Readiness	0,33	0,25	0,50	0,25	0,32
Traffic Volume - Cost of Investment	5,00	5,00	4,00	6,00	4,95
Traffic Volume - Land Readiness	3,00	3,00	4,00	4,00	3,46
Cost of Investment - Land Readiness	3,00	4,00	4,00	5,00	3,94

Weight Calculation

The data from the collected and averaged pairwise comparisons are then calculated to determine the weight of each criterion and alternative. Before the calculation process, the data is arranged in a pairwise comparison matrix, which can be seen in the Appendix.

The weight calculation process is carried out using software called SuperDecision. This decision-making software is based on the Analytical Hierarchy Process method.

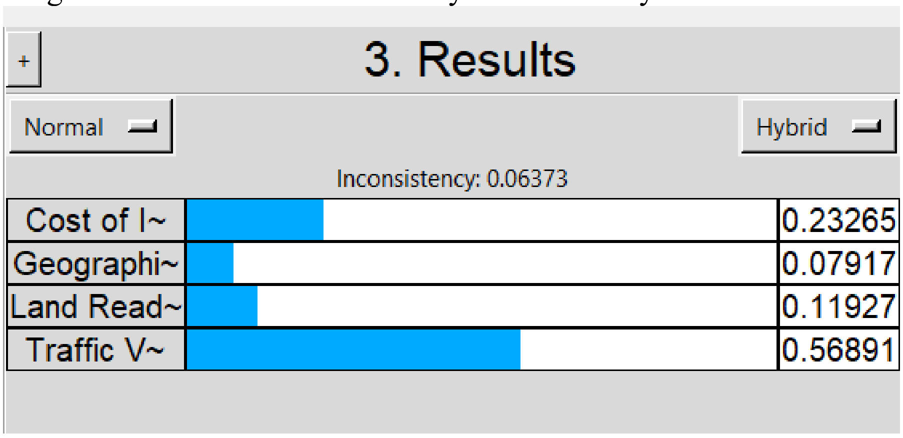


Figure 6. Criteria result
Source : Data by Researcher

Based on the SuperDecision software calculation results, the priority weight of each criterion used in decision-making is obtained. The results are shown in Figure X, with an inconsistent ratio value of 0.06373, which is below the threshold of 0.1. This shows that the respondents' assessment is consistent and acceptable.

Of the four criteria analyzed, traffic volume has the highest weight, 0.56891. This shows that, according to experts, the potential volume of vehicles that will cross the toll road section is the most important factor in determining development priorities because it is directly related to the projected income from the section.

The following criterion is the investment cost with a weight of 0.23265, which reflects attention to the efficiency of fund use and the complexity of technical design. Followed by land readiness with a weight of 0.11927, which, although its value is smaller, remains an important indicator in the smooth initial progress of development. Finally, the geographical condition gets the lowest weight of 0.07917, showing that although technically important, this factor is still manageable if other aspects, such as traffic and funding, are supportive.

This result illustrates that the decision on the priority of toll road segment development is greatly influenced by user demand (traffic) and its financial feasibility.

Develop Priority Ranking

This study analyzes four alternative road segments and compares them based on previously determined criteria: traffic volume, land readiness, investment costs, and geographical conditions. The goal is to determine which segment is most appropriate to prioritize according to the company's conditions and needs.

The four alternatives were assessed by interviewing expert respondents to obtain their views on which alternative is superior in each criterion. Furthermore, calculations were carried out using SuperDecision software to process and produce more accurate results. The following are the assessment results and weighting for each alternative based on input from respondents.

