

A Model for the Economic Feasibility Assessment of Urban Road Development in Agglomeration Areas based on Land Value Changes

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ABSTRACT

This study develops a model to evaluate the economic feasibility of urban road network development by incorporating land value changes as a key component of the evaluation process. The model addresses the limitations of conventional approaches that focus solely on transportation efficiency by integrating transportation benefits, such as Vehicle Operating Cost (VOC) savings and Value of Time (VoT), with long-term fiscal benefits derived from increases in Taxable Value of Objects (TVO) and Land and Building Tax (LBT). The methodology includes Cost-Benefit Analysis (CBA), traffic simulation using PTV Visum, and a log-linear regression model to quantify the impact of improved accessibility on land value. The model is applied and validated through a case study of the Mamminasata bypass road project in South Sulawesi, Indonesia. The project shows a Benefit-Cost Ratio (BCR) of 2.86, a Net Present Value (NPV) of 7,329.47 million IDR, and an Internal Rate of Return (IRR) of 12.05%, with full payback of the investment within 12 years. This model provides a more integrated, sustainable, and forward-looking approach to assessing the economic viability of road infrastructure development by linking transport efficiency with land value dynamics.

Keywords-land value changes; tax revenue; cost-benefit analysis; urban road development

I. INTRODUCTION

The development of road infrastructure is crucial for stimulating economic growth and achieving balanced regional development throughout Indonesia [1]. Productive road systems minimize transportation and calculated costs, speed up product dispersion, and strengthen the connectivity between neighborhoods [2]. Research on discoveries shows that a viable network leads to higher community efficiency and better asset transportation [3, 4]. The Mamminasata locale, comprising

Makassar, Maros, Sungguminasa, and Takalar, experienced accelerated financial development while its population increased. Basic streets have extreme activity congestions, which are progressively worse during peak hours [5]. The developing activity congestion leads to longer travel times and higher vehicle working costs, diminishing transportation framework productivity [6]. Successful problem determination requires a key approach that aligns with maintainable advancement standards. The government has started the development of the Mamminasata bypass, which covers 48.25

km and includes four sections, as part of its key development plan [7]. The expansion will reduce traffic congestion in the city center through an elective course with expanded capacity options. Current projections show that the bypass will significantly reduce travel time and vehicle emissions [8]. The development of the Mamminasata bypass will expand transportation choices and is expected to increase the TVO within the surrounding areas [9] resulting in higher LBT incomes, which leads to an increase in Regional Original Income (ROI) [10]. Research shows that foundation development affects TVO development by influencing arrival costs, depending primarily on openness and framework quality [11]. This study evaluates how the construction of a bypass road affects arrival costs using the Hedonic Pricing Method (HPM) [12]. The research strategy evaluates how openness variables influence framework quality and financial center proximity [13]. This paper deploys HPM examination to determine how bypass road development influences TVO improvement. The financial examination of non-toll road development inside Indonesia has customarily emphasized reserve funds on vehicle working costs and travel time esteem without accounting for long-term impacts, like upgraded TVO and LBT incomes [14]. The current study presents a progressive financial possibility evaluation system by incorporating the impacts of arrival esteem varieties and LBT income changes into the CBA [15]. The Mean Absolute Percentage Error (MAPE) strategy is used to assess how accurately the expectations of TVO development and LBT incomes work [16]. The results are compared with historical data to better understand the economic impact of the bypass project. In this context, the study seeks to address how the economic feasibility of urban road network development can be assessed based on land value changes in urban agglomeration areas. This study provides empirical evidence to support a forward-looking approach to evaluating road infrastructure development - one that not only focuses on transportation efficiency, but also considers the fiscal return to local governments through land value changes. The model provides practical insights for policymakers in formulating sustainable, value capture-based infrastructure investment strategies.

II. METHODOLOGY

A. Study Area

The Mamminasata bypass street traverses four distinct administrative regions within South Sulawesi, Indonesia. The road's route originates in Makassar City and traverses the municipalities of Maros, Gowa, and Takalar Regencies. This infrastructure initiative constitutes the completion of a 48.175-km corridor, a development aimed at addressing regional transportation challenges. The project's objective is to establish a well-integrated and sustainable road network with bypass elements, with the aim of alleviating traffic congestion in Makassar. Moreover, the development supports urban expansion in the Mamminasata metropolitan area by fostering economic growth and enhancing societal well-being. The project's overarching objective is to enhance regional connectivity by attracting local investment, generating

employment opportunities, and facilitating access to public services, as presented in Figure 1.

B. Study Design and Data Collection

The study on the Mamminasata bypass road Project employs a mixed-method approach, integrating both quantitative and qualitative methodologies to enhance the depth of analysis, and the research framework is depicted in Figure 2.



Fig. 1. Project plan for Mamminasata bypass road.

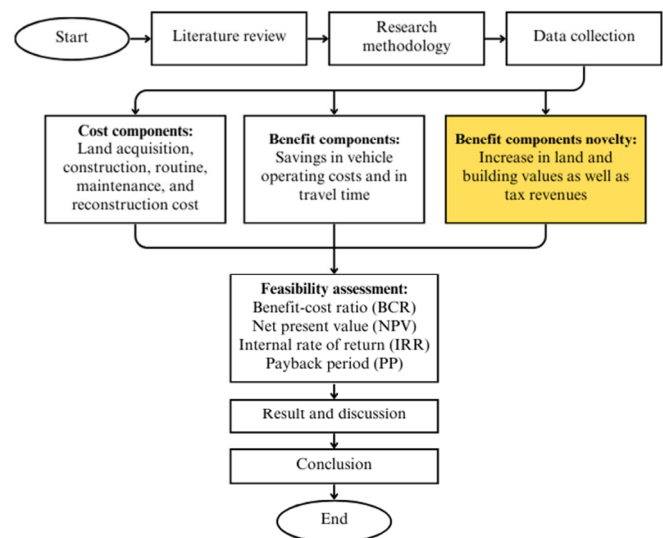


Fig. 2. Research Flowchart.

The study is supported by planning documents, project evaluations, and secondary data sourced from BPS and the South Sulawesi Public Works Agency, which serve as the study's primary quantitative data. The qualitative data were obtained through in-depth, semi-structured interviews with key stakeholders, including policymakers and transportation professionals.

C. Data Analysis

1) PTV Visum

The preliminary data analysis used PTV Visum software, a tool designed for modeling large-scale transportation networks. In this stage, traffic data were processed to examine vehicle flow trends, assess roadway performance, and locate congestion hotspots. PTV Visum is a software that assists in the evaluation of current traffic conditions and the development of future planning scenarios by combining variables, such as traffic volume, mean speed, and road capacity. The findings of this analysis provide a foundation of empirical evidence upon which effective transportation policies can be formulated [17].

2) Stata Program

The impact of land value was analyzed using a log-linear regression model, with data being processed through Stata software. This modeling approach was used to determine and measure the effects of various independent variables. The application of a logarithmic transformation to the dependent variable proved useful in mitigating heteroskedasticity issues and facilitating a more straightforward interpretation of elasticity. The findings from this analysis provide a quantitative perspective on how each factor influences land value changes within the research area [18].

