Journal of Social Research

P-ISSN: 2827-9832
E-ISSN: 2828-335x
http://ijsr.internationaljournallabs.com/index.php/ijsr

The Impact of Pavement Condition Index on Life Cycle Cost of Tiom-Kuyawage and Tiom-Balingga Road Sections in Lanny Jaya Regency

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ABSTRACT

The Papua Mountains region has extreme geographical challenges that have an impact on the high need for road infrastructure maintenance. This study aims to analyze the relationship between the value of the Pavement Condition Index (PCI) and Life Cycle Cost (LCC), and to consider estimated inflation and net present value (NPV) as the basis for long-term budget planning. The study was conducted on the Tiom–Kuyawage (4.6 km) and Tiom–Balingga (2.7 km) roads in Lanny Jaya Regency. The PCI value in Tiom–Kuyawage has decreased significantly from 89.19 (2023) to 58.30 (2025), while Tiom–Balingga remains high at 87.44 (2025). The projected total maintenance cost for 20 years (2025–2045) shows a need of IDR 201.42 billion for Tiom–Kuyawage and IDR 122.62 billion for Tiom–Balingga. However, if calculated based on present value (NPV), assuming inflation of 3.09% and an interest rate of 5.04%, the actual need will be IDR 105.75 billion and IDR 64.58 billion, respectively. These findings suggest that the deterioration of road conditions (PCI) directly raises the cost of maintenance (LCC), and that the use of an NPV-based financial approach is important for budget efficiency. This study recommends a road maintenance strategy based on actual conditions, to be carried out periodically in the mountainous Papua region.

Keywords: Pavement Condition Index, Life Cycle Cost, Net Present Value, Inflation, Papua Pegunungan

INTRODUCTION

The American Society for Testing and Materials (ASTM D6433-13, 2013) provides an international standard for the practice of assessing road surface conditions, known as the Pavement Condition Index (PCI). The Pavement Condition Index is used to provide a numerical index to assess road damage based on visual observations. The PCI scale ranges from 0 (zero) to 100 (one hundred), with 0 indicating a severely damaged road and 100 indicating perfect road conditions.

In 2021, the Lanny Jaya Regency PUPR Office carried out road construction and maintenance with a budget allocation of Rp. 72,138,790,075; in 2022, with a budget allocation of Rp. 72,472,898,450; in 2023, with a budget allocation of Rp. 103,054,591,338; and in 2024, with a budget allocation of Rp. 101,177,817,061. Meanwhile, in 2025, according to the Regional Revenue and Expenditure Budget (APBD) of Lanny Jaya Regency of Rp. 1,339,397,867,241, with infrastructure expenditure of Rp. 100,272,598,963, the implementation of road construction and maintenance only received a budget allocation of Rp. 7,204,008,000, down 92.88% from the previous year's budget allocation (Public Works and Spatial Planning Office of Lanny Jaya Regency, 2025).

The Tiom–Kuyawage road section and the Tiom–Balingga road section in Lanny Jaya Regency have the status of regency roads that connect the city center with the national road section. These two roads are often damaged due to landslides that occur at several points, as well as the activities of logistics vehicles that have begun to operate in greater numbers. Maintenance is often carried out, but road damage is still inevitable, causing the function of

road conditions to decline over time (Public Works and Spatial Planning Office of Lanny Jaya Regency, 2023).

The implementation of the Pavement Condition Index (PCI) and Life Cycle Cost (LCC) is very important to ensure cost-effectiveness in road maintenance, especially on road sections that have varying levels of damage. Based on existing conditions, this study aims to analyze the effect of the Pavement Condition Index (PCI) value on Life Cycle Cost (LCC) on the Tiom–Kuyawage road section and the Tiom–Balingga road section in Lanny Jaya Regency.

Previous studies have investigated the application of the Pavement Condition Index (PCI) and Life Cycle Cost (LCC) models in road maintenance. For instance, Zhang et al. (2022) highlighted the importance of PCI in assessing road surface conditions and its direct impact on maintenance planning and budgeting. The study found that a systematic evaluation using PCI helps prioritize repair efforts based on road deterioration levels. Similarly, Prabowo et al. (2021) explored the integration of LCC and PCI in road maintenance, focusing on the cost-effectiveness of road repairs. They concluded that combining these two metrics significantly improves the sustainability of infrastructure projects by optimizing resource allocation. However, both studies focused primarily on urban roads, leaving a gap in research regarding rural or regency-level roads, which often face unique challenges such as limited budgets and frequent environmental factors like landslides.

The objective of this research is to analyze the effect of the Pavement Condition Index (PCI) on the Life Cycle Cost (LCC) for the Tiom–Kuyawage and Tiom–Balingga road sections in Lanny Jaya Regency, focusing on how PCI values impact the cost-effectiveness of road maintenance decisions. The findings will benefit local authorities in improving infrastructure management by offering a more accurate, cost-effective approach to road maintenance that can be adapted to similar rural regions with constrained budgets.

METHOD

This study analyzed road condition data and types of road rehabilitation using the Pavement Condition Index (PCI) method, as well as road repair budgeting through the Life Cycle Cost (LCC) method. The research focused on assessing the influence of the PCI method on LCC calculations for road segments in Lanny Jaya Regency, Highland Papua Province. The independent variables included the PCI method for evaluating road conditions and the LCC method for estimating maintenance budgets, while the dependent variable was the road condition measured through PCI scores. The research utilized quantitative data derived from PCI assessments and LCC-based budget projections. Primary data consisted of road damage levels assessed using the PCI method and documentation of road damage, while secondary data included road location maps, road dimensions, types of maintenance, and road maintenance budgets.

