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Techniques for Assessing the Benefit-Cost Ratio and Net Present Value of Kaligunting-Bajulan Road Improvements in Madiun Regency

Pepiet Elyswisnoto[1]*, Budi Witjaksana[2], Hanie Teki Tjendanie[3]
Civil Engineering Master's Study Program, Faculty of Engineering Universitas 17 Agustus 1945 Surabaya, Indonesia
Corresponding Author: Pepiet Elyswisnoto, pepiet.elyswisnoto@gmail.com

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ABSTRACT

Only about 22% of the 4,975 km of the Kaligunting-Bajulan road stretch in Madiun Regency was considered to be in acceptable condition prior to the upgrading. The evaluation process used cost-benefit evaluations using Net Present Value (NPV) and Benefit Cost Ratio (BCR). Road conditions, routine maintenance costs, and vehicle operating costs (VOC) were assessed both before and after the intervention. By reducing routine maintenance expenses by about 80%, this innovation reduced vehicle operating costs by around Rp787 million annually and saved approximately Rp3.34 billion annually. The economic evaluation's NPV of Rp25.09 billion and BCR of 3.31 show that the project is very economically viable because the benefits far outweigh the costs.

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INTRODUCTION

Road damage is a common transportation infrastructure problem in various regions. Highways play a vital role in supporting public mobility and the economy, but they often experience deterioration due to various factors. Factors causing road damage include poor construction quality, overloaded vehicles, and inadequate weather conditions and drainage. Substandard construction, such as the use of substandard materials, can accelerate the development of cracks or potholes in the pavement. Heavy vehicle traffic that exceeds the road's design capacity also accelerates the wear and tear of the pavement structure over a short period of time. Furthermore, heavy rainfall and standing water on the road surface accelerate damage, especially if the drainage system is not functioning properly. This combination of factors often results in a shorter-than-planned road lifespan, necessitating maintenance and road improvements earlier than the planned lifespan when the road condition has deteriorated.

Road damage that is left unrepaired has a negative impact on road users and the surrounding environment. Potholed and damaged road surfaces disrupt the comfort and safety of road users and increase the risk of traffic accidents. Vehicles traveling on damaged roads experience reduced speed, increase travel time, and potentially cause congestion. This condition reduces the efficiency of community activities and logistics distribution due to travel delays. Furthermore, damaged roads increase vehicle operating costs (VOK) (e.g., higher fuel consumption and wear and tear on spare parts). Public access to essential facilities such as education, health services, and economic centers is also disrupted if road infrastructure is inadequate. Therefore, the availability of roads in good condition is a crucial prerequisite for ensuring the smooth mobility of people and goods to support economic activity. The government places great emphasis on the development and maintenance of road infrastructure, given its role as the backbone of the economy. Provincial roads, for example, play a crucial role as interregional connections and support for community economic activity Local governments.

Good provincial roads improve accessibility and reduce transportation costs, thus providing significant economic benefits to surrounding communities. Conversely, neglected road damage can lead to socio-economic losses. The legal basis also establishes the government's obligation to maintain road conditions. Law No. 38 of 2004 concerning Roads and Government Regulation No. 34 of 2006 concerning Roads stipulate that road maintenance (including construction, improvement, and maintenance) is the responsibility of the government, depending on the road's status (national, provincial, or district) (Government of the Republic of Indonesia, Law No. 38 of 2024 concerning Roads, 2024).

Furthermore, Law No. Article 24 paragraph (1) of Law No. 22 of 2009 concerning Traffic and Road Transportation in conjunction with Article 273 mandates that road operators are required to immediately repair damaged roads that could result in traffic accidents. Failure to properly fulfill this obligation can result in criminal sanctions of up to 6 months' imprisonment or a fine of up to IDR 12,000,000 (Government of the Republic of Indonesia, 2009).

This legal provision emphasizes the urgency of addressing road damage quickly and appropriately for the safety of road users. In the context of the Kaligunting-Bajulan Road, repeated damage indicates that improving the capacity and quality of the road's pavement is urgent. Repeated patching efforts each year are only temporary and do not address the underlying structural problems of the pavement (Radar Madiun, 2021). The Madiun Regency Government recognizes that comprehensive management (road rehabilitation/reconstruction) requires high costs, so it has proposed upgrading this road to a provincial road so that it can be managed with the provincial government budget.

