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Assessing Compliance to Minimum Service Standards of Indonesian Toll Roads: An Examination of the Padaleunyi Toll Road

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Abstract: The primary objective of this study encompasses the evaluation of the Padaleunyi Toll Road's service performance, particularly in relation to Indonesia's established minimum service standards for toll roads. Given that the Padaleunyi Toll Road currently stands at mid-life in terms of its service duration, it is crucial to undertake this assessment to predict its remaining useful life. Criteria for measuring minimum service standards' fulfillment were diversified to cover the conditions of the toll road, average vehicular speed, accessibility, mobility, safety parameters, availability of rescue units and service assistance, environmental impact, and features of rest and service areas. The employed research methodology was based on the guidelines provided by Regulation 16/PRT/M/2014 from the Indonesian Ministry of Public Works. Findings indicate a compliance level of 66.04% to the minimum service standards, with the poorest indicator being the condition of the toll roads at a mere 14%. This study hopes to contribute by offering comprehensive insights into the current state and future prospects of the Padaleunyi Toll Road. It further highlights the importance of effective maintenance and operation strategies in prolonging its service life. Overall, the implications of this study can significantly enhance the planning and development process of toll roads, particularly in developing countries such as Indonesia, by incorporating key aspects like pavement quality, road geometric design, and efficient traffic management.

Keywords: Padaleunyi Toll Road; Compliance; Indonesian minimum service standards for toll roads; Cipularang toll road; Purbaleunyi toll road; Road conditions

1 Introduction

Toll roads serve as fundamental infrastructure, playing a significant role in regional economic growth in Indonesia. It has been observed that cities intersected by toll roads experience an enhanced economic growth rate, approximately 0.015 percent higher than cities devoid of such infrastructure. A shift in industrial locations towards toll gates, primarily to leverage their strategic placement, leads to increased regional revenue via taxation [1–3].

The condition of such infrastructure directly influences transportation mobility on toll roads, which in turn impacts the efficacy of goods distribution. An efficient distribution network is integral to the production sector, particularly in terms of production costs. Reduced costs typically result in heightened consumer purchasing power, consequently fostering regional progress [4–6].

Public roads that include toll roads are considered a part of the national road network system in Indonesia, and users are mandated to pay the stipulated toll rates. According to Government Regulation No. 15 of 2005 [7], the establishment of toll roads aims at promoting balanced and equitable development across regions, enhancing the efficiency of distribution services, and thus bolstering economic growth, especially in areas with high development rates.

Effective toll road management, reflected through the optimization of provided services, is imperative in enhancing community economic growth. As of June 2022, Indonesia boasts an operational toll road stretch of 2,500 km, distributed across 66 individual toll roads [8].

Among these, the Purbaleunyi toll road, one of Indonesia's longest toll roads, serves as a vital connection between the Jakarta Capital Region and the city of Bandung, along with its neighboring areas [9]. A detailed description of the Purbaleunyi toll road is provided in Table 1.

Table 1. Purbaleunyi toll road description

Parameter	Explanation
Segment	Padaleunyi, Cipularang
Length	123 km
Concession until year	2044
Year of operation	1990 (segment of Padaleunyi) & 2003 (segment of Cipularang)
Number of employee	538
Number of substations	92
Transaction system	Closed
Operation location	Padalarang, Cileunyi, Cikampek, Purwakarta

Table 1 reveals a concession period of 54 years for the Purbaleunyi toll road, with the Padaleunyi section operating for 26 years and the Cipularang section for 13 years. Thus, the Padaleunyi section is roughly at mid-concession life, while the Cipularang section is at a quarter of its total life span. The Purbaleunyi Toll Road is among the busiest toll roads, subjected to heavy traffic services and an annually increasing traffic volume. It's observed that the growth rate surpasses the initially projected traffic growth rate.

An imminent concern pertains to the potential degradation in the performance of the Purbaleunyi toll road, specifically the risk of not fulfilling the intended service period due to damages. A considerable rise in vehicle volume leading to increased road load has resulted in various levels of damage at several toll road locations, ranging from minor to severe, posing potential risks to road users. Reported damage types include cracks, undulations, and potholes of varying depths.