The data analysis techniques involved calculating PCI values to determine existing road conditions and predicting maintenance and improvement costs using the LCC method.

RESULTH AND DISCUSSION

The following presents the results of the calculation of the Pavement Condition Index value on the Tiom-Kuyawage road section and the Tiom-Balingga road section**.**

Table 1. Recapitulation of the Calculation of PCI Values and Handling Recommendations on the Tiom – Kuyawage Road Section Along ± 4600 m in 2025

Station	PCI Value	Rating	Description	Handling Recommendations
0 + 000 - 0 + 100	56	Good	Light damage	Regular maintenance
0 + 100 - 0 + 200	88	Excellent	Almost no damage	No maintenance required
0 + 200 - 0 + 300	34	poor	Lots of damage	Rehabilitation

0 + 300 - 0 + 400	70	Good	Light damage	Regular maintenance
0 + 400 - 0 + 500	90	Excellent	Almost no damage	No maintenance required
0 + 500 - 0 + 600	28	Poor	Lots of damage	Rehabilitation
0 + 600 - 0 + 700	20	Very Poor	Severe damage	Moderate reconstruction
0 + 700 - 0 + 800	35	poor	Lots of damage	Rehabilitation
0 + 800 - 0 + 900	31	poor	Lots of damage	Rehabilitation
0 + 900 - 1 + 000	40	poor	Lots of damage	Rehabilitation
1 + 000 - 1 + 100	49	Fair	Damage begins to be visible	Periodic maintenance
1 + 100 - 1 + 200	70	Good	Light damage	Regular maintenance
1 + 200 - 1 + 300	54	Fair	Damage begins to be visible	Periodic maintenance
1 + 300 - 1 + 400	35	poor	Lots of damage	Rehabilitation
1 + 400 - 1 + 500	81	Very Good	Light damage	Regular maintenance
1 + 500 - 1 + 600	92	Excellent	Almost no damage	No maintenance required
1 + 600 - 1 + 700	45	Fair	Damage begins to be visible	Periodic maintenance
1 + 700 - 1 + 800	87	Excellent	Almost no damage	No maintenance required
1 + 800 - 1 + 900	54	Fair	Damage begins to be visible	Periodic maintenance
1 + 900 - 2 + 000	56	Good	Light damage	Regular maintenance
2 + 000 - 2 + 100	43	Fair	Damage begins to be visible	Periodic maintenance
2 + 100 - 2 + 200	70	Good	Light damage	Regular maintenance
2 + 200 - 2 + 300	30	poor	Lots of damage	Rehabilitation
2 + 300 - 2 + 400	54	Fair	Damage begins to be visible	Periodic maintenance
2 + 400 - 2 + 500	22	Very Poor	Severe damage	Moderate reconstruction
2 + 500 - 2 + 600	93	Excellent	Almost no damage	No maintenance required
2 + 600 - 2 + 700	70	Good	Light damage	Regular maintenance
2 + 700 - 2 + 800	23	Very Poor	Severe damage	Regular maintenance
2 + 800 - 2 + 900	15	Very Poor	Severe damage	Regular maintenance
2 + 900 - 3 + 000	76	Very Good	Light damage	Regular maintenance
3 + 000 - 3 + 100	82	Very Good	Light damage	Regular maintenance
3 + 100 - 3 + 200	66	Good	Light damage	Regular maintenance
3 + 200 - 3 + 300	80	Very Good	Light damage	Regular maintenance
3 + 300 - 3 + 400	70	Good	Light damage	Regular maintenance
3 + 400 - 3 + 500	89	Excellent	Almost no damage	No maintenance required
3 + 500 - 3 + 600	44	Fair	Damage begins to be visible	Periodic maintenance
3 + 600 - 3 + 700	78	Very Good	Light damage	Regular maintenance
3 + 700 - 3 + 800	98	Excellent	Almost no damage	No maintenance required
3 + 800 - 3 + 900	86	Excellent	Almost no damage	No maintenance required
3 + 900 - 4 + 000	50	Fair	Damage begins to be visible	Periodic maintenance
4 + 000 - 4 + 100	69	Good	Light damage	Regular maintenance
4 + 100 - 4 + 200	76	Very Good	Light damage	Regular maintenance
4 + 200 - 4 + 300	80	Very Good	Light damage	Regular maintenance
4 + 300 - 4 + 400	81	Very Good	Light damage	Regular maintenance
4 + 400 - 4 + 500	78	Very Good	Light damage	Regular maintenance
4 + 500 - 4 + 600	75	Very Good	Light damage	Regular maintenance

Table 2. Recapitulation of PCI Value Calculation and Handling Recommendations on the Tiom-Balingga Road Section along ± 2700 m in 2025

Station	PCI Value	Rating	Description	Handling Recommendations
0 + 000 - 0 + 100	92	Excellent	Almost no damage	No maintenance required

