International Journal of Sustainable Building, Infrastructure, and Environment

Comparative Analysis Of Vehicle Operating Cost (BOK) Using the Pacific Consultant International (PCI) Method On The Kaliwungu – Krapyak Toll Road and Non-Tol Road

Putri Ameliya Sari[1*], Larasati Welas Yuliasih[1], Agustina Wardani[1] , Farida Yudaningrum[1]

[1]Faculty of Engineering and Informatics, Universitas PGRI Semarang, Jl. Sidodadi-Timur No.24 Semarang, Central Java 50232, Indonesia

*daniek258@gmail.com

Abstract. The Kaliwungu–Krapyak Toll Road is one of the road sections that connects Kendal Regency and Semarang City and is part of the Trans Java Toll Road network. Differences in traffic conditions and road characteristics between toll roads and non-toll roads can affect the magnitude of Vehicle Operating Costs (VOC) incurred by road users. This study aims to identify the variables that influence Vehicle Operating Costs (VOC) and to analyze the VOC values on the Kaliwungu–Krapyak Toll Road and the Kaliwungu–Krapyak Non-Toll Road using the Pacific Consultant International (PCI) method. The research data were obtained through the collection of primary and secondary data related to vehicle operating cost variables, including fuel consumption, lubricant usage, vehicle maintenance costs, tire wear, vehicle depreciation, capital interest, insurance costs, and unexpected costs. The results show that the VOC value is influenced by vehicle speed and traffic conditions on each road segment. The lowest VOC value on the Kaliwungu–Krapyak Toll Road occurs at a speed of 70 km/h, while on the Kaliwungu–Krapyak Non-Toll Road it occurs at a speed of 57 km/h. Based on these results, the analysis of VOC variables can be used to describe the efficiency of vehicle operating costs on both road sections.

Keywords: Vehicle Operating Costs (VOC), PCI Method, Toll Road, Non-Toll Road, Kaliwungu–Krapyak

1. Introduction

Vehicle Operational Costs (BOK) are an important indicator in transportation system analysis, encompassing all costs incurred by road users in operating vehicles, such as fuel consumption, maintenance, depreciation, and travel time. The BOK value reflects the efficiency of a transportation network and serves as the basis for infrastructure policy-making and passenger route planning. One method widely used to systematically calculate BOK is the Pacific Consultants International (PCI) method, which is the sum of variable and standing costs, which are influenced by vehicle speed and type. [1] The PCI method is one of the standard methods often used to calculate vehicle operating costs in Indonesia. It is also utilized by the Highways Department (Bina Marga), which is conducting research on several roads in Indonesia, both toll and non-toll roads. [2]

Semarang, as the capital of Central Java Province, holds a highly strategic position in supporting regional economic, logistics, and trade activities. A smooth transportation system is a key factor in

supporting these activities. Along with improvements and enhancements to the smoothness of the transportation system, public interest in using private vehicles tends to increase, resulting in an increase in the number of vehicles operating on the roads. Consequently, various problems arise, such as increased congestion, increased travel times, and increased vehicle operating costs for both the general public and the goods and services transportation sector.

As a solution to this problem, the government has been operating the approximately 10.9 km Kaliwungu-Krapyak Toll Road since 2019, which is part of the Trans-Java Toll Road network. This toll road provides an alternative for road users who want to avoid congestion on the approximately 10-15 km Kaliwungu-Krapyak non-toll road, which is one of the main corridors in the western part of Semarang City. The main objective of this toll road construction is to reduce traffic congestion and improve travel time efficiency. According to Law Number 38 of 2004 concerning Roads, Article 43 Paragraph 3 states that toll road users are required to pay a toll fee, which is used to recoup investment, maintenance, and development of the toll road. Although users are required to pay toll fees, they benefit from savings in Vehicle Operating Costs (BOK) and travel costs compared to non-toll roads.[3]

Differences in traffic conditions and road surface quality directly affect the BOK. Therefore, a comparative BOK analysis between the Kaliwungu-Krapyak Toll Road (KM 409-KM 420) and the Kaliwungu-Krapyak Non-Toll Road is relevant for assessing the efficiency of toll infrastructure in Semarang City. This research was conducted because the differences in traffic conditions between the Kaliwungu-Krapyak Toll Road and the Kaliwungu-Krapyak Non-Toll Road in Semarang City have had a significant impact on costs Vehicle Operational Costs (BOK). Congestion that frequently occurs on non-toll roads results in longer travel times, increased fuel consumption, and reduced vehicle movement efficiency, especially for logistics transportation. Meanwhile, toll roads with better road surface conditions and fewer traffic obstacles are thought to be able to reduce the overall BOK. To date, studies specifically comparing the BOK between the two roads using the Pacific Consultant International (PCI) method are still very limited.