3) Q-Gis

The spatial data were analyzed and processed using QGIS software, which enables detailed visualization, editing, and examination of geospatial datasets. During this stage, spatial elements, such as land use maps, transportation networks, and administrative boundaries were evaluated to support spatial analysis and regional modeling efforts. The incorporation of geospatial data has been found to enhance the precision and contextual relevance of the study outcomes [19].

4) Vehicle Operating Cost and Value of Time Analysis

The research flowchart presents a systematic analytical approach that integrates new components to optimize the traditional evaluation framework. The revised framework includes an evaluation of long-term ramifications by means of quantifying revenue growth through TVO and LBT within the CBA. Consequently, the evaluation provides a more comprehensive perspective, transcending conventional metrics, such as VOC savings and VoT reductions.

The present study employs CBA to assess the financial viability of the Mamminasata bypass road project. The CBA approach was selected for its ability to provide a detailed comparison between projected costs and the benefits generated [20]. It comprises cost elements, such as safety, construction, maintenance, and environmental impacts, while the benefits encompassed include reductions in VOC, travel time savings, TVO gains, and additional revenue from LBT. To ascertain the impact of road development on TVO, the research employs the HPM, a technique that identifies the determinants of land value based on accessibility and proximity to economic centers [21]. Field surveys were conducted to obtain land price data in areas affected by the bypass development. To this end, a multiple linear regression model was employed to estimate LBT revenue based on fluctuations in TVO. The analysis of VOC

and travel time savings was supported through simulations conducted using PTV Visum software, which models traffic flow conditions by considering factors, such as traffic volume, road capacity, and daily travel patterns. The output of these simulations serves as the primary data source for estimating the economic benefits of the project. To ensure the validity of the model, the MAPE method was employed to compare the simulated results with historical data on TVO and LBT revenues. The model exhibited a high degree of accuracy with minimal error, thereby validating its suitability as a decision-making tool. The key financial feasibility indicators derived from the analysis are presented in Table I.

TABLE I. ESTIMATED LAND ACQUISITION COSTS AND CONSTRUCTION COSTS

Mode I	Formula	Purpose/Usage
BCR	$BCR = \frac{\text{Present Worth Benefits (PWB)}}{\text{Present Worth Costs (PWC)}}$	The BCR serves as a metric for evaluating the economic efficiency of a project by comparing the present value of anticipated benefits to the present value of projected costs over the duration of the project.
NPV	$= \sum \frac{NPV}{(1+r)^t} B_t - \sum \frac{C_t}{(1+r)^t}$	The NPV is used to determine the total net worth of a project by accounting for the time value of money. A positive NPV indicates that the project generates value exceeding its associated costs.
IRR	$= \sum \frac{0}{(1+IRR)^t} B_t - \sum \frac{C_t}{(1+IRR)^t}$	The IRR indicates a project's profitability by identifying the discount rate at which the NPV becomes zero—meaning that the present value of benefits equals the present value of costs. A project is considered financially attractive if its IRR surpasses the cost of capital, enabling stakeholders to make informed investment choices through comparative evaluation.
PP		The Payback Period (PP) assesses how long it takes for a project's net cash inflows to recover its initial investment. This indicator determines the time frame needed for the cumulative cash flow to turn positive.

III. RESULTS

The development of the Mamminata bypass road consists of four sequential stages. Segments I and II, which comprise phase 1, will undergo planning for their 3.90-km stretch during 2023 and 2024, with implementation commencing in 2024 and operation beginning in 2025. Phase 2, Sections III and IV of the Mamminata bypass road will extend 9.82 km. The planning of these sections is scheduled to commence in 2024 through 2026, with their implementation being set to begin in 2025 and conclude in 2026. The project is scheduled to have been operational by 2027. Segments V through VII of phase 3, which cover 18.38 km, are scheduled to enter the planning stage between 2026 and 2029, followed by construction from 2027 to 2028 before operations commence in 2029. Phase 4 will address segments VIII through X, encompassing a total distance of 16.15 km. Concurrent with the planning and implementation phases, which will span from 2029 to 2030, will be the initiation of operations in 2031. The Mamminasata bypass road project uses a phased strategy to boost management efficiency by synchronizing construction works

with financial availability and site conditions. The construction project encompasses the development of a 47.65-km roadway and 0.6-km bridge structures. This strategy facilitates the efficient allocation of regional development resources. The land acquisition cost for the road infrastructure project was estimated by combining land area data obtained through spatial analysis using QGIS with land value data derived from the Land Value Map (PNT) issued by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN). The integration of these datasets was carried out using the spatial join method in QGIS, by overlaying the 45-meter-wide road alignment on top of the land value zoning layer. This process yielded detailed information regarding the land area falling within each land value zone, thereby enabling an estimation of the total land acquisition cost based on the zones intersected by the proposed road alignment as presented in Table II.

TABLE II. ESTIMATED LAND ACQUISITION COSTS AND CONSTRUCTION COSTS

No	Description	Length (km)	Land acquisition costs (IDR)	Construction cost (IDR)
1	Phase 1	3.90	118,714,121,000	187,687,500,000
2	Phase 2	9.82	481,458,470,000	356,212,500,000
3	Phase 3	18.38	366,623,525,300	561,225,000,000
4	Phase 4	16.15	417,741,291,400	555,187,500,000
Total		48.250	1,384,537,407,700	1,660,312,500,000

The estimated construction cost for the project comprises several major components, including road and bridge construction, as well as design and supervision services. The estimated road construction cost is 25 billion per km, while the estimated bridge construction cost is 650 billion per km. Furthermore, the construction design is budgeted at 2% of the total construction cost, and supervision services are at 3%. The estimates provided constitute the financial basis for planning and budgeting for the project, with the said planning and budgeting being aligned with the total length and structural composition of the proposed corridor. In Table II, it is evident that although phase 3 has the longest road length at 18.38 km, its land acquisition cost is not the highest, amounting to 366.62 billion. Conversely, phase 2, with a length of 9.82 km, has the

highest land acquisition cost of 481.46 billion. This finding suggests that land acquisition costs are not solely influenced by road length, but also by the land value in the areas traversed. Furthermore, phase 1 has the highest construction cost per km, which may indicate technical challenges or more complex terrain conditions compared to the other phases. Therefore, meticulous planning for each phase must consider two factors: the length of the road alignment and the socio-economic and geographical conditions of the project area. The total expenditure of 1,384.53 million allocated for land acquisition includes expenses associated with property acquisitions and owner compensation. The construction of roads and bridges necessitates a budget of 1,660.31 million, which is required to cover expenses related to materials, labor, and equipment. The project extends 48.25 km and is organized into multiple stages, which support efficient project task management. Project estimates are derived by combining initial spending expenses with inflation adjustments, unexpected delay costs, and environmental and safety management costs. The effective management of resources and risk mitigation are achieved through budgetary constraints at each stage. Furthermore, the feasibility of a project is determined by its projections, which in turn improve long-term financial returns.