The application for the status upgrade was submitted in 2019 and was accompanied by a functional study that showed that the Kaligunting-Bajulan section meets the criteria for a Primary Collector Road (JKP-3/JKP-4) worthy of being designated as a provincial or national road. With this upgraded road status, it is hoped that more adequate budgetary support can be allocated for this road improvement project. Indeed, in 2021, the Kaligunting-Bajulan section was officially designated a provincial road after undergoing a multi-level evaluation (national, provincial, and district) (Koran Memo, 2021). This paved the way for the East Java Provincial Government, through the Public Works Agency, to plan road improvement work.

The technical planning for the Kaligunting-Bajulan Road improvement project refers to the latest national standard, the 2024 Pavement Design Manual (MDP). According to the planning data, the planned service life of this road pavement is set at 20 years (2024–2044), assuming traffic reopening in 2025. The average traffic growth rate is 3.5% per year, according to the regional growth rate for collector roads. The road is planned to remain two lanes (two directions) with a traffic distribution factor of 0.8 for the design lane, considering the significant proportion of commercial vehicles. Initial Average Daily Traffic (ADR) data shows that the vehicle composition is dominated by motorcycles and passenger cars, but there are hundreds of heavy trucks each day (e.g., >500 light two-axle trucks and >300 three-axle trucks per day). The cumulative traffic load over 20 years is estimated to reach millions of ESA (Equivalent Standard Axles), so a pavement reinforcement (overlay) design is required to withstand this load until the end of the design life.

The planned improvements include the addition of a structural overlay, accompanied by patching at locations with severe damage. The design thickness of the overlay is determined based on analytical methods (mechanistic-empirical) in accordance with the 2024 MDP guidelines, to ensure the post-upgrade pavement performs optimally throughout its service life.

Road improvement projects certainly require a significant initial investment, but are expected to provide long-term economic benefits for road users and the public. Public investment in the road sector must be economically justifiable, meaning the benefits generated by the project must be commensurate with or exceed the costs. Therefore, before the physical project is implemented, an economic feasibility analysis is necessary to assess whether the planned Kaligunting-Bajulan Road improvement is feasible. Economic feasibility analyses for road projects generally use cost-benefit analysis methods with quantitative criteria such as Net Present Value (NPV) and Benefit Cost Ratio (BCR). NPV is the difference between the present value of total benefits and the present value of total costs over the project's planning horizon; an NPV value > 0 indicates the project provides a net economic benefit. The BCR is the ratio of the present value of benefits to the present value of costs. An infrastructure project is considered economically feasible if the BCR > 1 (because it means the discounted benefits exceed the discounted costs).

In a cost-benefit analysis, the cost and benefit components calculated must be relevant to the road improvement project. Project costs typically include construction investment costs and maintenance costs over the service life of the infrastructure. Meanwhile, the economic benefits of road projects generally include savings in vehicle operating costs (VOC) and reduced travel time for road users. Improving road quality will reduce road congestion and damage, thereby increasing average travel speeds and reducing fuel consumption and vehicle component wear. This results in cost savings for both road users and transportation operators.

In addition, road improvements can reduce traffic accidents (cost savings) by reducing hazardous conditions such as potholes and uneven surfaces. Previous studies have shown that these benefit components can be estimated quantitatively and summed. For example, (Yudhanto, 2015), in a feasibility study of the Lawang-Batu bypass road upgrade, found that the total project benefits over its service life reached approximately IDR 7.1 trillion. These benefits consisted of savings in vehicle operating costs of approximately IDR 3.0 trillion, savings in travel time of approximately IDR 2.97 trillion, and reductions in accident costs of approximately IDR 1.13 trillion. The analysis showed a BCR of 7.07 (well above 1) and a NPV of approximately IDR 5.36 trillion (positive) at a 12% discount rate, confirming the road project's economic feasibility. This example illustrates that the NPV and BCR evaluation methods are capable of capturing the direct monetary benefits of road construction or improvement, thus serving as a basis for consideration in investment decision-making.

Based on the description above, it can be concluded that the Kaligunting-Bajulan Road section, as part of the provincial road network, does indeed need to be upgraded to address damage issues and improve traffic service performance. However, given resource limitations,The decision to implement this project must be supported by a comprehensive economic feasibility study. Therefore, this study will analyze the economic feasibility of the Kaligunting-Bajulan Road improvement plan using the Net Present Value (NPV) and Benefit Cost Ratio (BCR) methods.

This analysis will obtain the project's NPV and BCR values, which will then be used to assess whether the benefits outweigh the costs.