Therefore, this study is important to analyze and compare vehicle operational costs on these two types of roads, thereby determining the efficiency of toll road use compared to non-toll roads. The results of this study are expected to serve as a consideration for local governments and policymakers in formulating strategies to improve transportation network performance and control logistics costs in Semarang City.

2. Methods

A. Research Methods

Research design is a conceptual framework that guides researchers in designing, implementing, and evaluating scientific studies. [4] This design encompasses not only how the research is conducted, but also how the problem is addressed The research questions are formulated, the variables are determined, the method is chosen, and the data analysis techniques are used. This study uses a descriptive method. Based on research, a descriptive method is a research method used to create a picture of a situation or event. Therefore, this method is used solely to accumulate target data. Through this method, researchers are expected to produce an accurate picture of the comparison of Vehicle Operating Costs (BOK) when traveling on the Kaliwungu-Krapyak toll road (KM 409 - KM 420) and the Kaliwungu-Krapyak non-toll road. The approach used in this study is quantitative.

The quantitative approach is a research approach based on the philosophy of positivism and is used to study specific populations or samples. [5]

B. Research Location

The research location covers the Kaliwungu-Krapyak Toll Road section from KM 409 to KM 420, which stretches from the Kaliwungu Toll Gate to the Krapyak 2 Toll Exit, as well as the Kaliwungu-Krapyak non-toll road section.

C. Research Work Stages

In general, this research was conducted through several stages, as shown in the following diagram:

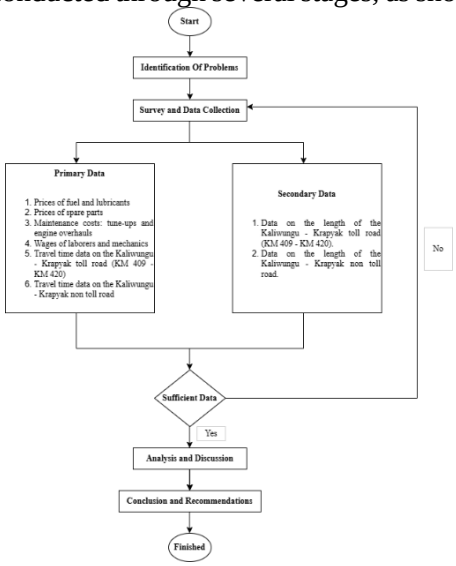

Figure 1. Research Flow Diagram

D. Data Collection Techniques

In the process of preparing this thesis, there are data collection techniques and data sources that will be studied and collected. The data used in this research consists of primary and secondary data.

1. Primary Data

   Primary data is data collected directly from the field or through direct sources. The BOK data sought for use in calculating the BOK using the PCI method is considered to be representative of vehicle samples, including:

   a. Fuel and lubricant prices
   b. Spare parts prices
   c. Maintenance costs: engine tune-ups and overhauls
   d. Labor and mechanic wages
   e. Travel time data for the Kaliwungu – Krapyak Toll Road (KM 409 – KM 420)
   f. Travel time data for the Kaliwungu – Krapyak Non-Toll Road

2. Secondary Data

   In addition to primary data, secondary data is also an important element in this research. Secondary data was collected from the Public Works Department of Highways. [6]The data obtained as secondary data include:

   a. Data on the length of the Kaliwungu-Krapyak Toll Road (KM 409-KM 420).
   b. Data on the length of the Kaliwungu-Krapyak Non-Toll Road.