The long-term operational cost estimate for this project is based on three primary components: routine maintenance, periodic maintenance, and major reconstruction. Routine maintenance is estimated to account for 3% of the total construction cost on an annual basis. This is regarded as a recurring expense throughout the project's operational life. It is estimated that periodic maintenance, which is scheduled to occur every five years, will account for 10% of the construction cost and the costs for major reconstruction are expected to reach 15% of the initial construction cost and will be incurred every fifteen years. These components are critical to ensuring the long-term performance and sustainability of the infrastructure. As shown in Figure 3, the project's expenses are categorized into the following cost types: the land acquisition cost, the construction planning cost, the construction cost, the construction supervision cost, the routine maintenance cost, the preservation cost, and the reconstruction cost.

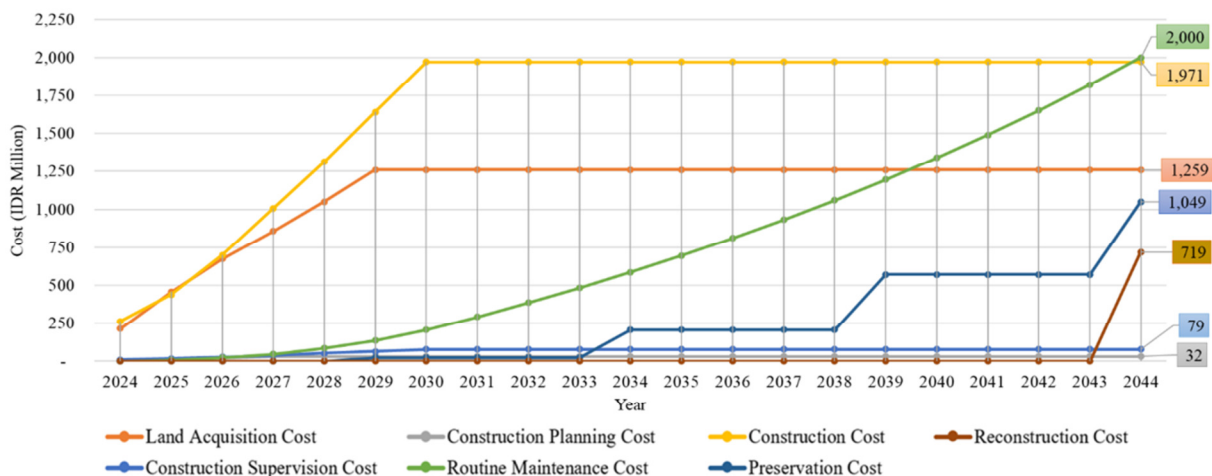


Fig. 3. Estimated cost for Mamminasata bypass construction diagram.

The Mamminasata bypass construction costs continue to escalate on an annual basis, resulting in an estimated expenditure of 7,109 million in 2044. The acquisition of land will reach its zenith in 2028, at which point it will maintain a constant level of 1,259 million, commencing in 2029. The financial requirement for construction planning shall remain at a steady level of 32 million from 2027 onwards. The total supervision amount has reached 79 million, while maintenance and preservation expenditures are estimated to reach 2,000 million and 1,049 million in 2044. The reconstruction expenses are showing a total of 719 million in 2044. A substantial increase in land acquisition costs is observed during the project's initial phase, particularly from 2024, before potentially reaching a stable state through 2044. This phenomenon suggests that the initial phase of the project was characterized by a concentration of land acquisition activities, with the subsequent construction phases being supported by these acquisitions. Concurrently, construction costs and construction planning costs will reach their zenith in 2029 and will remain stable until the conclusion of the period under study. This finding suggests that the physical development of infrastructure was executed in a single major phase rather than incrementally. Conversely, routine maintenance costs and preservation costs demonstrate a steadily rising trend, indicative of the long-term maintenance requirements for developed infrastructure assets. A future increase in reconstruction costs in 2044 indicates a planned major maintenance cycle or structural replacement, which will be anticipated from the project's inception. The graph presents a systematic life cycle asset management strategy. The strategy commences with a substantial initial investment, subsequently followed by continuous maintenance efforts, and culminating in reconstruction at the conclusion of the infrastructure's technical lifespan. Table III shows the projected expenses for the Mamminasata bypass road development, including the costs of land acquisition, construction, routine maintenance, and reconstruction for road and bridge construction. The financial projections for the Mamminasata bypass road extend from 2024 to 2044, with a cumulative estimated expenditure of 7,108.91 million over the next two decades.

To produce reliable traffic forecasts for the Mamminasata area, the PTV Visum was used and integrated localized datasets tailored to the region. The modeling process entailed the synthesis of origin-destination matrices from travel behavior surveys, traffic volume counts from key locations, and a digitized road network map. The characterization of each segment of the network was executed through the usage of functional classifications, road capacity data, and lane details derived from field observations and standardized design references. A comprehensive four-step transportation model, thoroughly calibrated to ensure precision, was utilized to replicate the traffic situation in 2024. This model includes a comprehensive range of functions, such as trip generation, distribution, mode selection, and traffic assignment. The calibration and validation of the model were performed using actual traffic counts and travel time observations. The performance of the model was measured using MAPE and R-squared analysis. For the 2025–2044 projection period, the model was updated to incorporate expected demographic

growth and changes in land use. Two simulation scenarios were evaluated: one reflecting the existing network without intervention, and another incorporating the proposed Mamminasata bypass. The model underwent annual updates to align with changes in infrastructure and demand, facilitating continuous improvement and refinement.

TABLE III. ESTIMATED TOTAL COST OF THE MAMMINASATA BYPASS CONSTRUCTION

No	Year	Cost (IDR million)	Cumulative cost (IDR million)
0	2024	492.36	492.36
1	2025	437.55	929.91
2	2026	515.66	1,445.57
3	2027	537.19	1,982.76
4	2028	549.72	2,532.48
5	2029	626.96	3,159.43
6	2030	411.24	3,570.68
7	2031	87.17	3,657.85
8	2032	92.14	3,749.99
9	2033	97.40	3,847.39
10	2034	286.17	4,133.55
11	2035	108.81	4,242.37
12	2036	115.02	4,357.39
13	2037	121.57	4,478.96
14	2038	128.50	4,607.46
15	2039	499.01	5,106.47
16	2040	143.57	5,250.04
17	2041	151.75	5,401.80
18	2042	160.40	5,562.20
19	2043	169.55	5,731.75
20	2044	1,377.16	7,108.91

The simulation results are illustrated in Figure 4, while Tables III and IV compare saturation levels and vehicle speeds across both scenarios. These results provide a robust technical foundation for the development of long-term transportation strategy and support sustainable planning efforts in the Mamminasata region. Tables IV and V provide a comparison between the Degree of Saturation (DoS) and vehicle speeds for primary road segments in the Mamminasata area from 2024 through 2044. The analysis comprised three primary scenarios: the current state of traffic in 2024, one in which no changes are implemented, and another one in which the Mamminasata bypass road construction is completed. The implemented bypass road has led to a significant enhancement in traffic flow, accompanied by a notable reduction in congestion levels.

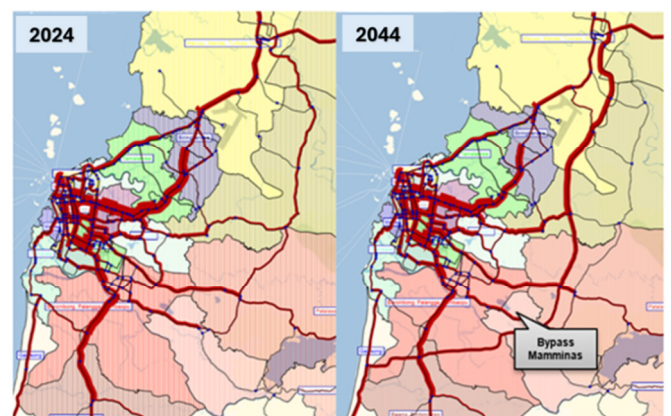


Fig. 4. Traffic projections in the Mamminasata area using PTV Visum.

