EVALUATING TOLL-ROAD REVENUE PERFORMANCE AND RISK FACTORS THROUGH MONTE CARLO SIMULATION: CASE-BASED LEARNING IN ENGINEERING ECONOMICS

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ABSTRACT
Although the Manado–Bitung Toll Road is a National Strategic Project intended to improve connectivity and logistics efficiency in North Sulawesi, realized revenues have not yet covered operating and maintenance expenditures, raising uncertainty about investment recovery within the 50-year concession period. This study evaluates the project's financial feasibility based on realized revenue performance and examines how key risk factors influence break-even and payback prospects. Using realized financial data from October 2020 to June 2025, the analysis applies cash-flow assessment, Break-Even Point (BEP), and Payback Period indicators, complemented by Quantitative Risk Analysis (QRA) with Monte Carlo simulation to model uncertainty in revenue growth, policy conditions, user behavior, and maintenance costs. The findings show cumulative revenue of IDR 232.75 billion against operating costs of IDR 253.56 billion, resulting in a persistent cash-flow deficit and a negative interim BEP. Monte Carlo outputs suggest that break-even is most likely to occur near the end of the concession (around year 48), with an estimated profitability probability of only 28% under the current trajectory, and the most influential risks are annual revenue growth and government policy/regulation, followed by user behavior and maintenance-cost escalation. The study concludes that while the project has high strategic value, it is not financially feasible in the medium term without intervention; therefore, policy support is needed to strengthen Bitung SEZ-driven logistics demand, improve traffic capture, and implement structured risk mitigation and efficiency measures. Future research should incorporate discounted cash-flow metrics (NPV/IRR), test alternative policy scenarios (tariff adjustments and incentives), and integrate broader socio-economic benefits into investment appraisal.

Keywords: Break-even analysis; Cash flow; Monte Carlo simulation; Revenue risk; Toll road investment

INTRODUCTION

The development of toll road infrastructure in Indonesia has become a strategic agenda of the government in its efforts to strengthen the foundation of national economic growth, enhance interregional connectivity, and support more equitable development across various regions. Since the acceleration of infrastructure development was mandated in the National Medium-Term Development Plan (RPJMN), the government has positioned the construction of toll road networks as one of the main drivers of national economic transformation. Toll roads are not merely viewed as transportation facilities but also as instruments of regional economic development that create supply chain efficiency, accelerate population mobility, and increase industrial competitiveness. In line with this objective, several National Strategic Projects (PSN) in the toll road sector continue to be promoted, including the Manado–Bitung Toll Road located in North Sulawesi Province. This toll road is a key infrastructure expected to link the administrative and public service center in Manado City with industrial zones, the international port, and the Special Economic Zone (KEK) in Bitung City. Its presence aligns with the government's vision to stimulate the eastern Indonesian region as a new economic hub integrated with international trade routes, natural resource–based industrial activities, and priority tourism destinations. Geographically and economically, the relationship between Manado and Bitung has long held strategic significance. Manado functions as a center of government activities, health services, education, commerce, and various service and business sectors that support regional activities. Conversely, Bitung has developed as an industrial and logistics hub centered around the Bitung International Port, the fisheries harbor, and several industrial processing facilities. The national government has also designated KEK Bitung as a special zone oriented toward agro-industry, fisheries, export logistics, and manufacturing. Given this substantial potential, the need for

infrastructure capable of facilitating economic activities between the two regions has become increasingly urgent. The Manado–Bitung Toll Road, with a length of approximately 39.79 kilometers, was developed as a solution to address supply chain delays, high logistics costs resulting from traffic congestion, and long travel times on the non-toll route. Constructed with an investment of more than IDR 4.5 trillion and operational in phases since 2020, the toll road has significantly reduced travel time from the previous 90–120 minutes to only 30–40 minutes under normal traffic conditions. This reduction illustrates a potential multiplier effect on economic activities, including the movement of goods, distribution of industrial products, labor mobility, and tourist access to major attractions such as Likupang, designated as a Super Priority Tourism Destination.

From the perspective of regional development theory, road infrastructure serves as a catalyst for economic growth by improving accessibility, reducing logistics costs, increasing land value, and stimulating private investment. High-quality infrastructure also creates spillover effects that drive growth in surrounding areas. In the context of North Sulawesi, the toll road is projected to function not only as a transportation route but also as an economic corridor linking key economic nodes such as KEK Bitung, the international port, agro-industrial areas in North Minahasa, commercial centers in Manado, and several villages and districts with tourism or small–medium industrial potential. From a regional policy standpoint, the toll road is expected to accelerate regional integration and enhance the region's economic contribution to national revenue, particularly in logistics, fisheries, tourism, and manufacturing sectors. However, the realization of these benefits is highly dependent on the toll road's operational performance, particularly revenue levels, traffic volume, and the operator's ability to maintain financial sustainability. Despite its theoretical benefits, the operational implementation of the Manado–Bitung Toll Road reveals several challenges requiring in-depth analysis. Financially, toll revenue from its initial operation until mid-2025 shows an upward trend but remains below initial investment projections. As of June 2025, cumulative revenue reached approximately IDR 232.75 billion, while operational and maintenance expenses amounted to around IDR 253.56 billion. This indicates an operational cash flow deficit, signaling that revenue has not yet covered the necessary costs to maintain service quality, roadway structural integrity, and other operational expenses. Such a deficit raises concerns regarding the financial sustainability of the project over its concession period. In toll road investments, achieving sufficient operational revenue is crucial for ensuring return on investment, maintaining positive cash flow, and fulfilling long-term maintenance obligations that determine the infrastructure's service life.