3. Results and Discussion

A. Description of the Kaliwungu – Krapyak Toll Road

The Kaliwungu-Krapyak Toll Road is an 11-km section of the Batang-Semarang Toll Road, connecting the Kaliwungu-Kendal area with the Krapyak area in Semarang City. This toll road section is located in the northern coastal region of Central Java, with relatively flat to gently sloping topography. It traverses fishponds, business activities, agricultural land, and industrial areas. This toll road serves as the primary infrastructure supporting traffic movement from Kendal to West Semarang City and serves as part of the Trans-Java Toll Road network.

Traffic problems on the Kaliwungu-Krapyak Toll Road are generally influenced by high vehicle volumes during peak hours, weekends, and holidays, stemming from commuter traffic, industrial freight

transport, and intercity traffic. Traffic congestion frequently occurs around the Kaliwungu Toll Gate and the Krapyak Interchange due to the intersection of toll traffic with the urban road network, coupled with the presence of relatively low-capacity heavy vehicles.

The pavement conditions on the Kaliwungu-Krapyak Toll Road generally use flexible asphalt designed to withstand heavy traffic. However, the subgrade, which is soft to moderately soft, has the potential to cause land subsidence, which can affect pavement performance, such as the appearance of grooves and cracks. Therefore, regular pavement maintenance and evaluation are necessary to maintain the level of service and comfort for road users.

The geometric conditions of the Kaliwungu-Krapyak Toll Road are designed according to toll road standards to accommodate high-speed traffic and large vehicle volumes. The road's alignment is generally relatively straight, with horizontal alignments consisting of large-radius curves, providing adequate visibility and promoting safe driving. Wide lanes and shoulders are designed in accordance with toll road regulations, ensuring the safe and comfortable operation of both light and heavy vehicles. In terms of vertical alignment, this toll road section has a small longitudinal gradient due to its location in a coastal lowland area, resulting in virtually no steep inclines or declines. These geometric conditions allow vehicle operational speeds to remain stable and support a good level of road service, especially on parts of the Trans-Java Toll Road network.

B. Selecting a Non-Toll Road Route

When analyzing Vehicle Operating Costs (BOK) using the PCI method, there are differences in calculating BOK on toll roads and BOK on non-toll roads. Therefore, it is necessary to determine the non-toll road routes used by road users as alternative routes. These alternative routes are conventional roads that drivers can use without using the Kaliwungu-Krapyak Toll Road. This route needs to be explained because the PCI method formulation distinguishes between the characteristics of toll roads and non-toll roads.

In this study, non-toll alternative routes are considered conventional roads that drivers can use without incurring tolls. These roads have different geometric and operational characteristics than toll roads, such as lower vehicle speeds and the influence of side obstacles and at-grade intersections. These alternative routes were chosen because they serve the same function of connecting origins and destinations as the Kaliwungu-Krapyak Toll Road, and therefore can be used as a comparison in calculating Vehicle Operating Costs (BOK) using the PCI method.

The non-toll alternative road used in this study is the Kaliwungu – Kendal – Krapyak Pantura Route which consists of the Kaliwungu Toll Road, the Soekarno-Hatta Kendal Toll Road, the Kendal – Semarang Pantura Toll Road, and the West Semarang Siliwangi Road with a distance of 15 km.

C. Data Processing

For information on new vehicle prices, new tire prices, labor costs, and fuel and lubricant costs, see Tables 4.1 through 4.4.

Table 4.1 New Vehicle Prices (February,2026)

Vehicle Type	Representative Vehicle (taken)	New Vehicle Price (in Rupiah)
Class I	Passenger Car	Rp 187.700.000,00

Source: Nasmoco Youth Workshop [7]

Table 4.2 New Vehicle Tire Prices (as of February,2026)

Vehicle Type	Representative Vehicle (taken)	Tire Size/ Used	New Tire price (in Rupiah)
Class I	Passenger Car	175/65 R14	Rp 810.000,00

Source: Nasmoco Youth Workshop

Table 4.3 Labor Requirement Price (as of February,2026)

Labor Needs	Price (Rupiah/Hour)
Mechanic	Rp 29.265,625,00

Source: Nasmoco Youth Workshop

Table 4.4 Labor and Lubricant Prices (as of February,2026)

Fuel and Lubricant prices (Rupiah/liter)	Harga (Rupiah/liter)
Gasoline (Pertalite)	Rp 10.000,00
FK Elite 10W-30 Lubricating Oil 4 liters	Rp 552.000,00

Source : Pertamina [8]

D. Calculation of BOK using the PCI methode

Example of operating Cost Calculation this vehicle is a Class I vehicle or passenger car. It operates on the Kaliwungu-Krapyak Toll Road.