TABLE IV. COMPARISON OF DOS BEFORE AND AFTER THE MAMMINASATA BYPASS

No	Road name	Length (km)	DoS		
			2024		2044
			Existing	Without project	With project
1	Jl. Poros Mks - Maros	11.61	0.739	1.056	0.700
2	Jl. S. Alauddin	5.20	0.741	1.010	0.961
3	Jl. AP. Pettarani	4.35	0.772	1.061	0.929
4	Jl. Perintis Kemerdekaan	15.42	0.791	1.089	0.933
5	Jl. Gowa Takalar	5.45	0.701	0.918	0.706
6	Jl. Poros Malino	8.99	0.641	0.884	0.638
7	Jl. Hertasning	7.50	0.662	1.040	0.875
8	Jalan Poros Moncongloe	9.70	0.550	0.971	0.826
9	Jl. Bypass MMA I & II	3.77	-	-	0.474
10	Jl. Bypass MMA III & IV	9.67	-	-	0.512
11	Jl. Bypass MMA V - VII	18.26	-	-	0.507
12	Jl. Bypass MMA VIII-X	15.95	-	-	0.471

TABLE V. COMPARISON OF VEHICLE SPEEDS BEFORE AND AFTER THE MAMMINASATA BYPASS

No	Road name	Length (km)	Speeds (km/h)		
			2024		2044
			Existing	Without project	With project
1	Jl. Poros Mks - Maros	11.61	43.27	21.97	44.61
2	Jl. S. Alauddin	5.20	43.22	26.61	30.78
3	Jl. AP. Pettarani	4.35	42.02	21.53	33.24
4	Jl. Perintis Kemerdekaan	15.42	41.17	18.40	32.93
5	Jl. Gowa Takalar	5.45	44.57	34.05	44.40
6	Jl. Poros Malino	8.99	46.19	36.26	46.28
7	Jl. Hertasning	7.50	45.67	23.66	36.83
8	Jalan Poros Moncongloe	9.70	47.94	29.97	39.55
9	Jl. Bypass MMA I & II	3.77	-	-	48.86
10	Jl. Bypass MMA III & IV	9.67	-	-	48.46
11	Jl. Bypass MMA V - VII	18.26	-	-	48.51
12	Jl. Bypass MMA VIII-X	15.95	-	-	48.89

By 2044, the Mamminasata area is projected to have experienced substantial DoS growth in conjunction with significant reductions in road speed for the majority of thoroughfares, if no measures are implemented. This scenario indicates a rise in congestion. The Mamminasata bypass road has been demonstrated to reduce DoS values and significantly enhance speeds, thereby leading to a notable reduction in traffic congestion. For instance, the average speed on Jl. Poros Mks - Maros increased from 21.97 km/h to 44.61 km/h. The bypass has been found to support travel speeds ranging from 48.46 km/h to 48.89 km/h, thus demonstrating its efficacy in enhancing traffic flow and reducing travel duration. The strategic value of the bypass road is evident in its improved traffic performance, which supports economic development and regional transportation links. The project scenario demonstrates that increased average speeds lead to reduced VOC because they decrease fuel consumption and maintenance expenses per km and save time according to users' VoT.

In this case study, a customized spreadsheet-based model was developed to assess VOC using detailed local data from the Mamminasata region. This methodological framework enabled the quantification of the economic benefits of the proposed bypass road, with the said benefits being determined based on real traffic conditions and cost structures. The components of VOC, including fuel, maintenance, tire wear,

oil, and depreciation, were calculated utilizing region-specific unit rates and vehicle classifications derived from the traffic output of the PTV Visum model. The estimated fuel costs were determined by multiplying consumption rates (L/km) for each vehicle type by the current local fuel prices. The allocation of maintenance, tire, and oil costs was conducted in accordance with the national standards, with the costs being calculated per km. The depreciation values were derived from the vehicle acquisition costs divided by the lifespan in km, as defined by the Indonesian transport planning guidelines. All inputs were integrated into the model to simulate two conditions: with and without the Mamminasata bypass road. The annualized VOC savings were calculated by determining the cost difference per km between the two scenarios and subsequently multiplying by the aggregate annual traffic volume, which was disaggregated according to vehicle type. To capture long-term impacts, cumulative VOC savings were summed over the entire project horizon (2024–2044). Furthermore, the modeled travel time reductions per trip were used to calculate the time savings, with the application of vehicle-specific VoT and trip frequencies from traffic forecasts. These detailed steps enabled the generation of precise, context-specific estimates of the bypass impact. As presented in Table VI, the project is projected to generate savings in VOC emissions amounting to 18,157.14 million over a 20-year period, commencing in 2031. This underscores the project's economic viability, substantiated by enhanced traffic performance and diminished operating expenditures.

TABLE VI. SUMMARY OF VOC SAVINGS DUE TO MAMMINASATA BYPASS ROAD

No	Year	VOC (IDR million)			
		Without project	With project	Annual saving	Cumulative saving
0	2024	3,671.43	3,671.43	-	-
1	2025	4,032.84	4,032.84	-	-
2	2026	4,369.53	4,369.53	-	-
3	2027	4,736.60	4,736.60	-	-
4	2028	5,138.53	5,138.53	-	-
5	2029	5,579.42	5,579.42	-	-
6	2030	6,064.01	6,064.01	-	-
7	2031	6,653.35	5,885.53	767.82	767.82
8	2032	7,246.95	6,487.16	759.79	1,527.61
9	2033	7,904.12	7,148.85	755.27	2,282.88
10	2034	8,633.93	7,876.86	757.06	3,039.95
11	2035	9,447.22	8,678.20	769.03	3,808.97
12	2036	10,357.13	9,560.70	796.42	4,605.40
13	2037	11,379.67	10,533.21	846.45	5,451.85
14	2038	12,534.70	11,605.73	928.97	6,380.82
15	2039	13,847.12	12,789.57	1,057.55	7,438.37
16	2040	15,348.76	14,097.68	1,251.08	8,689.45
17	2041	17,081.07	15,544.88	1,536.20	10,225.65
18	2042	19,099.50	17,148.26	1,951.23	12,176.88
19	2043	21,480.52	18,927.72	2,552.80	14,729.68
20	2044	24,334.02	20,906.56	3,427.47	18,157.14

The VoT calculation is a statistical analysis that estimates the annual savings from trip time reductions and road users' hourly income rates while monitoring traffic volume levels. A joint analysis of VOC and VoT reveals short-term economic advantages, with the potential for extended benefits. The method enables transportation planners to assess time-related benefits and vehicle operating costs, therefore facilitating the

attainment of optimal planning outcomes. The project has been shown to enhance productivity, connectivity, and economic efficiency by reducing congestion and travel time, as displayed in Table VII.