0 + 100 - 0 + 200	98	Excellent	Almost no damage	No maintenance required
0 + 200 - 0 + 300	98	Excellent	Almost no damage	No maintenance required
0 + 300 - 0 + 400	98	Excellent	Almost no damage	No maintenance required
0 + 400 - 0 + 500	99	Excellent	Almost no damage	No maintenance required
0 + 500 - 0 + 600	96	Excellent	Almost no damage	No maintenance required
0 + 600 - 0 + 700	75	Very Good	Light damage	Regular maintenance
0 + 700 - 0 + 800	95	Excellent	Almost no damage	No maintenance required
0 + 800 - 0 + 900	35	Poor	Lots of damage	Rehabilitation
0 + 900 - 1 + 000	95	Excellent	Almost no damage	No maintenance required
1 + 000 - 1 + 100	99	Excellent	Almost no damage	No maintenance required
1 + 100 - 1 + 200	95	Excellent	Almost no damage	No maintenance required
1 + 200 - 1 + 300	94	Excellent	Almost no damage	No maintenance required
1 + 300 - 1 + 400	97	Excellent	Almost no damage	No maintenance required
1 + 400 - 1 + 500	80	Very Good	Light damage	Regular maintenance
1 + 500 - 1 + 600	95	Excellent	Almost no damage	No maintenance required
1 + 600 - 1 + 700	92	Excellent	Almost no damage	No maintenance required
1 + 700 - 1 + 800	98	Excellent	Almost no damage	No maintenance required
1 + 800 - 1 + 900	91	Excellent	Almost no damage	No maintenance required
1 + 900 - 2 + 000	98	Excellent	Almost no damage	No maintenance required
2 + 000 - 2 + 100	94	Excellent	Almost no damage	No maintenance required
2 + 100 - 2 + 200	97	Excellent	Almost no damage	No maintenance required
2 + 200 - 2 + 300	96	Excellent	almost no damage	No maintenance required
2 + 300 - 2 + 400	95	Excellent	Almost no damage	No maintenance required
2 + 400 - 2 + 500	18	Very Poor	Severe damage	Moderate reconstruction
2 + 500 - 2 + 600	42	Fair	Damage begins to be visible	Periodic maintenance
2 + 600 - 2 + 700	89	Excellent	Almost no damage	No maintenance required

Source: Analysis Results, 2025

Table 3 Recapitulation of the Calculation of PCI Values and Handling Recommendations on the Tiom-Kuyawage Road Section Along ± 4600 m in 2023

Station	PCI Value	Rating	Description	Handling Recommendations
1 + 313 - 1 + 400	45	Fair	Damage begins to be visible	Periodic maintenance
1 + 500 - 1 + 700	100	Excellent	Almost no damage	No maintenance required
1 + 700 - 1 + 900	44	Fair	Damage begins to be visible	Periodic maintenance
2 + 325 - 2 + 400	100	Excellent	Almost no damage	No maintenance required
2 + 400 - 2 + 500	46	Fair	Damage begins to be visible	Periodic maintenance
2 + 500 - 2 + 600	100	Excellent	Almost no damage	No maintenance required
2 + 600 - 2 + 800	100	Excellent	Almost no damage	No maintenance required
2 + 800 - 3 + 000	100	Excellent	Almost no damage	No maintenance required
3 + 000 - 3 + 200	100	Excellent	Almost no damage	No maintenance required
3 + 200 - 3 + 400	100	Excellent	Almost no damage	No maintenance required
3 + 400 - 3 + 600	92	Excellent	Almost no damage	No maintenance required
3 + 600 - 3 + 800	100	Excellent	Almost no damage	No maintenance required
3 + 800 - 4 + 000	100	Excellent	Almost no damage	No maintenance required
4 + 000 - 4 + 200	100	Excellent	Almost no damage	No maintenance required
4 + 200 - 4 + 400	100	Excellent	Almost no damage	No maintenance required
4 + 400 - 4 + 600	100	Excellent	Almost no damage	No maintenance required

Source : Analysis Results, 2025

Table 4. Recapitulation of PCI Value Calculation and Handling Recommendations on the Tiom – Balingga Road Section Along ± 1040 m in 2024

Station	PCI Value	Rating	Description	Handling Recommendations
0 + 000 - 0 + 050	100	Excellent	Almost no damage	No maintenance required
0 + 050 - 0 + 100	100	Excellent	Almost no damage	No maintenance required
0 + 100 - 0 + 150	100	Excellent	Almost no damage	No maintenance required
0 + 150 - 0 + 200	100	Excellent	Almost no damage	No maintenance required
0 + 200 - 0 + 250	100	Excellent	Almost no damage	No maintenance required
0 + 250 - 0 + 300	100	Excellent	Almost no damage	No maintenance required
0 + 300 - 0 + 350	100	Excellent	Almost no damage	No maintenance required
0 + 350 - 0 + 400	100	Excellent	Almost no damage	No maintenance required
0 + 400 - 0 + 450	100	Excellent	Almost no damage	No maintenance required
0 + 450 - 0 + 500	100	Excellent	Almost no damage	No maintenance required
0 + 500 - 0 + 550	100	Excellent	Almost no damage	No maintenance required
0 + 550 - 0 + 600	100	Excellent	Almost no damage	No maintenance required
0 + 650 - 0 + 700	100	Excellent	Almost no damage	No maintenance required
0 + 700 - 0 + 750	100	Excellent	Almost no damage	No maintenance required
0 + 750 - 0 + 800	100	Excellent	Almost no damage	No maintenance required
0 + 800 - 0 + 850	100	Excellent	Almost no damage	No maintenance required
0 + 850 - 0 + 900	100	Excellent	Almost no damage	No maintenance required
0 + 900 - 0 + 950	100	Excellent	Almost no damage	No maintenance required
0 + 950 - 1 + 000	100	Excellent	Almost no damage	No maintenance required
1 + 000 - 1 + 040	100	Excellent	Almost no damage	No maintenance required

Routine road maintenance is planned to be carried out once every year, periodic maintenance is carried out every 3 years and rehabilitation maintenance is carried out every 10 years. The Road Maintenance Plan can be seen in Table 4 below.