THEORETICAL REVIEW

Assessing the economic viability of road improvement projects, such as the Kaligunting-Bajulan road in Madiun Regency, typically involves established techniques for calculating the Benefit-Cost Ratio (BCR) and Net Present Value

(NPV). The literature highlights that BCR analysis compares the present value of all anticipated benefits—such as reduced vehicle operating costs, travel time savings, accident reduction, and improved accessibility—to the present value of project costs, providing a straightforward indicator of economic efficiency when benefits exceed costs. Meanwhile, NPV techniques discount future streams of both benefits and costs to a common base year using an appropriate social discount rate, enabling evaluators to determine whether the project yields a positive net return over its lifecycle. Studies emphasize the importance of accurate data collection on traffic volumes, vehicle types, maintenance costs, and socio-economic impacts, as well as sensitivity analysis to test assumptions under different scenarios. Furthermore, the integration of Geographic Information Systems (GIS), cost forecasting models, and stakeholder valuation surveys has been shown to improve the robustness of these assessments. Collectively, this body of research underscores that rigorous application of BCR and NPV methods is crucial for informed decision-making in infrastructure investment and prioritization.

METHODOLOGY

The subject of this research is the Kaligunting-Bajulan road infrastructure improvement project in Madiun Regency. This means that the object of study includes the Kaligunting-Bajulan road section, including its existing technical condition (before the improvement) and its condition after the improvement. Therefore, the subject's scope encompasses two situations: the initial condition before the improvement (the road is in an unstable condition) and the post-improvement condition (the road is in a stable condition). Focusing on this road section (as a case study) aims to ensure that the project's benefit analysis—particularly regarding vehicle operating costs and travel time—is truly relevant to the actual characteristics of the location. This specific research subject allows for an in-depth evaluation of the impact of the road improvement on road users (the community). By focusing on the Kaligunting-Bajulan section from its initial condition to the post-improvement period, the research can comprehensively assess changes in road performance and its economic benefits. This aligns with the case study approach in civil transportation engineering, where a single road project is evaluated in depth to determine its effectiveness.

The primary data collected directly in the field is the Average Daily Traffic (ADR) data on the Kaligunting-Bajulan Road section. The ADR survey is conducted manually 24 hours a day (day and night) to comprehensively capture daily traffic patterns. Each passing vehicle is counted and classified according to its type, including: motorcycles, passenger/private cars, small passenger vehicles (microbuses), small goods vehicles (pickups), buses, two-axle trucks, three-axle trucks, and so on. The results of this survey provide daily traffic volumes per vehicle type, which will serve as key input in calculating the BOK and time benefits.

Secondary data was obtained from agencies and project-related documents:

1. Project Planning Documents. Includes road improvement design drawings and the Cost Budget Plan (RAB). This document provides information

on the length of the section to be improved, the planned pavement specifications (e.g., the planned overlay thickness), the work volume, the implementation schedule, and the required construction investment costs (contract value).

2. Road Section Technical Condition Data.

Including reports on road pavement condition surveys (e.g., quarterly PKRMS reports for provincial roads). This data provides the length of the road in each condition (Good, Moderate, Lightly Damaged, Severely Damaged) before and after the improvement, the thickness of the existing pavement layers, the width of the road and shoulders, and other geometric conditions. This data is important for analyzing road performance and maintenance needs.

3. Routine Maintenance Plan and Cost Data.

The standard routine maintenance cost per kilometer per year is obtained based on the road condition, based on East Java Gubernatorial Regulation No. 39 of 2023

Concerning Price Standards (Attachment to ASB/HSPK). This data includes the Basic Unit Price for provincial road maintenance activities in Good, Moderate, Lightly Damaged, and Severely Damaged conditions (with and without VAT). This data will be used to calculate the annual routine maintenance costs before and after road upgrades.

4. Economic Data and Unit Prices

Including current fuel prices, spare parts prices (tires, oil, etc.), vehicle service/maintenance costs, average unit vehicle prices, and the discount interest rate used as the social discount rate. For example, data on Premium/Pertalite or Diesel prices (per liter), oil prices per liter, and tire prices per unit are obtained from official sources for 2025. The discount interest rate (e.g., 4.75% per year) is determined based on the benchmark interest rate.

With a combination of actual primary data and comprehensive secondary data, the analysis in this study is based on a strong database. Complete and accurate data ensures that the calculation results (both costs and benefits) are scientifically sound and reflect actual conditions on the ground.