TABLE VII. SUMMARY OF VOT SAVINGS DUE TO MAMMINASATA BYPASS ROAD

No	Year	VoT (IDR million)			
		Without project	With project	Annual saving	Cumulative saving
0	2024	320.74	320.74	-	-
1	2025	353.03	353.03	-	-
2	2026	384.25	384.25	-	-
3	2027	418.59	418.59	-	-
4	2028	456.52	456.52	-	-
5	2029	498.52	498.52	-	-
6	2030	545.14	545.14	-	-
7	2031	601.76	574.88	26.89	26.89
8	2032	660.11	622.27	37.85	64.74
9	2033	725.53	673.97	51.57	116.31
10	2034	799.19	730.45	68.74	185.05
11	2035	882.52	792.25	90.27	275.32
12	2036	977.32	859.98	117.34	392.66
13	2037	1,085.84	934.35	151.50	544.16
14	2038	1,211.00	1,016.17	194.83	738.99
15	2039	1,356.59	1,106.42	250.17	989.16
16	2040	1,527.66	1,206.22	321.44	1,310.59
17	2041	1,731.14	1,316.92	414.22	1,724.81
18	2042	1,976.76	1,440.14	536.61	2,261.42
19	2043	2,278.68	1,577.84	700.84	2,962.27
20	2044	2,658.46	1,732.43	926.02	3,888.29

The reduction in travel time will result in annual VoT savings increasing from 26.89 million to 926.02 million between 2031 and 2044. By 2044, the Mamminasata bypass road will have achieved cumulative VoT savings amounting to 3,888.29 million. The researchers developed a system for analyzing road infrastructure project outcomes by integrating land value alterations with TVO. The full benefits of infrastructure projects become apparent when analysts employ supplementary evaluation metrics that extend beyond conventional feasibility elements, such as vehicle operating costs and travel time savings. The development of enhanced road networks facilitates increased access to areas, leading to higher land values in proximity to these roads and stimulating economic development and urban growth. The analysis yielded a multiple linear regression model, which was developed using Stata software:

$$\ln(y) = 9.9740 - 0.0244 \ln(x_1) - 0.0399 \ln(x_2) + 0.3506(x_3) + 0.5881(x_4) + 0.0281 \ln(x_5) - 0.0364(x_6) \tag{1}$$

The log-linear regression analysis conducted in the current study examined the interaction between TVO (y) and variables, including road access (x₃), land use (x₄), proximity to city centers (x₁), and major roads (x₂). TVO growth experiences positive effects due to enhanced road access and optimized land use. Conversely, adverse effects are observed when TVOs are located farther from city centers and primary roadways. TVO growth is enhanced by the development of infrastructure and effective land use management strategies. However, the organization encounters challenges in locations that are distant from central urban areas. The development of infrastructure has

been demonstrated to exert a significant influence on property value. The enhancement of accessibility, for instance, has been shown to stimulate investment and construction projects, thereby increasing the appeal of real estate and, consequently, elevating its value. The MAPE method demonstrated remarkable accuracy of 5.41%, which validates the model's effectiveness. The assessment of the Mamminasata bypass road's impact on property values required the application of a series of processing steps within the QGIS platform. The analysis commenced with the integration of numerous spatial datasets, including land use maps and road networks, followed by georeferencing to ensure layer alignment. The research team employed buffer analysis and spatial join tools to evaluate accessibility gains by ascertaining the proximity of land parcels to the newly constructed road. The computation of land value enhancements necessitated the measurement of distances, in conjunction with additional factors determined through regression analysis. As portrayed in Table VIII, the improvement of transportation infrastructure has been found to result in enhanced accessibility, which is expected to lead to an increase in land values. Table VIII presents a side-by-side analysis of land values before and after the project was initiated, using the initial property price, the subsequent property price following infrastructure development, and the calculated difference representing land value appreciation. The Mamminasata bypass road project resulted in a property value appreciation of 14,326.36 million.

TABLE VIII. SUMMARY OF THE BENEFITS FROM THE INCREASE IN LV

No	Year	LV (IDR million)			
		Without project	With project	Annual	Cumulative
0	2024	770.79	770.79	-	-
1	2025	770.79	770.79	-	-
2	2026	770.79	770.79	-	-
3	2027	912.47	918.79	6.33	6.33
4	2028	912.47	918.79	6.33	12.65
5	2029	912.47	918.79	6.33	18.98
6	2030	1,179.72	1,250.26	70.54	89.52
7	2031	1,179.72	1,250.26	70.54	160.06
8	2032	1,179.72	1,250.26	70.54	230.60
9	2033	1,321.89	1,709.83	387.94	618.55
10	2034	1,321.89	1,709.83	387.94	1,006.49
11	2035	1,321.89	1,709.83	387.94	1,394.43
12	2036	1,548.30	2,620.51	1,072.22	2,466.64
13	2037	1,548.30	2,620.51	1,072.22	3,538.86
14	2038	1,548.30	2,620.51	1,072.22	4,611.08
15	2039	1,957.54	3,426.25	1,468.71	6,079.79
16	2040	1,957.54	3,426.25	1,468.71	7,548.49
17	2041	1,957.54	3,426.25	1,468.71	9,017.20
18	2042	2,172.02	3,941.73	1,769.72	10,786.92
19	2043	2,172.02	3,941.73	1,769.72	12,556.64
20	2044	2,172.02	3,941.73	1,769.72	14,326.36

The Mamminasata bypass road initiative has the effect of elevating TVO, which in turn causes Indonesian landowners to experience increased LBT responsibilities. The LBT is:

$$LBT = Tax\ Rate \times (TVO - NTVO) \tag{2}$$

The applicable tax rate ranges from 0.1% to 0.3%, while the Non-Taxable Value of Object (NTVO) signifies the tax-exempt portion of a property's value. Table IX presents a summary of

the benefits derived from the increase in the LBT as a result of the Mamminasata bypass road project, and the financial benefits accrued from elevated land values, a consequence of the Mamminasata bypass road development. The data indicate a continuous yearly increase in tax savings, with cumulative benefits demonstrating consistent expansion. It is projected that by 2044, the accumulated savings will have amounted to 28.29 million. The implementation of the bypass project results in an increase in land values, which subsequently leads to an augmentation in property tax revenue. This, in turn, supports local government budgets and regional economic development. The additional revenue generated from property taxes plays a critical role in financing infrastructure projects and public service enhancements, hence contributing to an overall enhancement in the living standards of the community. The continuous process of development and reinvestment promotes sustainable economic growth, which benefits local communities while also contributing to the overall development of the region over time, as presented in Figure 5 and Table X. The development of the Mamminasata bypass road is expected to generate significant advantages, including reduced VOC, saved travel time, and increased LBT revenue. The benefit categories independently enhance transportation efficiency and regional income through their economic impacts, while functioning collaboratively. It has been determined that the most significant portion of total benefits comprises 18,157.14 million VOC savings, followed by the 17,222.22 million VoT savings.