Table 5. Road Maintenance Plan

Year	Types of Road Maintenance
0	Road Construction
1	Routine Maintenance 1
2	Routine Maintenance 2
3	Periodic Maintenance 1
4	Routine Maintenance 1
5	Routine Maintenance 2
6	Periodic Maintenance 2
7	Routine Maintenance 1
8	Routine Maintenance 2
9	Periodic Maintenance 1
10	Rehabilitation Maintenance 1
11	Routine Maintenance 1
12	Routine Maintenance 2
13	Periodic Maintenance 2
14	Routine Maintenance 1
15	Routine Maintenance 2
16	Periodic Maintenance 1
17	Routine Maintenance 1
18	Routine Maintenance 2
19	Periodic Maintenance 2
20	Rehabilitation Maintenance 2

Source: Analysis Results, 2025

Table 6. Recapitulation of the Total Price of Routine Maintenance Work of the Tiom-Kuyawage Road Section along ± 4600 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Shoulder & channel cleaning	4.600 m	m	40.000	184.000.000
2	Small patchwork (cold mix)	25 m³	m³	3.200.000	80.000.000
3	Road markings (thermoplastic paint)	4.600 m	m	28.000	128.800.000
4	Lawn mowing & shrubs	27.600 m²	m²	4.800	132.480.000
5	Field mobilization & supervision	1 ls	ls	160.000.000	160.000.000
	Subtotal (A)				685.280.000
	General costs & taxes (18%) = A x 18% (B)				123.350.400
	Total (A + B)				808.630.400

Source: Analysis Results, 2025

Table 7. Recapitulation of the Total Price of Routine Maintenance Work of the Tiom-Balingga Road Section along ± 2700 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Shoulder & channel cleaning	2.700 m	m	40.000	108.000.000
2	Small patchwork (cold mix)	20 m³	m³	2.500.000	50.000.000
3	Road markings (thermoplastic paint)	2.700 m	m	30.000	81.000.000
4	Lawn mowing & shrubs	16.200 m²	m²	5.000	81.000.000
5	Field mobilization & supervision	1 ls	ls	200.000.000	200.000.000
	Subtotal (A)				520.000.000
	General costs & taxes (18%) = A x 18% (B)				93.600.000
	Total (A + B)				613.600.000

Source: Analysis Results, 2025

Table 8. Recapitulation of the Total Price of Periodic Maintenance Work of the Tiom-Kuyawage Road Section along ± 4600 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Milling old surfaces	2,302 m³	m³	450.000	1.035.900.000
2	Paving AC-WC 4 cm	2,761 m³	m³	2.000.000	5.522.000.000
3	Channel/culvert repair	460 m	m	2.000.000	920.000.000
4	Road markings	4.600 m	m	30.000	138.000.000
5	Mobilization & supervision	1 ls	ls	350.000.000	350.000.000
	Subtotal (A)				7.965.900.000
	General costs & taxes (18%) = A x 18% (B)				1.433.862.000
	Total (A + B)				9.399.762.000

Table 9. Recapitulation of the Total Price of Periodic Maintenance Work of the Tiom-Balingga Road Section along ± 2700 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Milling old surfaces	1.351 m³	m³	450.000	607.950.000
2	Paving AC-WC 4 cm	1,619 m³	m³	2.000.000	3.238.000.000
3	Channel/culvert repair	270 m	m	2.000.000	540.000.000
4	Road markings	2.700 m	m	30.000	81.000.000
5	Mobilization & supervision	1 ls	ls	300.000.000	300.000.000
Subtotal (A)					4.766.950.000
General costs & taxes (18%) = A x 18% (B)					858.051.000
Total (A + B)					5.625.001.000

Source: Analysis Results, 2025

Table 10. Recapitulation of the Total Price of Maintenance Work for the Rehabilitation of the Tiom-Kuyawage Road Section along ± 4600 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Demolition of old pavement	4,600 m³	m³	700.000	3.220.000.000
2	Installation of new subgrades/subbases	5,526 m³	m³	900.000	4.973.400.000
3	Base course (aggregate class A)	4,600 m³	m³	1.100.000	5.060.000.000
4	AC-BC + AC-WC paving (9 cm)	5,526 m³	m³	2.000.000	11.052.000.000
5	Drainage repairs & large drains	920 m	m	2.500.000	2.300.000.000
6	Road markings	4.600 m	m	30.000	138.000.000
7	Mobilization & project management	1 ls	ls	2.000.000.000	2.000.000.000
Subtotal (A)					28.743.400.000
General costs & taxes (18%) = A x 18% (B)					5.173.812.000
Total (A + B)					33.917.212.000

Source: Analysis Results, 2025

Table 11. Recapitulation of the Total Price of Maintenance Work for the Rehabilitation of the Tiom-Kuyawage Road Section along ± 2700 m in 2025

No	Job Description	Volume	Unit	Unit Price (Rp)	Total (Rp)
1	Demolition of old pavement	2,700 m³	m³	700.000	1.890.000.000
2	Installation of new subgrades/subbases	3,243 m³	m³	900.000	2.918.700.000
3	Base course (aggregate class A)	2,700 m³	m³	1.100.000	2.970.000.000

4	AC-BC + AC-WC paving (9 cm)	3,243 m³	m³	2.000.000	6.486.000.000
5	Drainage repairs & large drains	540 m	m	2.500.000	1.350.000.000
6	Road markings	2.700 m	m	30.000	81.000.000
7	Mobilization & project management	1 ls	ls	1.500.000.000	1.500.000.000
		Subtotal (A)			17.195.700.000
		General costs & taxes (18%) = A x 18% (B)			3.095.226.000
		Total (A + B)			20.290.926.000

Source: Analysis Results, 2025

Initial Cost of the Tiom-Kuyawage road construction budget plan ± 4600 m and the Tiom-Balingga road construction budget plan ± 2700 m.