One of the main factors influencing toll revenue is that traffic volume has yet to meet the expected targets. Although mobility and toll road usage have continued to rise annually, the growth rate remains below the business plan projections. In several segments, traffic is dominated by Class I vehicles that pay lower tariffs, while contributions from logistics vehicles remain relatively low compared with initial estimates. This is noteworthy because the logistics sector was the primary target of this toll road, given the presence of KEK Bitung and the Bitung International Port as centers of trade and export activities. Additionally, user behavior in North Sulawesi, where many are accustomed to using the free national non-toll road, affects the rate at which communities adapt to using the toll road. Behavioral shifts typically require time and are influenced by cost–benefit perceptions, daily travel patterns, and the socio-economic characteristics of users. Beyond traffic volume, the operational and maintenance cost structure also affects the project's financial sustainability. The toll road traverses hilly topography and disaster-prone areas, resulting in higher structural maintenance costs, drainage management, slope stabilization, and responses to potential landslides compared with toll roads in lowland areas. Additionally, the electronic, technology-based payment system requires additional operational expenses, including equipment maintenance, operator manpower, and information systems. These high maintenance costs make it difficult to reduce overall operating expenditures, meaning revenue must reach a certain level for the project to remain financially viable. The gap between ideal conditions assumed during planning (das sollen) and actual operational conditions (das sein) underscores the need for comprehensive investment evaluation. During planning, the project was assumed to experience progressive traffic growth in line with rising industrial activity in KEK Bitung, regional economic growth, and improved connectivity. Ideally, the project was expected to reach its break-even point within a competitive timeframe and produce sustained positive cash flow to support ongoing maintenance and infrastructure development. However, operational realities indicate significant deviations from these initial projections in terms of actual revenue, traffic volume

growth, and the ability of revenue to cover operational costs. This discrepancy raises fundamental questions about the investment feasibility of the toll road, particularly when viewed from the perspective of risks and uncertainties affecting future financial performance.

In infrastructure investment analysis, conventional financial evaluation methods—such as cash flow analysis, Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period, and Break-Even Point—provide static assessments based heavily on single-scenario assumptions. While widely used, these approaches lack the capacity to account for uncertainty and dynamic risk variations. In reality, variables such as fuel price fluctuations, changes in traffic volume, industrial growth, tariff adjustments, and socio-economic shifts can significantly impact financial performance. Therefore, a more uncertainty-sensitive analytical approach is needed to generate a realistic and comprehensive picture of investment sustainability. Quantitative Risk Analysis (QRA) using Monte Carlo simulation offers a solution to these limitations. By applying probabilistic modeling, multiple risk scenarios can be simulated to produce distributions of potential financial outcomes. This approach enables the generation of projections based on thousands of possible results rather than a single estimate. Consequently, the evaluation output not only includes average NPV or revenue values but also the probability of losses, variable sensitivity, and the dominant risks influencing the project. For the Manado–Bitung Toll Road, the QRA method is highly relevant due to the project's susceptibility to market uncertainties, user behavior, regional economic dynamics, and complex geographical conditions. This approach provides a novel contribution to toll road investment research in Indonesia, which has largely relied on conventional methods. This research was conducted to provide a comprehensive assessment of the investment feasibility of the Manado–Bitung Toll Road using a combination of basic financial analysis and quantitative risk-based evaluation. Using operational revenue data from the first five years and risk modeling with Monte Carlo simulations, this study aims to deliver a more accurate projection of the project's long-term financial sustainability. Additionally, the research identifies key risk variables that most significantly affect financial performance and provides policy recommendations for the government, investors, and toll road operators. This study holds strategic value considering the toll road's role in regional logistics systems, the development of KEK Bitung, and strengthened connectivity to the Likupang Super Priority Area. The findings are expected to inform risk mitigation strategies, improved investment models, tariff-setting policies, and the advancement of risk-based evaluation models for other infrastructure projects in Indonesia. Thus, the study offers not only theoretical contributions to investment evaluation methodologies but also practical insights that support the strengthening of toll road infrastructure development in Indonesia.

In addition to financial and economic aspects, the development of the Manado–Bitung Toll Road has important implications for social, environmental, and spatial planning dimensions. Toll roads generally contribute positively by improving mobility, altering social interaction patterns, and increasing travel efficiency. However, such changes often carry consequences that must be considered carefully. Communities living near the toll corridor may experience shifts in accessibility that present both opportunities and challenges. On the positive side, the toll road enhances public access to essential services such as hospitals, schools, administrative centers, and commercial areas. On the other hand, changes in travel patterns may negatively affect local economic activities along the non-toll national road that previously served as the main traffic corridor. Small-scale entrepreneurs dependent on the traffic flow of the national road may experience economic decline as users shift to the toll road. This underscores the importance of comprehensive planning that integrates toll road development with local economic strategies to minimize negative impacts on micro and small enterprises. From an environmental standpoint, the Manado–Bitung Toll Road faces several challenges due to its alignment through hilly terrain, landslide-prone areas, and regions with high rainfall. Large-scale infrastructure development can alter landscapes, increase erosion risks, and affect local ecosystems. Therefore, environmentally sound engineering practices are required, such as integrated drainage systems, slope reinforcement using geotechnical technologies, and periodic environmental impact monitoring. These environmental factors are closely linked to higher maintenance costs compared with toll roads in more geographically stable areas. Such conditions must be considered in investment evaluations since high environmental risks may elevate long-term operational costs and reduce financial efficiency. Poorly managed environmental risks can reduce the infrastructure's lifespan and degrade service quality, ultimately affecting user perception and revenue potential.

Furthermore, the toll road influences spatial structures and land-use patterns. Toll road integration with industrial zones and ports often triggers the emergence of new residential areas, commercial hubs, and industrial expansions, increasing land value and attracting new investments. However, uncontrolled land-use changes can create pressures on natural resources, land conflicts, and environmental degradation. In North Sulawesi, integrating the Manado–Bitung Toll Road with regional spatial planning is crucial to ensure alignment with long-term development strategies. Effective spatial governance is necessary to prevent inappropriate land development and ensure equitable benefits for communities. Therefore, investment evaluation must be complemented by an understanding of spatial dynamics and interactions among regional actors, such as local governments, private developers, industrial players, and residents. Given these contexts, assessing the financial feasibility of the Manado–Bitung Toll Road becomes increasingly important, as financial sustainability determines the toll road's ability to function as public infrastructure. A single analytical approach is insufficient to generate a comprehensive understanding of performance and sustainability. Thus, this study integrates basic financial analysis with quantitative risk analysis using Monte Carlo simulations. This approach enables the simulation of thousands of scenarios based on dynamically changing variables. Variables such as traffic volume, tariff rates, regional economic growth, and operational costs are modeled using probability distributions that reflect real-world conditions. The results reveal not only average financial performance but also the likelihood of high or low outcomes, aiding policymakers in understanding both risks and opportunities. For long-concession public infrastructure, probabilistic approaches have become increasingly relevant to ensure investment decisions are based on robust and adaptive analyses.