A. Toll Road

The steps for calculating vehicle operating costs using the PCI method are:

1. Determine the vehicle's speed (the speed based on the smallest result of the total vehicle operating costs).

V = 78 km/h (Mondays, 12:00 PM – 2:00 PM, on the Kaliwungu – Krapyak Toll Road)

2. Calculate the following vehicle operating cost components:

a. Fuel Consumption Factor

$FCF = (0{,}04376.78^2) – (4{,}94078.78) + 207{,}04840$
$= 87{,}9034$

b. Lubricating Oil Consumption Factor

$LCF = (0{,}00029.78^2) – (0{,}03134.78) + 1{,}69613$
$= 1{,}01597$

c. Tire Wear Factor

$TWF = (0{,}0008848.78) + 0{,}0045333$
$= 0{,}073548$

d. Spare Parts Factor

$SPF = (0{,}0000064.78) + (0{,}0005567)$
$= 0{,}001056$

e. Labor Cost Factor

$LCF = (0{,}00362.78) + (0{,}36267)$
$= 0{,}64503$

f. Vehicle Depreciation Factor

$$VDF = \frac{1}{(2{,}5.78) + 125}$$
$= 0{,}003125$

g. Capital Interest Factor

$$CIF = \frac{150}{500.78}$$
$= 0{,}003846$

h. Insurance Cost Factor

$$ICF = \frac{38}{500.78}$$
$$= 0{,}000947$$

3. Calculating Vehicle Operating Costs

a. Fuel Consumption
= Fcf x distance x unit fuel price /1000
= 9669,374

b. Fmp x distance x unit lubricating oil price /1000
= 6168,97

c. Tire Consumption
= Fkb x distance x unit tire price /1000
= 655,31

d. Spare Parts Cost
= Fpc x distance x depreciated vehicle price /1000
= 6.812865

e. Labor Cost
= Fpk x distance x mechanic's hourly wage /1000
= 207649,3

f. Depreciation
= Fdp x distance x 0,5 x depreciated vehicle price /1000
= 10,08154

g. Interest on Capital
= Fbm x distance x 0,5 x depreciated vehicle price /1000
= 12,40805

h. Insurance
= Fas x distance x 0,5 x new vehicle price /1000
= 1005,879

i. Overhead
Because Group IA is considered a private car, the overhead is considered = 0

4. Add up the Vehicle Operating Costs from point 3, whinch is **IDR 17.529,00/km** for Class I (with a representative vehicle, a passenger car).

B. Non-Toll Roads

The steps for calculating vehicle operating costs using the PCI method are:

1. Determine the vehicle's speed (the speed based on the smallest result of the total vehicle operating costs).

V = 45 km/h (Mondays, 06:00 PM – 08:00 PM, on the Kaliwungu – Krapyak Non-Toll Road)

2. Calculate the following vehicle operating cost components:

a. Fuel Consumption Factor
$FCF = (0{,}04376.45^2) – (4{,}94078.45) + 207{,}04840$
$= 73{,}3273$

b. Lubricating Oil Consumption Factor
$LCF = (0{,}00029.45^2) – (0{,}0{,}03134.45) + 1{,}69613$

= 0,87308

c. Tire Wear Factor
TWF = (0,0008848.45) + (0,0045333)
= 0,044349

d. Spare Parts Factor
SPF = (0,0000064.45) + (0,0005567)
= 0,000845

e. Labor Cost Factor
LCF = (0,00362.45) + (0,36267)
= 0,52557

f. Vehicle Depreciation Factor
$VDF = \frac{1}{(2,5.45) + 125}$
= 0,004211

g. Capital Interest Factor
$CIF = \frac{150}{500.45}$

= 0,006667

h. Insurance Cost Factor
$ICF = \frac{38}{500.45}$
= 0,001689

3. Calculating Vehicle Operating Costs
a. Fuel Consumption
= Fcf x distance x unit fuel price /1000
= 10999,1

b. Fmp x distance x unit lubricating oil price /1000
= 7229,102

c. Tire Consumption
= Fkb x distance x unit tire price /1000
= 538,844

d. Spare Parts Cost
= Fpc x distance x depreciated vehicle price /1000
= 10,0137

e. Labor Cost
= Fpk x distance x mechanic's hourly wage /1000
= 230717

f. Depreciation
= Fdp x distance x 0,5 x depreciated vehicle price /1000
= 24,95734