Table 12. Recapitulation of Initial Cost of Tiom-Kuyawage Road Construction Work

No. Split	Description	Total Work Price (Rp)
1	Common	156.200.000
2	Drainage	418.485.228
3	Earthworks	5.756.329.834
4	Non-Asphalt Pavement	44.794.925.396
5	Asphalt Pavement	23.189.831.709,80
(A) Amount of Work Price (including General Costs and Benefits)		74.315.772.167,61
(B) Value Added Tax (VAT) = 11% x (A)		8.174.734.938,44
(C) Total Amount of Labor Price = (A) + (B)		82.490.507.106,04
(d) Total Rounded Number		82.490.500.000,00
Notable	Eighty-two Billion Four Hundred Ninety Million Five Hundred Thousand Rupiah	

Source: Analysis Results, 2025

Table 13 Recapitulation of the Initial Cost of Construction Work on the Tiom-Balingga Road Section

No. Split	Description	Total Work Price (Rp)
1	Common	156.200.000
2	Drainage	418.485.228
3	Earthworks	5.756.329.834
4	Non-Asphalt Pavement	40.794.925.396
5	Asphalt Pavement	20.189.831.709,80
(A) Amount of Work Price (including General Costs and Benefits)		67.315.772.167,61
(B) Value Added Tax (VAT) = 11% x (A)		7.404.734.938,44
(C) Total Amount of Labor Price = (A) + (B)		74.720.507.106,04
(d) Total Rounded Number		74.720.500.000,00
Notable	Seventy-Two Billion Seven Hundred and Twenty Million Five Hundred Thousand Rupees	

Source: Analysis Results, 2025

Table 14. Recapitulation of the Total Road Maintenance Budget on the Tiom-Kuyawage Road Section for the period 2025 to 2045

Year	Maintenance Type	Initial Fee (Rp)	Inflation (%)	Estimated Cost (Rp)
2025	Initial conditions	-	-	-
2026	Routine Maintenance I	808.630.400	3,09	IDR 833.617.079
2027	Routine Maintenance II	808.630.400	3,09	IDR 859,375,847
2028	Periodic Maintenance I	9.399.762.000	3,09	IDR10,298,322,225
2029	Routine Maintenance I	808.630.400	3,09	IDR 913,305,815
2030	Routine Maintenance II	808.630.400	3,09	IDR 941,526,965
2031	Periodic Maintenance II	9.399.762.000	3,09	IDR 11,282,779,356
2032	Routine Maintenance I	808.630.400	3,09	IDR 1,000,612,311
2033	Routine Maintenance II	808.630.400	3,09	IDR 1,031,531,231
2034	Periodic Maintenance I	9.399.762.000	3,09	IDR 12,361,344,617
2035	Rehabilitation Maintenance I	33.917.212.000	3,09	IDR45,981,754,907
2036	Routine Maintenance I	808.630.400	3,09	IDR 1,130,139,359
2037	Routine Maintenance II	808.630.400	3,09	IDR 1,165,060,665
2038	Periodic Maintenance II	9.399.762.000	3,09	IDR 13,961,493,312
2039	Routine Maintenance I	808.630.400	3,09	IDR 1,238,173,826
2040	Routine Maintenance II	808.630.400	3,09	IDR 1,276,433,397
2041	Periodic Maintenance I	9.399.762.000	3,09	IDR15,296,127,377
2042	Routine Maintenance I	808.630.400	3,09	IDR 1,356,535,732
2043	Routine Maintenance II	808.630.400	3,09	IDR 1,398,452,687
2044	Periodic Maintenance II	9.399.762.000	3,09	IDR 16,758,344,362
2045	Rehabilitation Maintenance II	33.917.212.000	3,09	IDR 62,337,723,523
	Total			IDR201.422.654.592

To obtain the estimated budget value for the period 2025-2045 on the Tiom-Balingga road section, the same calculation was made. Table 15 below shows the results of the calculation of the estimated budget for the period 2025 to 2045 for the Tiom-Balingga road section.

Table 15. Recapitulation of the Total Road Maintenance Budget on the Tiom-Balingga Road Section for the period 2025 to 2045

Year	Maintenance Type	Initial Fee (Rp)	Inflation (%)	Estimated Cost (Rp)
2025	Initial conditions	-	-	-
2026	Routine Maintenance I	613.600.000	3,09	IDR632,560,240
2027	Routine Maintenance II	613.600.000	3,09	IDR 652,106,351
2028	Periodic Maintenance I	5.625.001.000	3,09	IDR 6,162,716,972
2029	Routine Maintenance I	613.600.000	3,09	IDR693,029,162
2030	Routine Maintenance II	613.600.000	3,09	IDR 714,443,763
2031	Periodic Maintenance II	5.625.001.000	3,09	IDR 6,751,835,329
2032	Routine Maintenance I	613.600.000	3,09	IDR 759.278.545
2033	Routine Maintenance II	613.600.000	3,09	IDR782.740.252
2034	Periodic Maintenance I	5.625.001.000	3,09	IDR 7,397,269,828
2035	Rehabilitation Maintenance I	20.290.926.000	3,09	IDR27.508.522.404

2036	Routine Maintenance I	613.600.000	3,09	IDR 857,565,472
2037	Routine Maintenance II	613.600.000	3,09	IDR884.064.245
2038	Periodic Maintenance II	5.625.001.000	3,09	IDR 8,354,830,031
2039	Routine Maintenance I	613.600.000	3,09	IDR 939,543,529
2040	Routine Maintenance II	613.600.000	3,09	IDR 968,575,424
2041	Periodic Maintenance I	5.625.001.000	3,09	IDR 9,153,501,098
2042	Routine Maintenance I	613.600.000	3,09	IDR 1,029,358,191
2043	Routine Maintenance II	613.600.000	3,09	IDR 1,061,165,359
2044	Periodic Maintenance II	5.625.001.000	3,09	IDR10.028.520.275
2045	Rehabilitation Maintenance II	20.290.926.000	3,09	IDR 37,293,458,407
	Total			IDR 122,625,084,877