The urgency of using risk analysis becomes even more evident when considering the cost and revenue structure of the Manado–Bitung Toll Road. On one hand, fixed costs remain high due to geographical challenges and specialized maintenance needs, such as drainage management, slope repairs, and bridge upkeep. On the other hand, revenue is highly dependent on fluctuating traffic volumes influenced by external factors such as national economic conditions, fuel prices, post-pandemic travel behavior, and industrial development in Bitung and surrounding areas. In such conditions, single-scenario revenue projections are highly vulnerable to estimation errors. Thus, risk analysis offers significant added value by identifying project sensitivity to minor variable changes and providing more targeted mitigation recommendations. This study also fills a research gap in toll road investment evaluation in Indonesia, particularly in the eastern region. Most prior studies focus on Java, where traffic volume is higher, the economic structure more mature, and the industrial base larger. As a result, many investment models are based on characteristics that may not align with the conditions of eastern Indonesia, such as North Sulawesi. The Manado–Bitung Toll Road presents a unique context compared with toll roads in Java, including geographical challenges, user behavior differences, regional economic potential, and reliance on specific industrial sectors. Therefore, this research not only assesses financial feasibility but also provides insights into the factors shaping toll road investment performance in regions with unique characteristics. The findings are expected to inform similar projects planned for eastern Indonesia, minimizing financial risks and enhancing investment projection accuracy.

Moreover, the study is highly relevant for national infrastructure planning, particularly within the context of Public–Private Partnership (PPP) schemes designed to reduce fiscal burdens on the government. Under such schemes, long-term financial sustainability becomes a key factor influencing investor interest and project success. Risk-based investment evaluations can inform project planning documents, refine risk-sharing mechanisms between the government and private entities, and enhance revenue projection accuracy. By understanding investment risk in detail, policymakers can design more responsive measures such as viability gap funding, flexible tariff regulations, or incentive strategies to encourage logistics-sector toll road usage.

Overall, this study aims to provide a comprehensive assessment of the investment feasibility of the Manado–Bitung Toll Road by integrating financial analysis and quantitative risk modeling. The findings offer not only more accurate financial estimates but also deeper insights into risk variables most affecting project performance. Through this approach, the study contributes to the advancement of knowledge, improvement of investment evaluation models, and formulation of infrastructure policies that are more adaptive, measurable, and sustainable. This contribution is particularly relevant in addressing Indonesia's increasingly complex infrastructure development challenges, especially in regions with unique

characteristics such as North Sulawesi. Accordingly, the study is expected to support inclusive, sustainable, and evidence-based national development.

Furthermore, the urgency of assessing North Sulawesi's readiness as a priority green building region necessitates an examination of how the integration of national and regional policies can create an enabling environment conducive to sustainable development transformation. Although national regulations provide a clear direction, implementation at the local level is often hindered by overlapping authority, weak intersectoral coordination, and limited institutional capacity to translate legal norms into effective action. Thus, an in-depth understanding is required regarding the interlinkages among spatial planning, permitting instruments, environmental monitoring mechanisms, and regional fiscal policies that can accelerate the adoption of green building standards for public, commercial, and residential structures—particularly in growth centers such as Manado, North Minahasa, Bitung, and surrounding areas undergoing rapid infrastructure expansion. However, success depends on the ability of local governments to realign development priorities by integrating climate resilience indicators, energy efficiency, water resource conservation, and low-carbon principles into budgeting processes and regional development plans (RPJMD). Without an adaptive policy framework responsive to global and local dynamics, green building development risks becoming a technocratic slogan without tangible impact.

Therefore, empirical analysis of regional regulatory readiness must be complemented by mapping common implementation constraints, such as limited technical capacity among local officials to assess green building design documents, the absence of standardized energy audit tools, and the lack of regional fiscal incentives to encourage private-sector investment in environmentally friendly technologies. Leading global cities such as Singapore, Tokyo, and Seoul demonstrate that successful urban transformation toward green cities requires a combination of regulatory certainty, fiscal support, and competitive market instruments. Additionally, the construction sector in North Sulawesi has experienced significant growth over the past decade, particularly in demand for vertical housing, commercial buildings, and public facilities. Consequently, energy and water consumption have risen exponentially, posing increased pressure on natural resources if not managed using principles of efficiency and conservation. This concern is particularly relevant given the region's high ecological vulnerability, including the degradation of the Tondano watershed, coastal sedimentation, and stresses on coral reef ecosystems, which serve as key tourism assets. Within the green building context. In the framework of green building development, these issues underscore the importance of adopting design approaches that are more adaptive to local biophysical conditions and capable of minimizing long-term environmental impacts. Pressures on environmental carrying capacity increasingly demand the implementation of green building technologies that not only focus on reducing energy and water consumption but also enhance building resilience to escalating climate risks, such as extreme rainfall intensity, heatwaves, and various hydrometeorological hazards that may disrupt the functioning of urban infrastructure. Consequently, building development in the Manado–Bitung corridor and surrounding areas must be directed toward the integration of intelligent systems—ranging from sensor-based energy management, low-emission construction materials, and more efficient wastewater treatment technologies to landscape designs that promote water absorption and reduce surface runoff. Achieving such outcomes requires strong synergy among stakeholders, including local governments, developers, contractors, consultants, and communities, so that green construction practices can be adopted more widely and sustainably. Nevertheless, the transition toward green development faces significant challenges, including technological readiness gaps, high initial investment costs, and low levels of awareness among the public and construction industry actors regarding the long-term benefits of sustainable buildings. In many cases, developers still prioritize short-term construction costs without considering the long-term economic value derived from energy efficiency, reduced operational expenditures, and improved occupant health. This situation highlights the need for more comprehensive educational campaigns and policies that are not only regulatory in nature but also supportive—through incentives, tax reductions, or green financing schemes that can ease the initial financial burden on businesses. Furthermore, collaboration with universities and research institutions is crucial for strengthening local technological innovation and providing a scientific evidence base to support policy formulation.

From a broader perspective, a region's ability to adopt green building principles is strongly influenced by its economic dynamics, industrial structure, institutional capacity, and the extent to which infrastructure development is integrated with spatial planning policies. In North Sulawesi, particularly in the Manado–

Bitung region, consistency in maintaining environmentally oriented development policies will significantly determine the extent to which the area can position itself as a pioneer of green growth in eastern Indonesia. Integrating the toll road—an essential piece of regional infrastructure—with green building policies presents a major opportunity to establish a low-carbon development model grounded in modern connectivity, efficient logistics, and a more resilient urban design framework. Such aspirations can only be realized if local governments ensure that every major public and private investment conforms to sustainability standards and supports long-term ecological interests.