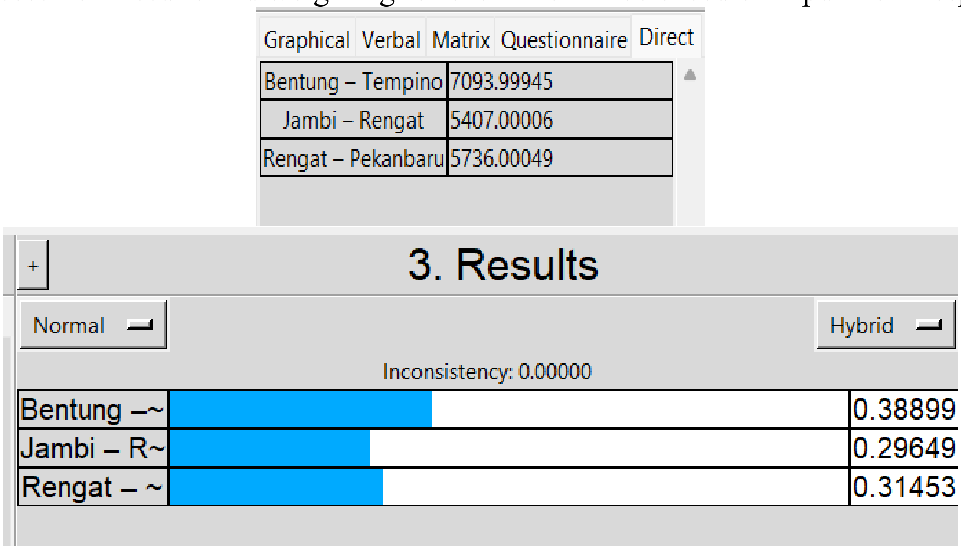


Figure 7. Alternative Result Based on Traffic Volume
Source : Data by Researcher

Figure IV.6 shows the results of alternative scores based on traffic volume criteria. The assessment was carried out using the direct input method, where the average daily traffic data (ADT) was entered directly into the system based on the available data. From these results, the Betung–Tempino–Jambi segment obtained the highest score of 0.38899, which reflects that this segment has the greatest traffic potential compared to the other two segments, namely Jambi–Rengat (0.29649) and Rengat–Pekanbaru (0.31453).

Traffic volume data shows that the Betung–Tempino–Jambi segment has an average daily traffic of around 7,094 vehicles, while Rengat–Pekanbaru has 5,736 vehicles, and Jambi–

Rengat has 5,407 vehicles. With these values, it can be concluded that in terms of vehicle demand, the Betung–Tempino–Jambi segment has the highest appeal and has the potential to provide the largest contribution to toll revenue in the future.

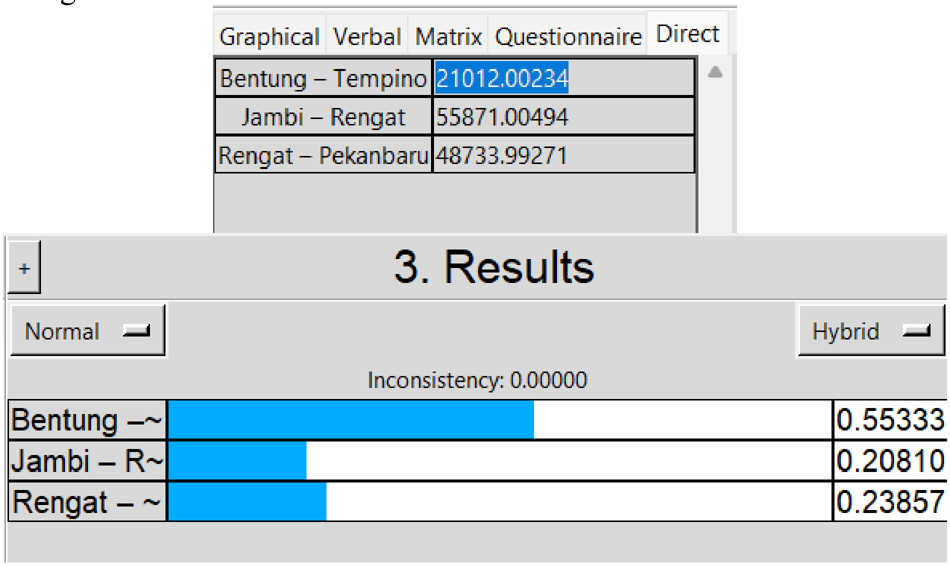


Figure 8. Alternative Result Based on Investment Cost
Source : Data by Researcher

Figure IV.7 shows the results of alternative weighting based on investment cost criteria. In this process, investment cost data for each segment is directly input into the system, then an inversion process is carried out, considering that in this context the segment with lower investment costs is considered more profitable and worthy of priority.

The assessment results show that the Betung-Tempino-Jambi segment has the highest weight of 0.55333, indicating that this segment is the best choice in terms of cost efficiency. Investment costs for this segment are recorded at Rp21 trillion, much lower than the other two segments. The Rengat-Pekanbaru segment has a weight of 0.23857, with a total investment of around Rp48.73 trillion, while the Jambi-Rengat segment has the lowest weight of 0.20810, with the highest investment requirement of Rp55.87 trillion.

From these results, it can be concluded that, if only considering the efficiency of budget use, the development of the Betung-Tempino-Jambi segment is the most rational choice. The relatively lower cost of investment allows the project to start more quickly and could attract faster funding support from the government and investors.