Table 16 Recapitulation of the Percentage of Life Cycle Cost for the Period of 2025 to 2045 on the Tiom-Kuyawage road section

Description	Life Cycle Cost (Rp)
(A) Initial Cost	82.490.500.000
(b) Maintenance Costs	201.422.654.592
Total Life Cycle Cost (A+B)	283.913.154.592
Initial Cost (%)	29,06%
Maintenance Costs	70,94%

Table 17. Recapitulation of the Percentage of Life Cycle Cost for the Period of 2025 to 2045 on the Tiom-Balingga road section

Description	Life Cycle Cost (Rp)
(A) Initial Cost	74.720.500.000
(b) Maintenance Costs	122.625.084.877
Total Life Cycle Cost (A+B)	197.345.584.877
Initial Cost (%)	37,86%
Maintenance Costs	62,14%

Source: Analysis Results, 2025

Table 18. Recapitulation of Present Value Calculation on the Tiom-Kuyawage Road Section for the period 2025 to 2045

Year	Maintenance Type	Budget (Rp)	BI Interest Rate (%)	Net Present Value
2025	Initial conditions		-	-
2026	Routine Maintenance I	833.617.079	5,04	IDR 793,618,697
2027	Routine Maintenance II	859.375.847	5,04	IDR778,885,677
2028	Periodic Maintenance I	10.298.322.225	5,04	IDR 8,885,918,735
2029	Routine Maintenance I	913.305.815	5,04	IDR 750,235,085
2030	Routine Maintenance II	941.526.965	5,04	IDR 736,307,454
2031	Periodic Maintenance II	11.282.779.356	5,04	IDR 8,400,165,000
2032	Routine Maintenance I	1.000.612.311	5,04	IDR709.223.064
2033	Routine Maintenance II	1.031.531.231	5,04	IDR 696,056,794
2034	Periodic Maintenance I	12.361.344.617	5,04	IDR 7,940,965,266
2035	Rehabilitation Maintenance I	45.981.754.907	5,04	IDR28,121,495,415
2036	Routine Maintenance I	1.130.139.359	5,04	IDR 658.006.458
2037	Routine Maintenance II	1.165.060.665	5,04	IDR645,790,992
2038	Periodic Maintenance II	13.961.493.312	5,04	IDR 7,367,507,770
2039	Routine Maintenance I	1.238.173.826	5,04	IDR 622,036,166
2040	Routine Maintenance II	1.276.433.397	5,04	IDR 610,488,465

2041	Periodic Maintenance I	15.296.127.377	5,04	IDR 6,964,758,823
2042	Routine Maintenance I	1.356.535.732	5,04	IDR588.032.210
2043	Routine Maintenance II	1.398.452.687	5,04	IDR 577,115,771
2044	Periodic Maintenance II	16.758.344.362	5,04	IDR 6,584,026,373
2045	Rehabilitation Maintenance II	62.337.723.523	5,04	IDR23.316.141.208
Total				IDR105.746.775.421

To obtain the estimated net present value in the period from 2025 to 2045, the same calculation is carried out. The following in Table 19 below shows the results of the calculation of the estimated net present value for the period 2025 to 2045 for the Tiom-Balingga road section.

Table 19. Recapitulation of Present Value Calculation on the Tiom-Balingga Road Section for the Period 2025 to 2045

Year	Maintenance Type	Budget (Rp)	BI Interest Rate (%)	Net Present Value
2025	Initial conditions		-	-
2026	Routine Maintenance I	632.560.240	5,04	IDR602.208.911
2027	Routine Maintenance II	652.106.351	5,04	IDR591.029.290
2028	Periodic Maintenance I	6.162.716.972	5,04	IDR 5,317,507,163
2029	Routine Maintenance I	693.029.161	5,04	IDR569,288,822
2030	Routine Maintenance II	714.443.762	5,04	IDR 558,720,342
2031	Periodic Maintenance II	6.751.835.329	5,04	IDR 5,026,822,649
2032	Routine Maintenance I	759.278.545	5,04	IDR538.168.330
2033	Routine Maintenance II	782.740.252	5,04	IDR 528,177,581
2034	Periodic Maintenance I	7.397.269.827	5,04	IDR 4,752,028,568
2035	Rehabilitation Maintenance I	27.508.522.403	5,04	IDR 16,823,646,427
2036	Routine Maintenance I	857.565.472	5,04	IDR499,304,457
2037	Routine Maintenance II	884.064.245	5,04	IDR490.035.191
2038	Periodic Maintenance II	8.354.830.030	5,04	IDR 4,408,860,413
2039	Routine Maintenance I	939.543.528	5,04	IDR472.009.698
2040	Routine Maintenance II	968.575.423	5,04	IDR 463,247,142
2041	Periodic Maintenance I	9.153.501.098	5,04	IDR 4,167,847,584
2042	Routine Maintenance I	1.029.358.190	5,04	IDR446.207.023
2043	Routine Maintenance II	1.061.165.358	5,04	IDR 437,923,477
2044	Periodic Maintenance II	10.028.520.274	5,04	IDR 3,940,009,857
2045	Rehabilitation Maintenance II	37.293.458.407	5,04	IDR 13,948,849,801
Total				IDR 64,581,892,731