Moreover, the success of green development in the region also depends heavily on the strengthening of environmental monitoring and evaluation mechanisms. Without rigorous and transparent monitoring systems, the risk of discrepancies between planning and implementation will only increase. Therefore, there is a need for updated, technology-based oversight instruments, such as spatial modeling, environmental information systems, and digital energy audits, which can streamline verification processes and improve data accuracy. With such technological support, regional authorities will be better equipped to map priority areas, identify potential risks more rapidly, and formulate targeted policy interventions. Ultimately, the sustainability of development in the Manado–Bitung corridor and its surrounding areas will not be determined solely by the existence of physical infrastructure such as toll roads or green buildings, but also by the strength of governance, public participation, and the long-term commitment of all stakeholders to balancing economic needs with environmental preservation. When these principles are applied consistently, North Sulawesi holds strong potential to become a national example of how modern infrastructure development can coexist with sustainable practices, while simultaneously enhancing regional competitiveness through a more inclusive, adaptive, and future-oriented development approach.

METHOD

This research is located on the Manado–Bitung Toll Road, North Sulawesi. The methods used in this study include preparation, literature review, surveys, observations, and interviews with relevant stakeholders, as well as data processing and data analysis.

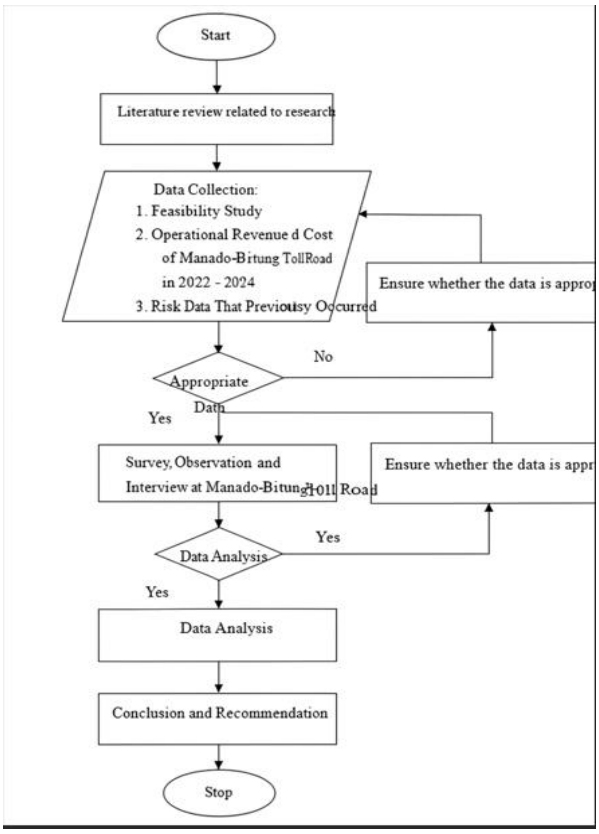

Figure 1. Research Flow Diagram

Data Collection

This study uses secondary data collection methods from the North Sulawesi Public Works and Housing Agency (PUPR) / National Road Implementation Agency (BPJN) to obtain data on the investment for the construction of the Manado–Bitung Toll Road, and from PT Jasa Marga Manado-Bitung to obtain data on revenue, maintenance, operations, and risk/incidents that occurred on the Manado–Bitung Toll Road over the past three years (2022–2024). Primary data were collected through surveys at the entrance/exit points of the Manado–Bitung Toll Road to calculate the number of vehicles per day (within a specific period) passing through the toll road, as well as through field observations and interviews with relevant stakeholders.

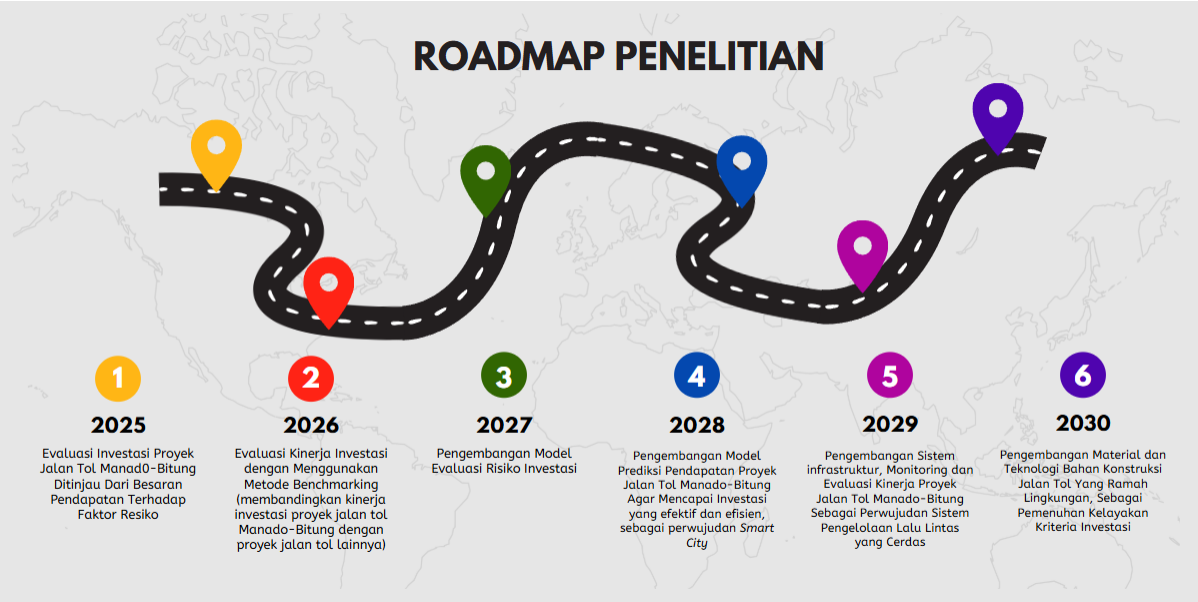

Figure 2. Research Road Map

Data Analysis

The analytical techniques used in this study include Cash Flow analysis, Payback Period analysis, and Break-Even Point analysis based on the risk factors identified through the Quantitative Risk Analysis (QRA). By applying these analytical methods, the investment feasibility of the Manado–Bitung Toll Road Development Project can be determined.