The data analysis technique was developed in accordance with the research objective, which is to assess the economic feasibility of road improvements, and follows the cost-benefit analysis framework as described in the literature review. Broadly speaking, the data analysis involves comparing pre- and post-project conditions in terms of cost and benefit components, followed by a feasibility evaluation using economic criteria. The primary economic benefits analyzed are reduced Vehicle Operating Costs (VOC) and travel time savings resulting from improved road conditions (increased speed). The primary cost components are project investment costs and routine maintenance costs. The results of these benefit and cost calculations are then used to determine economic feasibility indicators, such as the Net Present Value (NPV) and the Benefit Cost Ratio (BCR). Furthermore, sensitivity tests will be conducted to changes in key assumptions (e.g., changes in costs, benefits, or discount rates) if necessary.

Routine road maintenance activities are defined as minor maintenance/repairs carried out periodically to maintain the road's daily condition. These activities include patching potholes, asphalt surface maintenance, cleaning and repairing drainage, mowing grass on road shoulders, and maintaining simple signs and markings.

In the context of provincial road management, the Public Works and Highways Agency (PUBG) implements the Provincial/District Road Management System (PKRMS), where each section is assessed and categorized into "Satisfactory" (if the condition is "Good" or "Fair") and "Unstable" (if the condition is "Slightly or Severely Damaged").

In this study, annual routine maintenance costs were calculated based on cost standards established by the local government. East Java Governor Regulation Number 39 of 2023 concerning Price Standards provides the Basic Activity Unit Price (HSPK) for routine road maintenance per kilometer per year for each pavement condition category (Good, Moderate, Lightly Damaged, and Severely Damaged). Therefore, to calculate the routine maintenance costs for the Kaligunting-Bajulan section.

As mentioned, the Average Daily Traffic Volume (ADR) on the study section is obtained through a 24-hour survey. This ADR data is processed to obtain the traffic volume per vehicle type per day. The step is to add up the number of vehicles passing over a 24-hour period for each vehicle class. For example, the survey results may indicate that the ADR for motorcycles is several thousand vehicles per day, the ADR for passenger cars is several hundred vehicles per day, and so on.

This ADR data per vehicle class is crucial because it will be used in:

1. Calculating Vehicle Operating Costs (VOC): The ADR is combined with the section distance (4,975 km) and the operating cost per vehicle km to calculate the total operating cost of all vehicles passing through the section per day or per year.

2. Calculating travel time: If necessary, the passenger vehicle volume is multiplied by the time value per vehicle to calculate the total annual value of road user time.

Free-flow speed is the average speed a vehicle can achieve when traffic flow is very low (vehicles are not obstructed by other vehicles) and the road is in smooth, unobstructed condition. Free-flow speed analysis is important because many roadworthiness (BOK) components (e.g., fuel consumption, tire wear) are a function of vehicle speed. Improvements in road quality are expected to increase free-flow speed due to improvements in road physical factors.

RESULTS AND DISCUSSION

A project economic evaluation is conducted to assess the project's economic viability over its specified service life. The Net Present Value (NPV) method calculates the difference between the present value (discounted present value) of total benefits and total costs over the project horizon. If NPV > 0, the project provides a net economic benefit; if NPV < 0, the project is unprofitable (benefits do not cover costs). In this analysis, the evaluation horizon is 10 years, corresponding to the project's planned life (year 0 = 2025 construction, years of operation 2026–2044).

The discount rate used is 4.75% per year, referring to a Bank Indonesia press release dated November 19, 2025.

The parameters used in the NPV calculation are as follows:

• Initial Investment: Project construction costs (including contracts and addendums) = IDR 10,856,185,583.40. This cost was incurred in year 0 (end of 2024).

• Annual Benefits:

o Routine maintenance cost savings = Rp3,343,560,509.25 per year (from year 2 to 20; year 1 is considered 0 due to the contractor's maintenance period).

o BOK savings = Rp787,057,164.00 per year (from year 1 to 20, assumed to be felt immediately).

The project's NPV was obtained at +Rp 25,090,477,770.67. This positive and large NPV value indicates that in present value terms (2025 as a reference), the Kaligunting-Bajulan Road improvement project generates a net surplus of benefits for the economy. With a discount rate of 4.75%, the total discounted benefits (Rp 35,946,663,354.07) far exceed the total discounted costs (10,856,185,583.40), a difference of Rp 25,090,477,770.67. This indicates the project is economically feasible. Interpretatively, NPV = 25.09 billion means that if all costs and benefits of this project are projected to their present value, the net benefit is equal to Rp 25.09 billion. This figure can also be seen as the net added value the project creates for the community. The higher the NPV is above 0, the stronger the economic justification. In this context, Rp25.09 billion is a significant value, indicating the project is highly economically profitable because its cumulative benefits exceed its costs by more than three times (Rp35.95 billion vs. Rp10.86 billion).