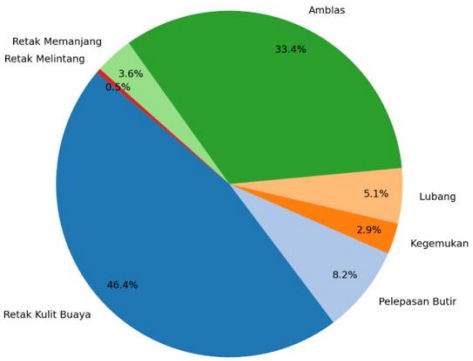

Figure 1. Percentage of Road Damage on the Tiom-Kuyawage Road Section in 2025

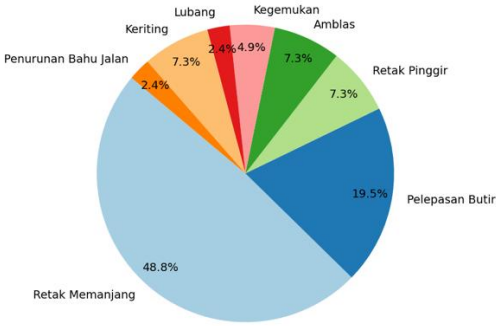

Figure 2 Percentage of road damage types on the Tiom-Balingga road section in 2025

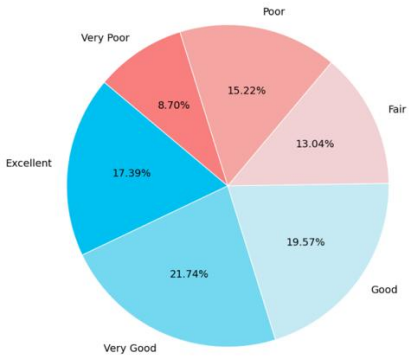

Figure 3 Average Pavement Condition Index Value Based on Ratting on Tiom-Kuyawage Road Section in 2025

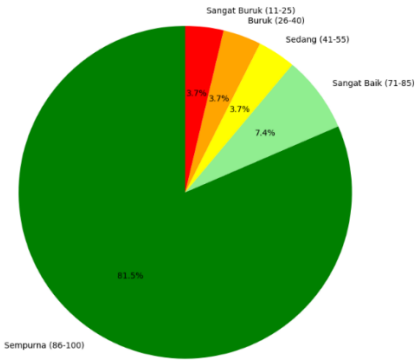

Figure 4. Average Pavement Condition Index Value Based on Ratting on the Tiom-Balingga Road Section in 2025

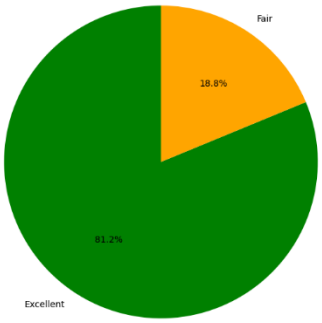

Figure 5. Average Pavement Condition Index Value Based on Ratting on the Tiom-Kuyawage Road Section in 2023

Based on analysis and calculations, the following is a recapitulation of the average value of the Pavement Condition Index based on its Rating presented in the following table. 20.

Table 20. Average Recapitulation of Pavement Condition Index Value by Rating

Year	Road Sections	Average PCI Score	Rating
2023	Tiom-Kuyawage	89,19	Excellent
2024	Tiom- Balingga	100	Excellent
2025	Tiom-Kuyawage	58,30	Good
2025	Tiom- Balingga	87,44	Excellent

Source: Analysis Results, 2025

Table 21. Recapitulation of Estimated Budget with Inflation and Net Present Value on the Tiom-Kuyawage Road Section in 2025-2045

Year	Maintenance Type	Initial Fee (Rp)	Inflation (%)	Estimated Cost (Rp)	BI Interest Rate (%)	Net Present Value (Rp)
2025	Initial conditions	-	-	-	-	-
2026	Routine Maintenance I	808.630.400	3,09	833.617.079	5,04	793.618.697
2027	Routine Maintenance II	808.630.400	3,09	859.375.847	5,04	778.885.677
2028	Periodic Maintenance I	9.399.762.000	3,09	10.298.322.225	5,04	8.885.918.735
2029	Routine Maintenance I	808.630.400	3,09	913.305.815	5,04	750.235.085
2030	Routine Maintenance II	808.630.400	3,09	941.526.965	5,04	736.307.454
2031	Periodic Maintenance II	9.399.762.000	3,09	11.282.779.356	5,04	8.400.165.000
2032	Routine Maintenance I	808.630.400	3,09	1.000.612.311	5,04	709.223.064
2033	Routine Maintenance II	808.630.400	3,09	1.031.531.231	5,04	696.056.794

2034	Periodic Maintenance I	9.399.762.000	3,09	12.361.344.617	5,04	7.940.965.266
2035	Rehabilitation Maintenance I	33.917.212.000	3,09	45.981.754.907	5,04	28.121.495.415
2036	Routine Maintenance I	808.630.400	3,09	1.130.139.359	5,04	658.006.458
2037	Routine Maintenance II	808.630.400	3,09	1.165.060.665	5,04	645.790.992
2038	Periodic Maintenance II	9.399.762.000	3,09	13.961.493.312	5,04	7.367.507.770
2039	Routine Maintenance I	808.630.400	3,09	1.238.173.826	5,04	622.036.166
2040	Routine Maintenance II	808.630.400	3,09	1.276.433.397	5,04	610.488.465
2041	Periodic Maintenance I	9.399.762.000	3,09	15.296.127.377	5,04	6.964.758.823
2042	Routine Maintenance I	808.630.400	3,09	1.356.535.732	5,04	588.032.210
2043	Routine Maintenance II	808.630.400	3,09	1.398.452.687	5,04	577.115.771
2044	Periodic Maintenance II	9.399.762.000	3,09	16.758.344.362	5,04	6.584.026.373
2045	Rehabilitation Maintenance II	33.917.212.000	3,09	62.337.723.523	5,04	23.316.141.208
		Sum		IDR201.422.654.592		IDR105.746.775.421