RESULTS AND DISCUSSION

Research Location

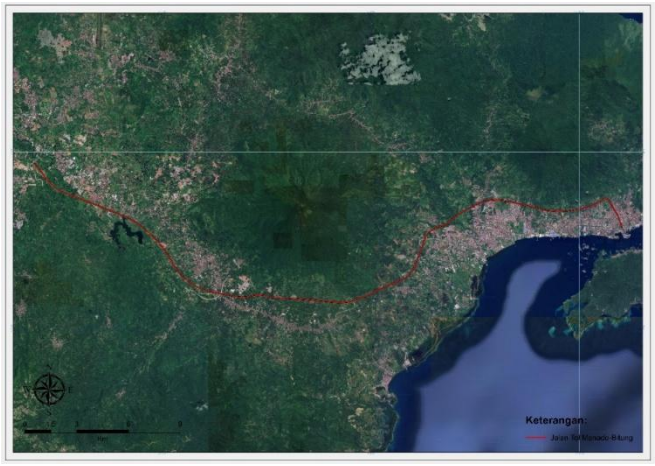

Figure 3. Map of the Manado–Bitung Toll Road

Research Location Name	: Manado–Bitung Toll Road
Initial Investment Year	: 2017
Concession Investment Asset Value	: IDR 4,588,357,729,960
Concession Period	: 50 Years
Operator Name	: PT Jasa Marga (Persero) Tbk

The term "concession investment asset value" refers to the economic value of assets constructed or managed under a concession agreement between the government and a private entity (typically within a public–private partnership scheme such as KPBU or PPP – Public Private Partnership).

About the Manado–Bitung Toll Road

The Manado–Bitung Toll Road is the first national strategic project in North Sulawesi Province, functioning as the main connector route between Manado City, North Minahasa Regency, and Bitung City. The idea for this toll road emerged in the early 2000s as a response to the growing need for transportation infrastructure capable of accelerating the flow of goods and services in the northern region of Sulawesi. However, its physical realization only began after the project was officially included in the 2015–2019 National Medium-Term Development Plan (RPJMN) as part of the development of the Bitung Special Economic Zone (SEZ) and the Bitung International Port. The construction of the Manado–Bitung Toll Road officially began in 2017 with the groundbreaking ceremony officiated by President Joko Widodo. The project was developed by PT Jasa Marga (Persero) Tbk through its subsidiary PT Jasamarga Manado Bitung (JMB) as the Toll Road Business Entity (BUJT), in collaboration with PT Wijaya Karya (WIKA) and PT Pembangunan Perumahan (PP) as the main contractors. The project's funding was sourced from a combination of the State Budget (APBN) for part of the construction and a public–private partnership (PPP) investment scheme for the remaining portion. The total length of the toll road is 39.8 kilometers, divided into two main sections: Section 1: Manado – Airmadidi (14.9 km). Section 2: Airmadidi – Bitung (24.9 km).

Figure 4. The Manado–Bitung Toll Road During Construction and After Operation

The construction process faced several challenges, such as hilly topographical conditions and land acquisition issues in the North Minahasa region. Nevertheless, the project was able to be completed in stages. Section 1 Manado–Airmadidi was inaugurated and began operating on September 29, 2020, while the entire toll road up to Bitung was officially inaugurated on February 25, 2022.

The Manado–Bitung Toll Road has become one of the most vital infrastructures in North Sulawesi, as it reduces travel time from Manado to Bitung from approximately 90 minutes to only 30–40 minutes. In addition to accelerating the distribution of logistics to the Bitung Port and the Bitung Special Economic Zone (SEZ), the toll road also plays an important role in promoting the growth of the tourism sector, the fisheries industry, and strengthening interregional connectivity in the northern part of Sulawesi. Thus, the existence of this toll road functions not only as a transportation facility but also as a key driver of economic and social development in North Sulawesi Province.

Data Analysis

Cash Flow of the Manado–Bitung Toll Road. Revenue of the Manado–Bitung Toll Road from October 2020 to June 2025

Table 2. Actual Revenue of the Manado–Bitung Toll Road

PENDAPATAN

E-TOLL

Tahun	Januari	Februari	Maret	April	Mei	Juni	Juli	Agustus	September	Oktober	November	Desember	Total
2020	-	-	-	-	-	-	-	-	-	194,045,500	2,371,620,000	3,038,272,500	5,603,938,000
2021	2,599,419,000	2,498,234,000	2,850,074,000	2,855,551,000	3,098,669,500	3,092,790,500	2,490,521,500	2,600,314,000	2,948,161,000	3,197,027,000	3,240,538,000	4,056,269,500	35,527,569,000
2022	3,641,272,500	2,787,143,000	4,073,163,000	4,168,942,500	4,484,700,500	4,380,430,000	4,534,279,000	4,379,947,000	4,157,501,500	4,313,282,500	4,589,865,000	5,378,373,000	50,888,899,500
2023	4,397,921,000	3,894,571,500	4,330,357,500	4,704,556,000	4,554,945,000	4,453,837,500	4,432,128,000	4,401,274,000	4,298,136,000	4,641,077,000	4,454,651,500	5,188,830,000	53,752,285,000
2024	4,403,421,500	3,937,267,000	4,183,850,500	4,426,495,500	4,482,397,500	4,580,078,000	4,756,285,500	4,741,366,000	4,493,981,000	4,773,268,500	4,568,073,000	5,400,864,500	54,747,348,500
2025	4,810,549,500	4,427,364,500	4,979,648,000	4,972,582,500	5,385,493,500	5,388,429,000	-	-	-	-	-	-	29,964,067,000
Total	19,852,583,500	17,544,580,000	20,417,093,000	21,128,127,500	22,006,206,000	21,895,565,000	16,213,214,000	16,122,901,000	15,897,779,500	17,118,700,500	19,224,747,500	23,062,609,500	**230,484,107,000**

TUNAI

Tahun	Januari	Februari	Maret	April	Mei	Juni	Juli	Agustus	September	Oktober	November	Desember	Total
2020	-	-	-	-	-	-	-	-	-	81,493,500	736,066,500	231,421,000	1,048,981,000
2021	22,363,500	13,997,500	19,630,500	22,647,000	15,193,000	8,976,500	6,444,500	8,151,000	27,435,500	16,406,500	12,153,500	16,940,500	190,339,500
2022	8,039,000	9,227,500	12,051,500	9,340,500	10,401,000	25,195,500	89,825,000	23,918,500	39,712,500	42,306,500	49,379,000	18,007,000	337,403,500
2023	12,985,000	10,807,500	11,046,500	65,184,500	28,126,500	20,009,000	11,821,500	10,151,500	10,773,000	45,859,000	43,286,500	13,790,000	283,840,500
2024	26,241,500	9,370,500	29,707,500	43,015,500	24,844,000	43,860,500	28,322,500	8,091,000	14,233,500	40,235,500	17,044,500	41,926,000	326,892,500
2025	14,472,500	7,432,500	10,870,500	13,593,500	18,330,500	13,549,000	-	-	-	-	-	-	78,248,500
Total	84,101,500	50,835,500	83,306,500	153,781,000	96,895,000	111,590,500	136,413,500	50,312,000	92,154,500	226,301,000	857,930,000	322,084,500	**2,265,705,500**