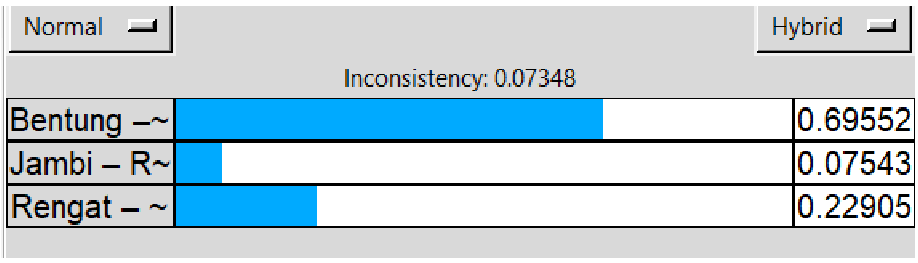


Figure 9. Alternatives Based on Geographical Condition
Source : Data by Researcher

Figure IV.8 shows the results of alternative weighting based on geographical condition criteria. This assessment considers the level of terrain difficulty, such as hilly land contours, swampy/peat areas, disaster risks such as floods or landslides, and ease of logistical access to the construction site. The more complex the geographical conditions of a segment, the greater the technical challenges that must be faced in the construction process.

The weighting results show that the Betung-Tempino-Jambi segment has the highest score of 0.69552, indicating that this segment has the most supportive geographical conditions compared to the other two segments. Based on technical information from the RJT Division, this section passes through an area with relatively flat land conditions and good accessibility, making it easier to work on technically.

The Rengat-Pekanbaru segment scored 0.22905, indicating that although the terrain is quite challenging, it is still in the category that can be handled. Meanwhile, the Jambi-Rengat segment showed the lowest score of 0.07543, which this mean a higher level of geographical difficulty, such as hilly contours, limited access, or other potential natural obstacles.

From these results, it can be concluded that in terms of geographical conditions, the Betung-Tempino-Jambi segment is the most feasible option to prioritize, because it has a lower technical risk.

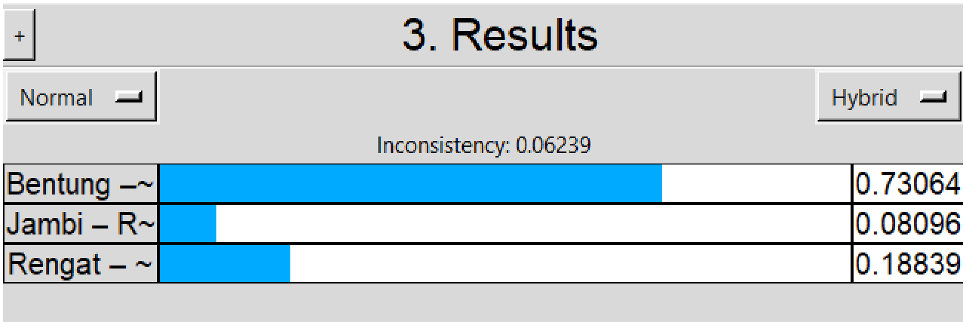


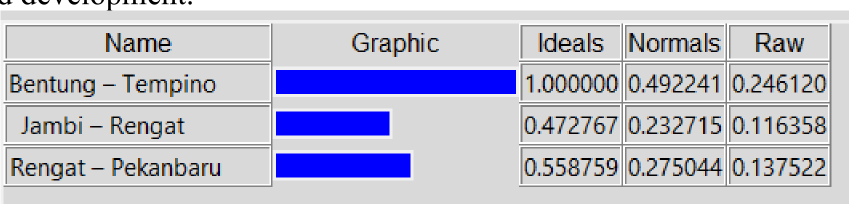
Figure 10. Alternative Result Based on Land Readiness
Source : Data by Researcher

Figure IV.9 displays the results of alternative weighting based on land readiness criteria. Land readiness is an important factor in toll road infrastructure projects, because the construction process cannot begin if the land has not been acquired. In addition, land unpreparedness often causes time deviations, technical design revisions, and additional unplanned costs.

Based on the results, the Betung-Tempino-Jambi segment has the highest weight of 0.73064, his segment is considered the readiest in terms of land availability compared to the other two segments. Information from internal parties' states that most of the land on this section is already in the final acquisition stage, and there is minimal potential for legal or social conflict.