The growth in vehicle number within Indonesia has a substantial impact on toll road traffic. For instance, the Purbaleunyi Toll Road, due to its high average traffic volume growth per month, is currently Indonesia's highest traffic volume toll road. Consequently, it has a significant effect on the increase in traffic-related accidents, causing serious injuries [10, 11]. The average monthly traffic volume growth on the Purbaleunyi Toll Road is displayed in Table 2.

Table 2. Average traffic volume per month on Purbaleunyi toll road

Year	Vehicle volume (unit)	Annual growth rate (%)
2012	381.781	5.07
2013	401.119	4.28
2014	415.122	12.93
2015	549.587	

Source: Jasa Marga, 2020 [9]

Indonesia's toll road tariffs have been deemed relatively expensive when compared to other Southeast Asian countries, according to Siswoyo [12], thereby demanding a commensurate level of quality. Periodic monitoring and evaluations based on the minimum service standards for toll roads are integral to maintaining the quality and ensuring that the roads remain in an optimal state. It is of importance, considering the yearly increase in vehicle volume, which may accelerate the rate of damage and potentially reduce the road's lifespan.

Given this situation, it is critical to evaluate the fulfillment of the Minimum Service Standards (SPM) for the Padaleunyi Toll Road. This research focuses specifically on the Padaleunyi Toll Road, taking into account its longer operational history compared to the Cipularang toll road.

2 Material and Methods

2.1 Data Collection

The study design adhered to a descriptive research framework. Evaluations were conducted on the condition of the toll road and equipment associated with the Padaleunyi Toll Road at the Purbaleunyi Branch of the Toll Road Provider. Data collection occurred between April and November 2016 through observation, interviews, and literature review. Observational procedures were conducted in an unrestricted environment, with investigators situated in the field to directly record, measure, and observe without limiting factors [13, 14].

Interviews served to determine the toll road's state, where questions regarding the Padaleunyi Toll Road management were posed. Semi-structured interviews were employed, affording both the interviewees and researchers the flexibility to reveal, clarify, and investigate based on the existing facts of the Padaleunyi Toll Road. The secondary data utilized in the literature reviews comprised documents pertinent to the Padaleunyi Toll Road. The data collected are summarized in Table 3.

Table 3. Research methodology of data collection

Technique	Data
Observation	**Condition of facilities and infrastructure** 1. Data location, dimensions/sections, and drainage conditions 2. Data location, length, and condition of curb, median, guardrail 3. Data on the number of signs, road markings, and guide posts and their condition 4. Data on the number of public street lighting, anti-glare, right-of-way fences and safety fences and their condition **Calculating daily traffic volume from each toll exit** 1. Number of vehicles served per vehicle class per Padaleunyi Toll Booth 2. Number of normal vehicle queues average per Padaleunyi Toll Booth 3. Number of vehicle queues in congested conditions average per Padaleunyi Toll Booth **Field measurement and testing** 1. Measurement of road pavement roughness (Mu-Meter) per Padaleunyi Toll Road section 2. Measurement ruggedness pavement (NAASRA Roughness meters) per Padaleunyi Toll Road section 3. Measurement of normal average travel speed per Padaleunyi Toll Road section 4. Measurement of average transaction speed per Padaleunyi Toll Road section
Interview	1. Manager of Traffic Management 2. Manager of Maintenance Service Management 3. Operator section to identify the type of damage to the Padaleunyi Toll Road
Literature studies	1. Road pavement roughness measurement data (Mu-Meter) per Padaleunyi Toll Road section 2. Measurement data ruggedness pavement (NAASRA Roughness meters) per Padaleunyi Toll Road section 3. Drainage data (location, length, dimension/section, condition) and type of maintenance performed 4. Location data, length and condition of curb, median, guardrail and the type of maintenance performed 5. Normal average travel speed data per Padaleunyi Toll Road section 6. Data number of vehicle served per vehicle class per Padaleunyi Toll Booth 7. Average transaction speed data per Padaleunyi Toll Road section 8. Data Number of normal vehicle queues on average per Padaleunyi Toll Booth 9. Data Number of vehicle queues in congested conditions average per Padaleunyi Toll Booth 10. Data on the number of highway patrol vehicles and their conditions, as well as the average time for handling Traffic Barriers (from information received to the scene) per Padaleunyi Toll Road section 11. Data on the number of cranes and their conditions, the number of incidents served by official and free cranes, as well as the towing handling time (from information received to the scene) per Padaleunyi Toll Road section 12. Data on the number of signs, road markings, and guide posts and their condition 13. Data on the number of public street lighting, anti- glare, right-of-way fences and safety fences and their condition 14. Data on the number of accidents and the number of victims of accidents 15. Measurement of daily volume of vehicles passing through toll exits along the Padaleunyi Toll Road section 16. Minimum Service Standards Report of Toll Road Provider at Purbaleunyi Branch