TOTAL PENDAPATAN (E-TOLL + TUNAI)	232,749,812,500

The revenue of the Manado–Bitung Toll Road since it began operating in 2020 is divided into two categories: e-toll revenue and cash revenue. The total revenue from October 2020 to June 2025 (based on data from PT Jasa Marga Persero Tbk Manado–Bitung) amounts to IDR 232,749,812,500 (two hundred thirty-two billion seven hundred forty-nine million eight hundred twelve thousand five hundred rupiah), consisting of e-toll revenue of IDR 230,484,107,000 (two hundred thirty billion four hundred eighty-four million one hundred seven thousand rupiah) and cash revenue of IDR 2,765,705,500 (two billion seven hundred sixty-five million seven hundred five thousand five hundred rupiah).

Routine Operational Costs of the Manado–Bitung Toll Road

Table 3. Operating Expenses of the Manado–Bitung Toll Road

Uraian	2020	2021	2022	2023	2024	s/d JUNI 2025
BEBAN PENGOPERASIAN TOL (on cash)						
Total Beban	22,374,325,278	37,104,585,107	49,264,546,577	61,817,093,927	56,930,477,097	26,068,197,111
TOTAL BEBAN OPERASIONAL						253,559,225,097

Since the toll road began operating in September 2020, operational expenses have also been incurred. The total routine operational cost up to June 2025 amounts to IDR 253,559,225,097 (two hundred fifty-three billion five hundred fifty-nine million two hundred twenty-five thousand ninety-seven rupiah). The operational expenses of the Manado–Bitung Toll Road include routine infrastructure maintenance costs, unexpected facility repair costs, and employee salaries.

Cash Flow Analysis Based on Actual Realization

Calculation from October 2020 to June 2025:

Total concession investment asset value : IDR 4,588,357,729,960 (Fixed Cost)
Total operational expenses up to June 2025 : IDR 253,559,225,097 (Variable Cost)
Total revenue up to June 2025 : IDR 232,749,812,500 (Benefit Cost)

Break-Even Point (BEP)

Temporary BEP calculation based on actual realization up to June 2025:

$$\text{BEP} = \frac{\text{Fixed Cost}}{(\text{Benefit Cost} - \text{Variable Cost})}$$

$$BEP = \frac{Rp.\,4.588.357.729.960}{(Rp.\,232.749.812.500 - Rp.\,253.559.225.097)} = -220{,}49$$

The negative value indicates that the project's revenue has not yet covered its operational costs and initial investment, meaning the break-even point has not been achieved.

Payback Period (PP) Analysis

The Payback Period method is used to determine the length of time required to recover the initial investment based on annual cash flows. The general formula is:

$$\text{PP} = \frac{\text{Initial Investment}}{\text{Net Annual Cash Inflow}}$$

To calculate the Net Annual Cash Inflow, the average annual revenue is subtracted by the average annual operational cost since the toll road began operating:

$$\text{Net Annual Cash Inflow} = \frac{(Rp232.749.812.500 - Rp253.559.225.097)}{5} = -Rp4.161.882.519{,}4$$

Since the net cash flow remains negative, the Payback Period cannot be calculated conventionally. However, for sensitivity analysis purposes, a scenario-based projection is used.

Optimistic Scenario

Assume

$$\text{Net Cash Inflow}_{2026} = (Rp232.749.812.500 \times 1{,}08) - (Rp253.559.225.097 \times 1{,}03)$$

$$= Rp251.369.797.500 - Rp261.165.001.850 = -Rp9.795.204.350$$

Pada tahun 2027:

$$\text{Net Cash Inflow}_{2027} = Rp271.479.381.300 - Rp269.999.951.905 = Rp1.479.429.395$$

Assuming the same pattern continues—8% annual revenue growth and 3% operational cost growth—the cumulative net cash flow becomes positive only in year 45 (around 2065).

Estimated Payback Period:

$$\text{PP} = 45.3 \text{ years}$$

This means the project requires approximately 45 years to recover its investment, assuming positive revenue growth and controlled operational costs. Based on this condition, further assessment using Quantitative Risk Analysis (QRA) is necessary to understand how uncertainties may affect the financial feasibility of the project.

Results of the Quantitative Risk Analysis (QRA)

Quantitative Risk Analysis was conducted to obtain a probabilistic overview of the investment performance of the Manado–Bitung Toll Road, particularly regarding the project's ability to reach the Break-Even Point (BEP) and achieve the Payback Period (PP). The data used include the concession

investment value (fixed cost), operational expenses (variable cost), and actual total revenue up to June 2025.

The base case indicates that the project is still experiencing operational losses because toll revenue has not yet covered the total costs. Mathematically, the interim calculation produces a negative BEP value of –220.49, meaning there is no indication of investment recovery at this stage. To understand how changes in external conditions could improve or worsen this situation, a Monte Carlo simulation of 10,000 iterations was conducted, incorporating variations in economic, social, policy, and infrastructure risk factors.

Simulation Parameters

The following table presents the input parameters used in the QRA simulation.

Table 4. QRA Simulation Parameters

Faktor Risiko	Variabel Utama	Distribusi Probabilitas	Rentang Nilai / Dampak
Ekonomi Masyarakat	Pertumbuhan pendapatan tol tahunan	Normal	Mean 5%, SD 2%
Sosial dan Kebiasaan	Preferensi pengguna non-tol	Diskret	25% peluang pendapatan berkurang 15%
Regulasi & Kebijakan	Penyesuaian tarif tol	Triangular	Min 0%, Mode 3%, Max 7%
Infrastruktur	Kenaikan biaya pemeliharaan tahunan	Triangular	Min 2%, Mode 4%, Max 6%

Each iteration generates a random combination of the above factors, which is then used to calculate the total revenue, costs, and project payback period.