Besides NPV, another economic evaluation criterion used is the Benefit-Cost Ratio (BCR). BCR is the ratio between the present value of benefits and the present value of costs. A project is considered economically feasible if BCR > 1 (meaning that discounted benefits exceed discounted costs); BCR = 1 means break-even;

BCR < 1 means the project is not feasible because benefits < costs. The BCR provides an indication of investment efficiency: how many rupiah of benefits are obtained per rupiah of costs incurred.

The BCR calculation in this study uses equation (2.42) as referenced. From the previous NPV calculation, we obtain:

c. Total PV Benefit = 35,946,663,354.07 (sum of discounted benefits over 10 years at 4.75%).

d. Total PV Cost = Rp10,856,185,583.40 (discounted cost, here because the investment cost is in year 0, the PV cost = the cost itself)

In other words, the present value of the project's benefits is 3.31 times the present value of its costs. A BCR of 3.31, well above 1, confirms that the project is highly economically viable. Interpretation: Every Rp1 spent generates Rp3.31 worth of benefits for the economy. This margin is very high, indicating significant efficiency. The reason for this high BCR is that the investment costs are relatively small compared to the accumulated annual benefits that continue over 10 years.

CONCLUSION

Based on the data analysis and discussion in Chapter 4, it can be concluded that the objectives of this study have been achieved. The main findings of the evaluation study of the Kaligunting-Bajulan Road improvement using the NPV method are as follows:

1. The Kaligunting-Bajulan Road improvement has been proven to improve the overall physical condition of the road while reducing annual routine maintenance costs. Prior to the improvement, of the total length of 4,975 km, only 1.10 km was in good condition (2.475 km had minor damage and 1.40 km had severe damage), requiring routine maintenance costs of approximately Rp 4.17 billion per year. After the improvement, 100% of the road was in good condition, resulting in a drastic reduction in routine maintenance costs to Rp 0.82 billion per year. In other words, the improvement in road quality resulted in a savings of Rp 3.34 billion in annual routine maintenance costs.
2. Based on the economic feasibility evaluation, the Kaligunting-Bajulan Road improvement project is deemed highly feasible. The calculation results show an NPV of +Rp25,090,477,770.67 (NPV > 0) and a BCR of 3.31 (BCR > 1). This positive NPV indicates a net project benefit surplus of approximately Rp25.09 billion in present value terms. A BCR of 3.31 means that every Rp1 of investment costs generates Rp3.31 in benefits for the economy. Therefore, the project's total discounted benefits far exceed its total discounted costs, making the project economically beneficial to the community.

RECOMMENDATION

Based on the limitations and findings of this study, there are several suggestions that can be considered for future improvements:

1. To obtain results that are more representative of the overall regional road network, it is recommended that future similar research expand the study area. For example, by examining the connecting section from Jalan Kaligunting - Bajulan to Jalan other routes or to local logistics distribution nodes to assess network effects. Research on other routes with different traffic characteristics and geometric conditions will provide broader insights into the effectiveness of road investments in various regional contexts.
2. In the future, it is recommended to include other external benefit components not yet considered in this study, such as savings in accident costs and reduced environmental impacts (emissions).
3. Improved road conditions typically reduce accident rates (due to more suitable and safe roads), which have significant economic value, as well as streamline traffic flow, resulting in reduced emissions per vehicle. Quantifying these components will provide a more comprehensive estimate of project benefits. For example, an accident cost analysis can be conducted using the Value of Statistical Life method or the cost of accident losses, and an environmental analysis can involve calculating local CO_2 emission reductions multiplied by the shadow price of carbon. By incorporating

these factors, future road economic feasibility studies will be more holistic and accurate in reflecting the socio-economic impacts of the project.

FURTHER STUDY

1. Suggestions for future research include considering the use of alternative methods or simulation models to verify the results.
2. For example, using traffic microsimulation software to examine the impact of road improvements on speed and travel time in more detail, or using the HDM-4 (Highway Development and Management) model for road economic analysis that considers the pavement life cycle. This approach can provide a second opinion on manual calculations, while also incorporating other factors such as driver comfort and surface roughness index (IRI) into the BOK estimates. This will strengthen the feasibility study, both academically and practically.
3. All of the above suggestions aim to ensure that future road project evaluations are more comprehensive and evidence-based.
4. Researchers and practitioners are expected to expand these studies by incorporating new variables and advanced methods, so that infrastructure investment decisions are consistently supported by comprehensive and accurate economic analysis.

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