The Rengat-Pekanbaru segment is in second place with a weight of 0.18839, which means that some land is still not ready, but the progress of its acquisition is considered quite good. Meanwhile, the Jambi-Rengat segment recorded the lowest weight of 0.08096, indicating that the land acquisition process in this segment is still far behind and risks delaying project implementation.

Thus, in terms of land readiness, the Betung–Tempino–Jambi segment is again the main choice for prioritization because it has the smallest risk of land acquisition and greater potential for accelerated development.



Name	Graphic	Ideals	Normals	Raw
Bentung – Tempino		1.000000	0.492241	0.246120
Jambi – Rengat		0.472767	0.232715	0.116358
Rengat – Pekanbaru		0.558759	0.275044	0.137522

Figure 11. Best Alternative Results
Source : Data by Researcher

Figure IV.10 displays the results of alternative calculations based on all criteria that have been analyzed using the AHP method. In this stage, the three toll road segments are compared to see which alternative is most worthy of being prioritized to be built first.

From the results displayed, the Betung-Tempino-Jambi segment obtained the highest score with an ideal value of 1,000 or a normal value of 0.492241, which means that this segment is the most superior choice compared to the other two alternatives. This result reflects the best performance of this segment based on four main criteria: traffic volume, land readiness, investment costs, and geographical conditions.

Meanwhile, the Rengat-Pekanbaru segment is in second place with an ideal value of 0.558759 and a normal value of 0.275044. This segment is quite good but is still less competitive than Betung-Tempino-Jambi, especially in terms of land readiness and cost efficiency.

The Jambi-Rengat segment is in last place with an ideal value of 0.472767 and a normal value of 0.232715, indicating that this segment is rated the lowest in terms of all the criteria used. Based on these results, it can be concluded that Betung-Tempino-Jambi is the most appropriate toll road segment to prioritize its development from a technical and strategic perspective.

Decision Analysis

The AHP process in this study aims to provide a clearer picture of the most appropriate decisions for the company. The final analysis is based on weighing all criteria for each alternative toll road section. The main objective of this analysis is to provide a clear picture to decision makers regarding which segments are most worthy of being prioritized in the implementation of Phase II of the Trans-Sumatra Toll Road (JTTS) project.

Best Priority Scheme

Based on the results of data processing using the Analytical Hierarchy Process method, the Betung-Tempino-Jambi segment was the alternative with the highest overall score. This segment excels in almost all main criteria, such as the highest daily traffic volume (7,094 vehicles/day), the lowest investment value (Rp21.01 trillion), relatively more mature land readiness, and geographical conditions considered the most favorable for construction implementation.

On the other hand, the Rengat-Pekanbaru segment is ranked second. Despite challenges related to peat land and a high investment value (Rp48.73 trillion), this segment still shows decent technical and daily traffic performance. The Jambi-Rengat segment is ranked third. Its investment value is the highest (Rp55.87 trillion) and faces technical challenges such as expansive soil and a limited land acquisition process. This makes this section less worthy of being prioritized in the early stages of development.

Business Plan and Solution

This implementation plan not only answers the technical aspects of the priority results of the sections but is also intended to answer the business challenges faced by the company, namely the delay in the realization of the JTTS Phase II project due to limited resources and inaccuracy in selecting development segments. By focusing on the Betung-Tempino-Jambi section, with the highest land readiness, the most efficient investment costs, and the lowest geographic risk, the company can optimize resource allocation and show significant progress towards the National Strategic Project target.

Based on the analysis results, PT Hutama Karya should start Phase II construction of the Betung–Tempino–Jambi segment, considering budget efficiency, technical readiness, and traffic potential. The implementation stages can be carried out in stages as follows:

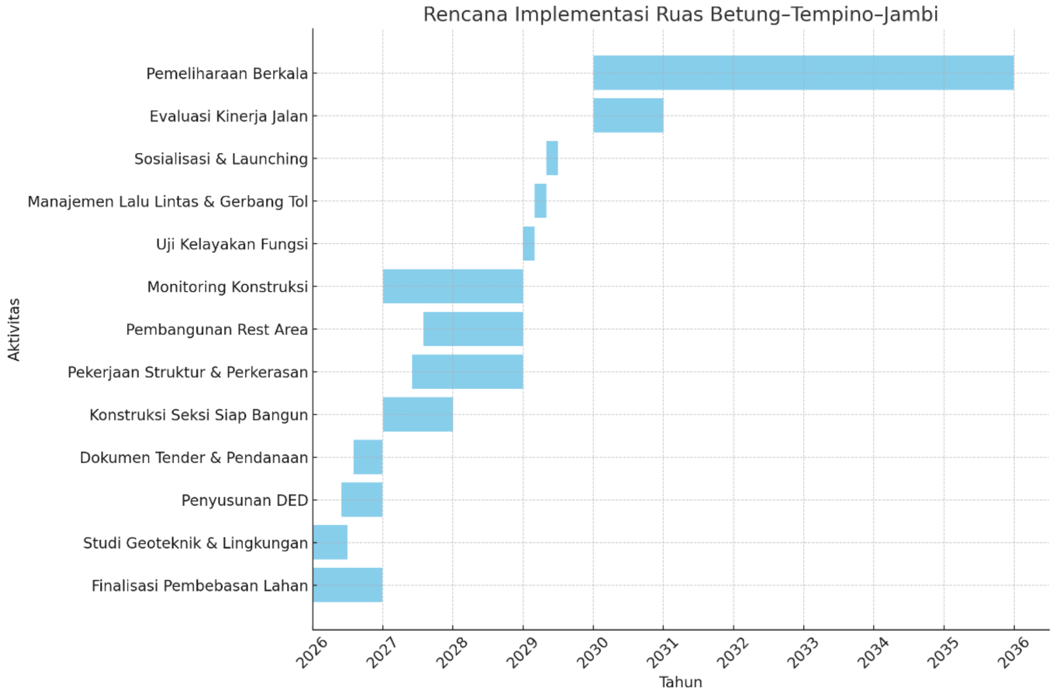


Figure 12. Implementation Plan for Bentung – Tempino-Jambi
Source : Data by Researcher

1. Stage 1: Pre-Construction
   This stage includes all preparatory activities before the start of physical construction. The main activities include finalizing the land acquisition process and collaborating with related agencies such as the Ministry of ATR/BPN and local governments. In addition, further geotechnical and environmental studies are carried out to identify potential technical risks, such as expansive soil At this stage, the Detail Engineering Design (DED) document is also prepared as well as procurement documents and financing schemes, both through government support (APBN) and business entity cooperation (KPBU). This entire process is planned to take place in 2026.
2. Stage 2: Construction
   Construction activities will begin in stages on land and on technically ready sections. The scope of work includes earthworks and structures such as embankments, excavations, and the construction of small bridges. The main pavement on this section uses rigid pavement according to the JTTS toll road technical standards. In addition, the main drainage channel, concrete median, road shoulder, and type A rest area, along with other supporting facilities, are also built. This construction phase is projected to take place from 2027 to 2028.
3. Phase 3: Initial Functional and Operational Testing
   Functional tests and improvements are carried out before the toll road is officially opened to the public. This stage includes a road feasibility test and the issuance of an Operational Certificate by the PUPR Ministry. Then, traffic signs, road markings, traffic control, and toll payment systems are installed. After that, socialization is carried out in the community and the official launch of operations by the government. This stage is planned to take place in 2029.
4. Phase 4: Operations and Maintenance
   After the toll road starts operating, routine monitoring and maintenance are carried out. These activities include evaluating daily traffic volume, toll road financial performance, and routine maintenance of road pavements, drainage channels, and public facilities.

Periodic evaluations are also carried out to review development needs, such as lane widening, if traffic increases. This stage is ongoing and starts in 2030.

This implementation plan is expected to be an initial guide for PT Hutama Karya in preparing technical and managerial strategies for effective and efficient construction following the objectives of the National Strategic Project to construct the Betung-Tempino-Jambi section.

CONCLUSION

This study was conducted to assist PT Hutama Karya (Persero), especially the Toll Road Planning Division (RJT), in determining the most appropriate toll road segment to be prioritized in implementing Phase II of the Trans-Sumatra Toll Road Project (JTTS). The main problems in this project are land readiness and technical resources, which can hinder the completion of the project according to the set time target. To answer these problems, a decision-making method based on the Analytical Hierarchy Process (AHP) was used.

The AHP method compares three alternative segments based on four main criteria: traffic volume, land readiness, investment costs, and geographical conditions. These criteria are determined based on the results of interviews with SMEs, internal technical data, and literature studies. Through pairwise comparisons, priority weights are obtained, which are then used to assess each alternative.

The analysis results show that the Betung-Tempino-Jambi segment has the highest score and is the best choice to prioritize. This segment excels in traffic volume and investment costs and has more supportive land readiness and geographical conditions compared to the other two alternatives. These findings are expected to be a strategic reference for PT Hutama Karya in designing and implementing the construction of Phase II of JTTS in a more focused and direct manner.

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