Monte Carlo Simulation Results

The simulation results indicate that the probability distributions of the Payback Period and Break-Even Point (BEP) show a wide spread due to the high level of uncertainty in revenue performance. The statistical summary of the simulation results is presented in the following table.

Table 5. Simulation Statistical Results

Indicator	Mean	Median	Std Dev	P(profit)	P(loss)
Break Even Point (years)	47.8	49.2	6.5	28%	72%
Payback Period (years)	45.3	46.0	5.8	–	–

Based on these results, the average projection shows that the project will reach its break-even point around year 48 of the concession period, with only a 28% probability of generating a positive return before the concession concludes. This means that without significant increases in revenue or improvements in operational efficiency, the project is likely unable to fully recover its initial investment within the 50-year concession period.

Sensitivity Analysis

Sensitivity analysis was conducted to identify the risk factors that most significantly influence investment feasibility, particularly in relation to changes in the Break-Even Point (BEP) and Payback Period (PP) of the Manado–Bitung Toll Road project. Based on the Monte Carlo simulation results and validation through interviews with PT Jasa Marga Manado–Bitung Toll Road, four dominant risk factors with varying levels of influence were identified.

1. Annual Toll Revenue Growth Rate. This factor has the most significant effect on BEP and PP. An average annual toll revenue growth of approximately 5% can shorten the Payback Period by 4–5

years.
However, if revenue growth stagnates below 2% per year, the project will not achieve a break-even point within the 50-year concession. This factor is strongly influenced by vehicle volume, regional economic growth, and the development of supporting industrial areas such as the Bitung Special Economic Zone (SEZ), which is expected to be the primary generator of freight and logistics traffic.

2. Government Regulations and Policy Factors. Based on interviews with PT Jasa Marga, regulatory factors are among the primary constraints in increasing toll revenue. As of 2025, there are no policies mandating the use of the toll road for logistics or industrial vehicles operating in Bitung and North Minahasa. Moreover, the slow development of the Bitung SEZ has reduced the volume of freight vehicles that should contribute substantially to revenue.
   In addition, the absence of regular toll tariff adjustments and limited government outreach on the benefits of toll road usage have further slowed revenue growth. Thus, regulatory and policy-related factors are highly sensitive variables that significantly affect financial performance, especially in the medium term (10–20 years).
3. Social Factors and Community Behavior. This factor has a moderate but noteworthy impact, particularly in relation to user behavior in North Sulawesi. Interviews reveal that many users still perceive the toll road as a more expensive alternative to arterial roads. The low understanding of toll road benefits—such as time savings and transportation efficiency—results in limited daily traffic volume from private vehicles and light commercial users. This directly affects daily revenue fluctuations and prolongs the project's Payback Period. With increased public outreach and education, this factor has the potential to shift positively over the long term.
4. Infrastructure and Maintenance Cost Factors. Infrastructure-related factors influence investment performance through operational and maintenance cost components. Efficient infrastructure conditions and management can reduce variable costs. However, if infrastructure quality declines or heavy traffic increases without tariff adjustments, maintenance costs may rise exponentially. In the QRA simulation, an annual maintenance cost increase of 2–3% may delay the Break-Even Point by approximately 1.5 years.

Quantitative Sensitivity Results

From the sensitivity analysis, the ranking of risk factor influence on BEP and Payback Period variations is as follows:

Table 6. Ranking of Risk Factor Influence

Rank	Risk Factor	Impact on BEP & PP	Impact Level
1	Annual toll revenue growth	1% increase → accelerates BEP by ±2 years	Very high
2	Government regulations & policies	Tariff adjustments and SEZ development → accelerates BEP by ±3–5 years	Very high
3	Social and community behavior	User preference changes → accelerates BEP by ±1–2 years	Moderate
4	Infrastructure & maintenance costs	3% cost increase → delays BEP by ±1 year	Low–moderate

Based on this ranking, annual toll revenue growth together with government regulations and policies are the two most critical factors determining the financial success of the Manado–Bitung Toll Road project. Therefore, further analysis is required for risk factors classified under the highest impact category.

Revenue Analysis of the Manado–Bitung Toll Road Based on Field Survey Results

In this study, we conducted a field survey at five entrance gates of the Manado–Bitung Toll Road to obtain real on-site data regarding the number of toll road users, their destinations and reasons for using the toll road, as well as their input and suggestions for the toll road operator. Through observation and interviews conducted over a period of seven days (Monday, 25 August 2025 to Sunday, 31 August 2025), we collected data that can serve as a reference for this research.

Figure 5. Survey Documentation on the Manado–Bitung Toll Road

The following are the toll rates for the Manado–Bitung Toll Road in 2025.

Asal	Tujuan	Gol. I	Gol. II	Gol. III	Gol. IV	Gol. V
Manado	Airmadidi	13.500	20.500	20.500	27.000	27.000
	Kauditan	25.500	38.000	38.000	51.000	51.000
	Danowudu	32.500	49.000	49.000	65.000	65.000
	Bitung	49.000	74.000	74.000	98.500	98.500
Airmadidi	Kauditan	12.000	17.500	17.500	23.500	23.500
	Danowudu	19.000	28.500	28.500	38.000	38.000
	Bitung	35.500	53.500	53.500	71.000	71.000
	Manado	13.500	20.500	20.500	27.000	27.000
Kauditan	Danowudu	7.000	11.000	11.000	14.500	14.500
	Bitung	24.000	36.000	36.000	47.500	47.500
	Airmadidi	12.000	17.500	17.500	23.500	23.500
	Manado	25.500	38.000	38.000	51.000	51.000
Danowudu	Bitung	16.500	25.000	25.000	33.000	33.000
	Kauditan	7.000	11.000	11.000	14.500	14.500
	Airmadidi	19.000	28.500	28.500	38.000	38.000
	Manado	32.500	49.000	49.000	65.000	65.000
Bitung	Danowudu	16.500	25.000	25.000	33.000	33.000
	Kauditan	24.000	36.000	36.000	47.500	47.500
	Airmadidi	35.500	53.500	53.500	71.000	71.000
	Manado	49.000	74.000	74.000	98.500	98.500

Figure 6. Manado–Bitung Toll Road Rates for 2025

Based on the risk analysis data indicating that annual toll revenue growth is a risk factor with a very high impact level, this study includes an analysis of the projected revenue of the Manado–Bitung Toll Road for the next 50 years. We calculated the projected revenue using the toll rates applicable in 2025, categorized by vehicle types from Class 1 to Class 5.