TABLE IX. SUMMARY OF THE BENEFITS FROM THE INCREASE IN LBT

No	Year	LBT (IDR million)			
		Without project	With project	Annual	Cumulative
0	2024	1.81	1.81	-	-
1	2025	1.81	1.81	-	-
2	2026	1.81	1.81	-	-
3	2027	2.15	2.16	0.01	0.01
4	2028	2.15	2.16	0.01	0.01
5	2029	2.15	2.16	0.01	0.02
6	2030	2.67	2.74	0.08	0.10
7	2031	2.67	2.74	0.08	0.17
8	2032	2.67	2.74	0.08	0.25
9	2033	3.10	3.63	0.53	0.77
10	2034	3.10	3.63	0.53	1.30
11	2035	3.10	3.63	0.53	1.82
12	2036	3.68	5.67	1.98	3.81
13	2037	3.68	5.67	1.98	5.79
14	2038	3.68	5.67	1.98	7.77
15	2039	4.52	7.62	3.11	10.88
16	2040	4.52	7.62	3.11	13.99
17	2041	4.52	7.62	3.11	17.09
18	2042	5.24	8.97	3.73	20.83
19	2043	5.24	8.97	3.73	24.56
20	2044	5.24	8.97	3.73	28.29

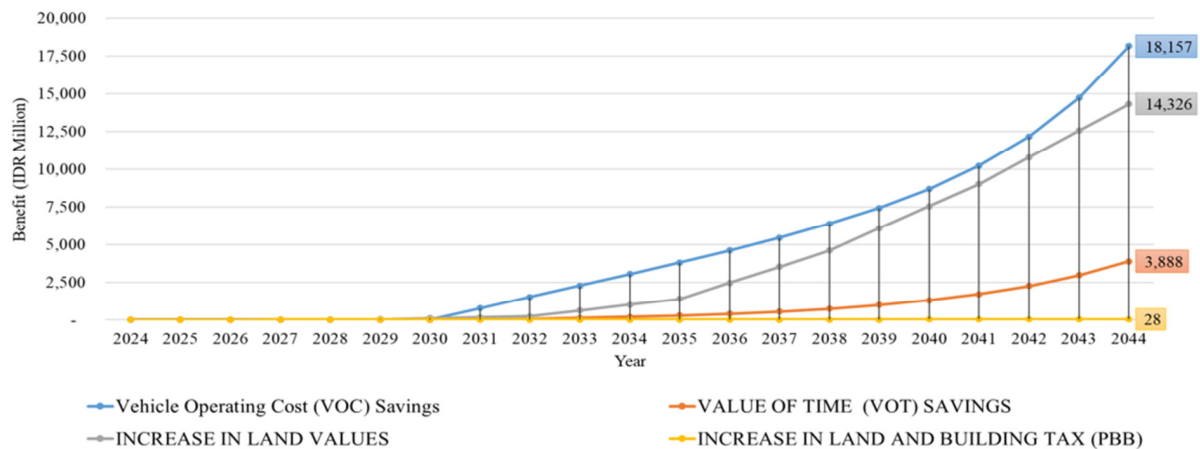


Fig. 5. Estimated benefit for Mamminasata bypass construction diagram.

The adoption of more efficient traffic patterns can yield substantial financial advantages, amounting to 3,888.29 million, primarily attributable to the reduction in travel time. The total project benefits comprise 60.6% savings from the VOC and VoT accounts, amounting to 22,045.43 million. Efficient transportation systems are critical for generating economic value. The Mamminata bypass road has been identified as a catalyst for economic growth, with an estimated impact on land values of 14,326.36 million and a corresponding increase in property tax revenues of 28.29 million. This is attributed to the enhanced accessibility and connectivity it has brought to the region. The advancement of regions is facilitated by infrastructure development, which

accounts for 39.4% of all project benefits. The project is expected to generate annual benefits of 6.33 million from 2027 to 2029, subsequently increasing to 865 million in 2031 and 868 million in 2032. This will have resulted in total benefits of 36,400 million by 2044. The bypass has been demonstrated to provide lasting benefits that enhance transportation infrastructure and stimulate business operations and investment prospects, leading to regional development and increased government revenue. The allocation of financial resources towards strategic infrastructure development has been demonstrated to be a catalyst for the attainment of sustained economic growth in neighboring regions. The standards to which upcoming development initiatives are held are derived

from these infrastructure projects, which ensure equitable economic growth distribution. The cashflow analysis employing an 8% discount rate is presented in Table XI.

TABLE X. ESTIMATED TOTAL BENEFIT OF THE MAMMINASATA BYPASS CONSTRUCTION

No	Year	Total benefit (IDR million)				
		VOC	VoT	LV	LBT	Total
0	2024	-	-	-	-	-
1	2025	-	-	-	-	-
2	2026	-	-	-	-	-
3	2027	-	-	6.33	0.01	6.33
4	2028	-	-	6.33	0.01	6.33
5	2029	-	-	6.33	0.01	6.33
6	2030	-	-	70.54	0.08	70.62
7	2031	767.82	26.89	70.54	0.08	865.33
8	2032	759.79	37.85	70.54	0.08	868.26
9	2033	755.27	51.57	387.94	0.53	1,195.30
10	2034	757.06	68.74	387.94	0.53	1,214.27
11	2035	769.03	90.27	387.94	0.53	1,247.77
12	2036	796.42	117.34	1,072.22	1.98	1,987.96
13	2037	846.45	151.50	1,072.22	1.98	2,072.15
14	2038	928.97	194.83	1,072.22	1.98	2,198.00
15	2039	1,057.55	250.17	1,468.71	3.11	2,779.53
16	2040	1,251.08	321.44	1,468.71	3.11	3,044.33
17	2041	1,536.20	414.22	1,468.71	3.11	3,422.23
18	2042	1,951.23	536.61	1,769.72	3.73	4,261.30
19	2043	2,552.80	700.84	1,769.72	3.73	5,027.09
20	2044	3,427.47	926.02	1,769.72	3.73	6,126.94
Total		18,157.14	3,888.29	14,326.36	28.29	36,400.08
		22,045.43		14,354.65		

TABLE XI. CASH FLOW ANALYSIS WITH 8% DISCOUNT RATE

Year	Cash flow analysis with 8% discount rate (IDR million)				
	Benefits	Costs	Net cash flow	Discounted benefits	Discounted costs
2024	-	492.36	492.36	-	492.36
2025	-	437.55	437.55	-	405.14
2026	-	515.66	515.66	-	442.10
2027	6.33	537.19	530.85	5.03	426.44
2028	6.33	549.72	543.38	4.65	404.06
2029	6.33	626.96	620.62	4.31	426.70
2030	70.62	411.24	340.62	44.50	259.15
2031	865.33	87.17	778.16	504.91	50.87
2032	868.26	92.14	776.12	469.09	49.78
2033	1195.30	97.40	1,097.91	597.95	48.72
2034	1,214.27	286.17	928.11	562.44	132.55
2035	1,247.77	108.81	1,138.95	535.15	46.67
2036	1,987.96	115.02	1,872.95	789.45	45.67
2037	2,072.15	121.57	1,950.58	761.93	44.70
2038	2,198.00	128.50	2,069.50	748.33	43.75
2039	2,779.53	499.01	2,280.52	876.22	157.31
2040	3,044.33	143.57	2,900.76	888.61	41.91
2041	3,422.23	151.75	3,270.47	924.92	41.01
2042	4,261.30	160.40	4,100.90	1,066.39	40.14
2043	5,027.09	169.55	4,857.54	1,164.84	39.29
2044	6,126.94	1,377.16	4,749.78	1,314.52	295.47

As illustrated in Table XII, a comprehensive cash flow analysis for the Mamminasata bypass road project has been conducted, employing an 8% discount rate from the year 2024 to the year 2044. From 2024 to 2026, the project will have had only expenditures without generating any benefits, resulting in negative net cash flows. The project will potentially yield benefits in 2027; however, it will continue to exhibit negative

net cash flows due to significant initial investment costs. The year 2030 represents the onset of a substantial expansion in benefits, which will lead to consistent enhancements in net cash flows on an annual basis. In 2044, the total benefits must be 6,126.94 million, while costs will reach 1,377.16 million, resulting in a net cash flow of 4,749.78 million. Present Worth Benefits (PWB) amounted to 1,314.52 million, which exceeded the Present Worth Costs (PWC) of 295.47 million, despite early-stage losses. The project will result in a positive NPV, indicating that it engenders favorable economic ramifications over time, notwithstanding the challenges encountered in its nascent stage.