Table 22. Recapitulation of Estimated Budget with Inflation and Net Present Value on the Tiom-Balingga Road Section in 2025-2045

Year	Maintenance Type	Initial Fee (Rp)	Inflation (%)	Estimated Cost (Rp)	Bank BI Interest Rate (%)	Net Present Value (Rp)
2025	Initial conditions	-	-	-	-	-
2026	Routine Maintenance I	613.600.000	3,09	632.560.240	5,04	602.208.911
2027	Routine Maintenance II	613.600.000	3,09	652.106.351	5,04	591.029.290
2028	Periodic Maintenance I	5.625.001.000	3,09	6.162.716.972	5,04	5.317.507.163
2029	Routine Maintenance I	613.600.000	3,09	693.029.162	5,04	569.288.823
2030	Routine Maintenance II	613.600.000	3,09	714.443.763	5,04	558.720.342
2031	Periodic Maintenance II	5.625.001.000	3,09	6.751.835.329	5,04	5.026.822.650

2032	Routine Maintenance I	613.600.000	3,09	759.278.545	5,04	538.168.330
2033	Routine Maintenance II	613.600.000	3,09	782.740.252	5,04	528.177.581
2034	Periodic Maintenance I	5.625.001.000	3,09	7.397.269.828	5,04	4.752.028.568
2035	Rehabilitation Maintenance I	20.290.926.000	3,09	27.508.522.404	5,04	16.823.646.427
2036	Routine Maintenance I	613.600.000	3,09	857.565.472	5,04	499.304.457
2037	Routine Maintenance II	613.600.000	3,09	884.064.245	5,04	490.035.191
2038	Periodic Maintenance II	5.625.001.000	3,09	8.354.830.031	5,04	4.408.860.413
2039	Routine Maintenance I	613.600.000	3,09	939.543.529	5,04	472.009.699
2040	Routine Maintenance II	613.600.000	3,09	968.575.424	5,04	463.247.142
2041	Periodic Maintenance I	5.625.001.000	3,09	9.153.501.098	5,04	4.167.847.584
2042	Routine Maintenance I	613.600.000	3,09	1.029.358.191	5,04	446.207.024
2043	Routine Maintenance II	613.600.000	3,09	1.061.165.359	5,04	437.923.477
2044	Periodic Maintenance II	5.625.001.000	3,09	10.028.520.275	5,04	3.940.009.857
2045	Rehabilitation Maintenance II	20.290.926.000	3,09	37.293.458.407	5,04	13.948.849.801
		Sum		122.625.084.877		64.581.892.731

Table 23. Recapitulation of Estimated Road Maintenance Budget on Tiom-Kuyawage and Tiom Balingga Road Sections for the Next 20 Years

Year	Road Sections	Budget and Inflation Estimates (3.09%)	Net Present Value (Rp)
2025-2045	Tiom-Kuyawage	IDR201.422.654.592	IDR105.746.775.421
2025-2045	Tiom- Balingga	IDR 122,625,084,877	IDR 64,581,892,731

Source: Analysis Results, 2025

The results of the Pavement Condition Index (PCI) analysis on the Tiom-Kuyawage and Tiom-Balingga road sections highlight the varying levels of road conditions, with the Tiom-Kuyawage road section showing a mixture of "Excellent" to "Poor" conditions, whereas the Tiom-Balingga road section predominantly remains in the "Excellent" category for most of its length. For the Tiom-Kuyawage road section, the recommendation includes routine maintenance for areas with minor damage and rehabilitation for sections with more severe damage, particularly in the segments where the PCI score dropped to poor or very poor levels. These results reflect the urgent need for continuous monitoring and periodic maintenance, especially considering the high traffic load and environmental challenges such as landslides.

The Tiom-Balingga road section, however, demonstrates a relatively better condition overall, with most parts falling under the "Excellent" category, requiring minimal maintenance. This difference between the two road sections could be attributed to factors such as traffic intensity and local environmental conditions, which are crucial in determining the rate of deterioration. Additionally, the budgeting and cost estimates for the maintenance of these

roads, particularly in terms of routine and periodic maintenance, offer insight into the financial commitment required over the next 20 years to maintain these roads in an optimal state.

The analysis of life cycle costs and net present values (NPV) further emphasizes the long-term financial impacts of road maintenance. The Tiom-Kuyawage road section has a significantly higher total life cycle cost compared to the Tiom-Balingga road section, primarily due to the extensive rehabilitation and ongoing maintenance required. These findings are crucial for road management authorities as they plan their maintenance strategies and budget allocations for the future.

CONCLUSION

The analysis of the Pavement Condition Index (PCI) and projected maintenance costs for the Tiom–Kuyawage and Tiom–Balingga road sections underscores their critical role in sustaining road infrastructure quality. The Tiom–Kuyawage section, initially rated as excellent (PCI 89.19 in 2023), is projected to decline to a "Good" PCI rating (58.30) by 2025, necessitating regular maintenance to mitigate further deterioration. In contrast, Tiom–Balingga maintains an excellent PCI score (87.44 in 2025), requiring minimal intervention. Over a 20-year period, projected maintenance costs total IDR 201.42 billion for Tiom–Kuyawage and IDR 122.62 billion for Tiom–Balingga, highlighting the financial impact of PCI-driven deterioration. Future research should investigate the influence of traffic load and environmental factors (e.g., landslides, rainfall) on road degradation rates, as well as evaluate cost-effective materials or technologies (e.g., geopolymer additives, modular pavement systems) to reduce long-term maintenance expenditures in mountainous regions.

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