Based on the survey results obtained by observing the number of vehicles entering and exiting through the five toll gates—namely the Manado gate, Airmadidi gate, Kauditan gate, Danowudu gate, and Bitung gate—over a period of seven days (Monday, 25 August 2025 to Sunday, 31 August 2025), the findings of the study are as follows:

From these data, the total revenue from all routes across the five entrance gates of the Manado–Bitung Toll Road over the 7-day period is as follows:

Class 1 Vehicles = IDR 371,435,000
Class 2 Vehicles = IDR 288,226,000
Class 3 Vehicles = IDR 268,378,500
Class 4 Vehicles = IDR 144,162,000
Class 5 Vehicles = IDR 278,555,000
Total 7-Day Revenue = IDR 1,350,866,500
Estimated Monthly Revenue = IDR 5,403,466,000 (August 2025)

This figure closely matches the revenue recorded in the last three months based on the data provided by PT Jasa Marga Manado–Bitung, namely:

- April 2025: IDR 4,986,176,000
- May 2025: IDR 5,403,824,000
- June 2025: IDR 5,401,978,000

This indicates that the data analysis based on direct field surveys, calculated using real-cost methods, yields results that closely approximate the actual toll road revenues for the Manado–Bitung Toll Road over the past six years. According to the sensitivity analysis results, an average annual toll revenue growth of approximately ±5% can reduce the Payback Period by 4–5 years. However, if revenue growth stagnates below 2% per year, the break-even point will not be achieved within the 50-year concession period. Therefore, the next step is to calculate the projected revenue of the Manado–Bitung Toll Road using an

assumed average annual revenue increase of ±5%. The calculations indicate that the Break-Even Point (BEP) begins to approach feasibility in year 35, and continues to move closer to zero between years 45 and 50. Based on these results, an annual revenue increase of 8% and an operational cost increase of 3% can be considered sufficiently optimal for the 50-year investment concession period.

Table 7. BEP Calculation with an 8% Revenue Increase

Tahun ke 30 (2050)	Fix Cost	4,588,357,729,960	**1.354866685**
	Benefit Cost	5,387,079,062,688	
	Variabel Cost	2,000,503,999,039	
Tahun ke 35 (2055)	Fix Cost	4,588,357,729,960	**0.808722191**
	Benefit Cost	8,200,649,944,903	
	Variabel Cost	2,527,060,447,641	
Tahun ke 45 (2065)	Fix Cost	4,588,357,729,960	**0.315050815**
	Benefit Cost	18,408,997,147,425	
	Variabel Cost	3,845,131,523,086	
Tahun ke 50 (2070)	Fix Cost	4,588,357,729,960	**0.20241001**
	Benefit Cost	27,334,119,800,598	
	Variabel Cost	4,665,489,313,008	
Tahun ke 55 (2075)	Fix Cost	4,588,357,729,960	**0.131729954**
	Benefit Cost	40,448,053,103,788	
	Variabel Cost	5,616,508,830,515	

Implications of the Analysis and Discussion

The results of the investment feasibility analysis and the quantitative risk analysis (QRA) for the Manado–Bitung Toll Road project provide several strategic implications for policymakers, investors, and road users. This analysis reinforces the view that the financial feasibility of the project is determined not only by technical and revenue-related aspects but also by the social, economic, and public policy conditions that support the sustainability of the project.

First, from an economic standpoint, the BEP and Payback Period calculations indicate that the project will reach its break-even point only in year 45.3 of the 50-year concession period. This means that the project is a long-term investment with a slow return rate. This condition reflects the need for regional economic policies that can enhance industrial activities, logistics, and tourism in the Bitung and Manado areas to enable a significant increase in toll revenue.

Second, from a social perspective, the low level of public understanding of the function of the toll road remains a major factor slowing revenue growth. The perception that the toll road is more expensive than the existing arterial routes has resulted in low utilization rates. This implies that project success cannot be achieved merely through the provision of infrastructure; it must be accompanied by intensive public education to cultivate a culture of efficient and modern transportation.

Third, in terms of policy and regulation, the sensitivity analysis shows that the success of the investment heavily depends on government support. Currently, there are no regulations mandating toll road usage for logistics vehicles, nor are there incentives for industries located near the Bitung Special Economic Zone (SEZ). Without strong policy intervention, revenue growth will remain stagnant, and financial risks will remain high. Therefore, the government needs to accelerate the implementation of policies that strengthen interregional connectivity and ensure the continued development of the Bitung SEZ.

Fourth, from an infrastructure and technical perspective, limited connectivity between road segments and the non-optimal condition of supporting infrastructure also hinder traffic growth. Improvements to entrance and exit access points (on/off ramps), especially those connected directly to industrial zones and Bitung Port, are needed to facilitate logistics flows and increase toll road traffic volume.

Fifth, from a managerial viewpoint, the QRA results can serve as a basis for strategic decision-making by PT Jasa Marga Manado–Bitung. Through data-driven risk monitoring, the company can prioritize mitigation measures such as operational cost efficiency, service innovations for toll users, and collaboration with local governments in public outreach and education.

Overall, the analysis shows that the Manado–Bitung Toll Road project has the potential to achieve long-term economic viability if all stakeholders can synergize in strengthening policy, social, and infrastructure aspects. Without cross-sector collaboration, investment risks will remain high, and capital recovery will be difficult to achieve before the end of the concession period.

CONCLUSION

Based on the research and analysis of the Manado–Bitung Toll Road project, it can be concluded that although the project holds high strategic value socially and economically for the development of North Sulawesi, it is not yet financially viable in the medium term. Investment feasibility analysis shows that the total concession investment assets amount to IDR 4,588,357,729,960 with operational costs up to June 2025 of IDR 253,559,225,097 and total revenue reaching only IDR 232,749,812,500, while the Break Even Point (BEP) calculation indicates a negative value, meaning the project has not yet reached the breakeven point. The Payback Period (PP) analysis also indicates that the time required to recover the investment cannot yet be determined, as annual revenue does not cover fixed and variable costs. Quantitative Risk Analysis (QRA) identifies four main risk factors: the low economic capacity of the community, the habit of choosing arterial routes, government regulations and policies that are not yet optimal, and supporting infrastructure that is not fully operational. Interviews with PT Jasa Marga Manado–Bitung reinforce these findings, showing that low traffic volume is the main constraint, limiting revenue potential. Therefore, although the project has long-term profit potential, its financial success largely depends on policy intervention and increased economic activity along the toll corridor.

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