Year	In IDR million			
	PWB	PWC	NPV (IDR million)	Cumulative net cash flow
2024	-	492.36	492.36	492.36
2025	-	405.14	405.14	897.50
2026	-	442.10	442.10	1,339.60
2027	5.03	426.44	421.41	1,761.01
2028	4.65	404.06	399.40	2,160.41
2029	4.31	426.70	422.39	2,582.80
2030	44.50	259.15	214.65	2,797.45
2031	504.91	50.87	454.05	2,343.40
2032	469.09	49.78	419.31	1,924.09
2033	597.95	48.72	549.23	1,374.86
2034	562.44	132.55	429.89	944.97
2035	535.15	46.67	488.48	456.49
2036	789.45	45.67	743.77	287.28
2037	761.93	44.70	717.22	1,004.50
2038	748.33	43.75	704.58	1,709.09
2039	876.22	157.31	718.92	2,428.00
2040	888.61	41.91	846.70	3,274.71
2041	924.92	41.01	883.91	4,158.61
2042	1,066.39	40.14	1,026.25	5,184.86
2043	1,164.84	39.29	1,125.55	6,310.41
2044	1,314.52	295.47	1,019.06	7,329.47
Total	11,263.25	3,933.78		

An analysis of the project's performance and long-term sustainability through key metrics is made, including PWB, PWC, NPV, and cumulative net cash flow. The Mamminasata bypass road project exhibits significant economic potential because improved transport efficiency supports regional growth plans to generate additional revenue. A thorough evaluation of the Mamminasata bypass road project by relevant stakeholders should take into account its capacity for fostering economic growth and adaptability. This evaluation necessitates a meticulous examination of financial aspects and related analyses. The venture initially opposes negative cash flows until substantial aggregate net cash flows begin to increase. The extent of the initial venture's recovery point is significant, generating significant long-term returns once aggregate net cash flows reach 7,329.47 million in 2044. The cumulative net cash flow is depicted in Figure 6. The Mamminata bypass road yields an exceptional financial return through its benefit-cost proportion, which exhibits benefits that exceed the speculation costs for each contributed unit by a factor of three. The venture's NPV is 7,329.47 million, indicating its financial viability and the potential for significant benefits following the completion of its venture stage. The extent of this potential is indicated by its 12.05% IRR, which exceeds the minimum threshold, even in circumstances where market conditions are

less than optimal. The project's PP is 12 years. This allows investors to recoup their initial investment within a reasonable timeframe. It also ensures that there is sufficient funds availability and effective cash flow management. The Mamminasata bypass road has been demonstrated to engender benefits through compelling fetched administration and

territorial financial incitement. The extension has been shown to develop more grounded territorial transportation associations and generate employment opportunities, thereby contributing to economic development and stability through its robust budgetary framework.

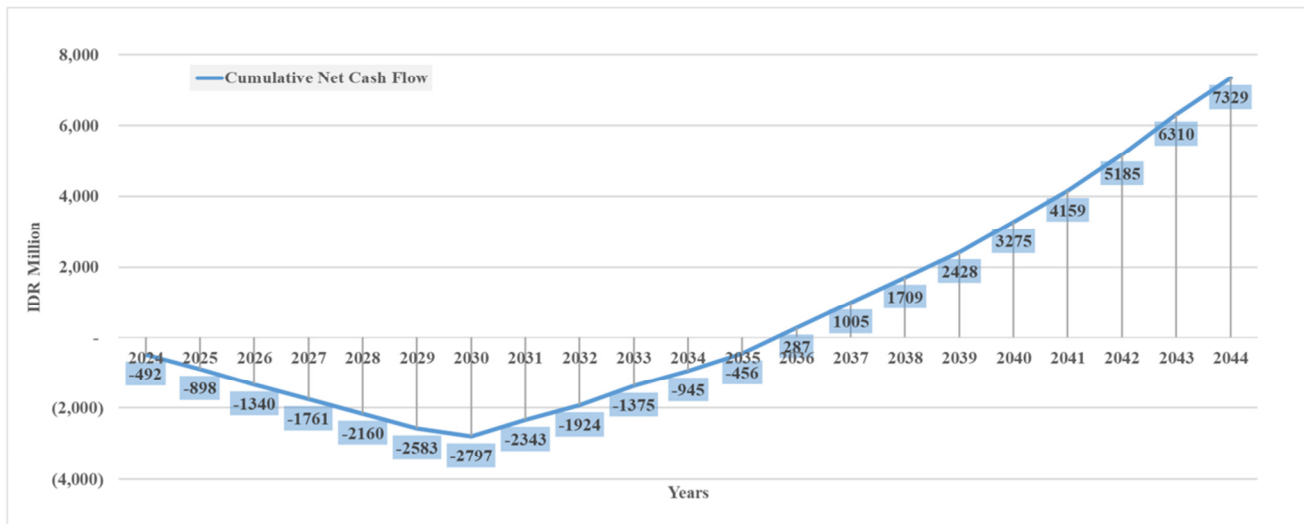


Fig. 6. Cumulative net cash flow diagram.

IV. DISCUSSION

The analysis underscores the direct savings in transportation and the broader socio-economic benefits associated with the Mamminasata bypass road. In a similar way, the advantages apply to local financial revenues, such as the LBT, contributing to the existing global literature on the impact of transport facilities on local economies. Authors in [22, 23] have noted an increase in user satisfaction and regional competitiveness driven by increased productivity, time savings, and improved infrastructure. Furthermore, there are long-term macroeconomic ramifications, as evidenced in [24]. The extensive South Korean expressway network has been shown to result in reduced travel and logistical expenditures, leading to financial savings. While previous studies have emphasized transport indicators, the current research aims to expand the scope of the economic assessment to include changes in land value and tax revenue. This aims to address the limitations identified in previous works, which highlighted the absence of comprehensive fiscal measures in traditional infrastructure valuation frameworks. These studies observed increases in land value as a result of expenditures on transport infrastructure [25, 26]. However, they lacked the analysis of how those shifts were reflected in monetary returns through taxation, specifically in property taxes. This study addresses this knowledge gap by analyzing the increase in LBT revenues in relation to land value appreciation, thus capturing an important feedback loop in urban finance. Another element is the systematic organization and the level of detail of the economic factors [27]. This study uses comprehensive financial metrics, including NPV, BCR, IRR, and PP. These metrics provide a robust foundation for the argument in favor of long-term

initiatives, offering substantiated evidence to support the case for continued investment. Specifically, the NPV of 7,329.46 million, the BCR of 2.86, and the IRR of 12.05% are rational indicators of the project's viability, particularly in the context of initial cash flow losses. Furthermore, the substantially high share of VOC and VoT (60.6% of total benefits) relative to land value and LBT (39.4%) shows that, although there is some transportation investment, its efficiency is important, while the cost from increased land value is not insignificant. This lends further support to the arguments in [28], where TOD models were developed predicated on the concept of land value capture financing. This study uses empirical evidence to substantiate the necessity of an interdisciplinary approach between transport planning and local government finance.