g. Interest on Capital
= Fbm x distance x 0,5 x depreciated vehicle price /1000
= 39,51579

h. Insurance
= Fas x distance x 0,5 x new vehicle price /1000
= 2377,533

i. Overhead
Because Group IA is considered a private car, the overhead is considered = 0

4. Add up the Vehicle Operating Costs from point 3, whinch is **IDR 21.221,4/km** for Class I (with a representative vehicle, a passenger car).

4. Conclusion

Based on the results of the analysis, the Vehicle Operating Cost (BOK) on the Kaliwungu–Krapyak Toll Road and the Kaliwungu–Krapyak Non-Toll Road is influenced by several main variables, namely fuel consumption, lubricant usage, vehicle maintenance costs, tire wear, vehicle depreciation, capital interest, insurance costs, and unexpected costs. In addition, the VOC value is also influenced by vehicle speed and traffic conditions on each road segment.

Based on the calculation of Vehicle Operating Cost (BOK) using the Pacific Consultant International (PCI) method, it was found that the vehicle speed corresponding to the lowest total Vehicle Operating Cost on the Kaliwungu–Krapyak Toll Road is V = 78 km/h, with a total Vehicle Operating Cost of Rp 17,529.00 per km for Class I vehicles (representative passenger cars). Meanwhile, on the Kaliwungu–Krapyak Non-Toll Road, the vehicle speed corresponding to the lowest total Vehicle Operating Cost is V = 45 km/h, with a total Vehicle Operating Cost of Rp 21,221.40 per km for Class I vehicles (representative passenger cars).

Thus, the results of this study indicate that there is a difference in vehicle speeds that produce the lowest Vehicle Operating Cost (BOK) on the two road segments. This difference is influenced by traffic conditions, road characteristics, and the level of service on the toll and non-toll roads.

Acknowledgements

Thanks to Allah SWT, Mrs. Ir.Agustina Wardani, S.T., M.T. Mrs. Ir.Farida Yudaningrum, S.T., M.T., PT. Jasa Marga Semarang and all parties who have helped and supported this research.

References

[1] Setiawan Dandy, Robby, and Supiyan, “Analysis of Vehicle Operating Costs (VOC) and Tariff Determination Using the Pacific Consultant International (PCI) Method,” 2024.

[2] L. M. A. R. Alfateh, “THE ANALYSIST OF ROAD PERFORMANCE AND THE VEHICLE OPERATIONAL COST AT MAJAPAHIT STREET AT MATARAM CITY,” 2024.

[3] R. Mahendra, V. Asih, P. Anggi, P. Suwandi, and F. Yudaningrum, “ANALYSIS OF VEHICLE OPERATING COSTS USING METHOD (PACIFIC CONSULTANT INTERNATIONAL) PCI ON SEMARANG TOLL ROAD SECTION A AND NON-TOLL ROAD (KRAPYAK-JATINGALEH),” *IJOSBIE International Journal of Sustainable Building, Infrastructure, and Environment*, 2022.

[4] Cynthia Paramitha Trisnanda, “Research Design: Definition, Types, and Examples,” https://penerbitdeepublish.com/tutorial-menulis/menulis-karya-ilmiah/pengertian-rumusan-masalah/.

[5] Sugiyono, *Quantitative, Qualitative, and Research and Development (R&D) Research Methods*. 2019.

[6] PT Jasa Marga, “Information on the Length of Jasa Marga Toll Roads,” https://www.jasamarga.com/.

[7] PT. NASMOCO. (2026, JANUARY 20). Retrieved from NASMOCO: https://nasmoco.co.id
[8] Pertamina, “Gasoline Price Information,” https://www.pertamina.com/id.