The current study has advanced knowledge by producing a dual-benefit model that simultaneously considers transport and land-derived economic benefits. Furthermore, it has measured the value of road infrastructure-induced land value increase in terms of LBT and has addressed a significant gap in the literature. Finally, it has aided long-term strategic investment choices through comprehensive financial appraisal frameworks alongside conventional CBA approaches [29]. This understanding transcends the realm of infrastructure economics and may hold relevance for policymakers grappling with the rapid expansion of urban areas. It is proposed that future road expansion projects employ these models for the purpose of explaining the necessity of funding, planning cost recovery, and strategically directing urban development while fostering sustainable economic growth. A more in-depth analysis of the infrastructures' social impacts is necessary to ensure the economic feasibility of the multi-bridged highway. The social

factors that influence accounting practices must be considered in order to develop effective strategies for the future of highway development. Moreover, the implementation of regional development initiatives frequently gives rise to adverse social consequences that necessitate thorough examination and resolution. These may include the removal and relocation of entire communities as a result of land acquisition, disruption of economically productive activities of the locals, and alteration of levels of access and mobility by marginalized groups. Additionally, there is a possibility of social division or gentrification in suburban areas and the emergence of new developments. Furthermore, the extent to which underserved groups perceive the initiative and their level of engagement during the planning and operational phases can significantly impact the eventual outcome of these initiatives. The integration of social attributes into project planning enhances the public perception, acceptability, and community inclusivity without compromising the expenditure perspective. Therefore, the integration of social equity with measures of infrastructural cost efficiency is essential for the subsidization of justified expenses and the promotion of socially responsible urban planning. In the future researchers must concentrate on developing mobile and web applications that integrate geospatial information, traffic simulation results, and automated economic impact analysis models into a unified coherent framework. These tools are expected to enhance the decision-making capabilities of planners and policymakers. Additionally, they will facilitate the integration of the model into rich contextual environments, thereby enabling tailored customization and applicability. These comprehensive partnerships will allow experts to address infrastructure planning and governance through intuitive, streamlining innovations that can operate on user-friendly interfaces along with integrated analytical tools. Furthermore, in order to include social and environmental factors, researchers must broaden the scope of economic evaluation. A more comprehensive approach, one which considers land use changes, displacement, equitable and fair distribution, air quality and pollution, and general welfare, requires all these factors, in addition to the other previously mentioned, in order to realize the vision of sustainable infrastructure. Machine learning techniques, such as decision trees, random forests, and gradient boosting should be used to enhance the accuracy of advanced land value forecasting. Due to their non-linear rendering capabilities, these models demonstrate a remarkable capacity to capture the intricate spatial and socio-economic interrelations of the described variables. These methodologies improve model responsiveness and accuracy, thus maximizing the potential for evaluating land value uplift. It is important to ascertain the model's relevance to the context and its applicability across various agglomeration areas, including Jabodetabek, Gerbangkertosusila, and Mebidangro. This validation process should consider the usage of diverse infrastructure, such as highways, transit systems, and TODs.

V. CONCLUSIONS

The Mamminasata bypass road offers substantial advantages, including a reduction in Vehicle Operating Costs (VOC) and Value of Time (VoT) expenses, while concurrently increasing land value and Land and Building Tax (LBT)

revenues. Despite the operational independence of these two benefit groups, their combined economic contributions ultimately enhance transportation efficiency and regional income. The total savings from the VOC and VoT perspective amounted to 18,157.14 million, representing the most substantial contribution to the total benefits. The observed savings can be attributed to enhanced traffic flow conditions. The reduction in travel times yielded benefits amounting to 3,888.29 billion, representing the Value of Time Saved (VoTS). The aggregate benefits from VOC and VoT amounted to 22,045.43 million, constituting 60.6% of the total project benefits. The data indicates that enhancements in transportation efficiency provide the most significant boost to the total economic benefits. Increases in land value and LBT revenue generation also contribute to significant project impacts resulting in an increase in land value of 14,326.36 million. This rise in land prices near the project area can be explained by the accessibility and connectivity enhancements. The project is expected to generate a 28.29 billion increase in LBT revenues from this development. The aggregate benefits from the increased land values and LBT revenues amount to 14,354.65 million, representing 39.4% of all project benefits. The development of road infrastructure can improve transportation flow and boost regional economic growth by elevating property values and tax revenues. A thorough examination of the project's cash flows reveals that, despite an initial negative cash flow, the project will ultimately generate positive economic outcomes in the long run. The project's economic viability is substantiated by its Net Present Value (NPV) of 7,329.46 million, which exhibits a Benefit-Cost Ratio (BCR) of 2.86 and an Internal Rate of Return (IRR) of 12.05%. The project's Payback Period (PP) of 12 years indicates that it employs effective strategies to mitigate liquidity risks. The developed framework in this study offers a detailed representation of the project's economic feasibility. The economic evaluation approach, which incorporates land value changes and LBT revenues within Cost-Benefit Analysis (CBA), demonstrates that road development brings economic benefits extending beyond transportation efficiency to include substantial regional revenue growth. This study offers novel insights into the economic assessment of infrastructure, particularly in the context of urban road development in agglomeration areas, such as Mamminasata. The research presents an original integration of traditional CBA with spatial-economic measures, such as land value increases and LBT revenues. This approach goes beyond evaluating traffic efficiency and offers a more complete and multidimensional evaluation of infrastructure projects. The objective of the present study is to provide a contextual framework for the localized impacts by employing specific local data to the Mamminasata bypass road project. The study provides an estimation of non-transportation benefits, which are typically absent in the evaluation of infrastructure projects. The significance of this research lies in its potential to promote sociable and environmentally sustainable urban region development. The project's favorable economic returns, as indicated by a positive NPV, a favorable BCR, and a manageable PP, serve to reinforce the rationality of public funding. This approach is particularly advantageous for metropolitan areas in developing countries, which often lack comprehensive economic evaluation tools. This research

contributes to the global discourse by promoting a more inclusive approach to infrastructure evaluation, integrating urban infrastructure economics with the existing structure planning system. The integration of geospatial information with traffic simulation and automated economic assessment would enhance the efficiency of decision-making processes. The incorporation of social and environmental concerns into the model, employing machine learning algorithms for enhanced land value prediction, is expected to enhance its reliability. Furthermore, it is important to assess the model's relevance and versatility in diverse geographical regions and across various infrastructure configurations.

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