2.2 Sample Collection

For this investigation, both the population and sample were the length of the Padaleunyi Toll Road (excluding the interchange) encompassing multiple sections. These sections, managed directly by the Purbaleunyi Branch of the Toll Road Provider, were used to ascertain the population's character and nature. Each segment of the Padaleunyi Toll Road was sampled, with the toll road subdivided into 200 m inspection segments for the purpose of simplification and in correspondence with the installed hectometer pegs along the Padaleunyi Toll Road section every 200 m. A 20% sample of the population was taken from each segment, thus the estimated sample size for each proportionate segment is represented in Table 4.

Table 4. Data on the length of the Padaleunyi Toll Road

No	Area	Length(km)	Segment	Number of sample segments
1	Padalarang - Pasteur	6	30	6
2	Pasteur - Pasir Koja	5	25	5
3	Pasir Koja - Kopo	3	15	3
4	Kopo - M. Toha	3	15	3
5	M. Toha - Buah Batu	4	20	4
6	Buah Batu – Cileunyi	14	70	14
	Total	35	175	35

3 Data Processing

The classification of damage type adhered strictly to the criteria outlined in Minister of Public Works and Housing Regulation No.13/PRT/M/2011 Concerning Procedures for Road Maintenance and Surveillance [15]. The gravimetric methodology was employed to quantify damage, pursuant to Eq. (1). This procedure incorporated both field data collection and a meticulous review of relevant literature from preceding studies. Special attention was given to the Padaleunyi section during the data collection process. A comprehensive overview of the data collection methods utilized is provided in Table 5.

Table 5. Measurement method for data collection

No	Service substance		Measurement method
1	Toll road condition	Roughness	Mu-Meter
		Ruggedness	NAASRA Roughness Meter
		Absence of hole,rutting, and crack	Calculation of the area of damage
		Drainage, median roadside	Observation
2	Average travel speed		Secondary data (report)
3	Mobility		Secondary data (report)
4	Safety		Secondary data (report)
5	Environment		Secondary data (report)
6	Aid/rescue unit and service assistance		Secondary data (report) and observation
7	Accessibility		Secondary data (report) and observation
8	Rest and service area		Secondary data (report) and observation

Furthermore, the processed data was summarized so that the results of measuring damage weight and the types of damage in the Padaleunyi Toll Road component can be estimated.

$$Damage\ weight = \frac{Number\ of\ component\ damage}{Total\ number\ of\ components} \times 100\% \quad (1)$$

4 Result and Discussion

The damaging weight of the Padaleunyi Toll Road components was used to assess their condition in relation to the toll road minimum service standards. These standards serve as a benchmark for toll road business entities to provide essential services to toll road users (Regulation of the Minister of Public Works and Housing Number 16/PRT/M/2014 Concerning Minimum Service Standards for Toll Roads [16]). Each criterion within these standards was analyzed to determine its fulfillment. Figure 1 presents a summary of the percentage of criteria fulfillment for the Padaleunyi section.

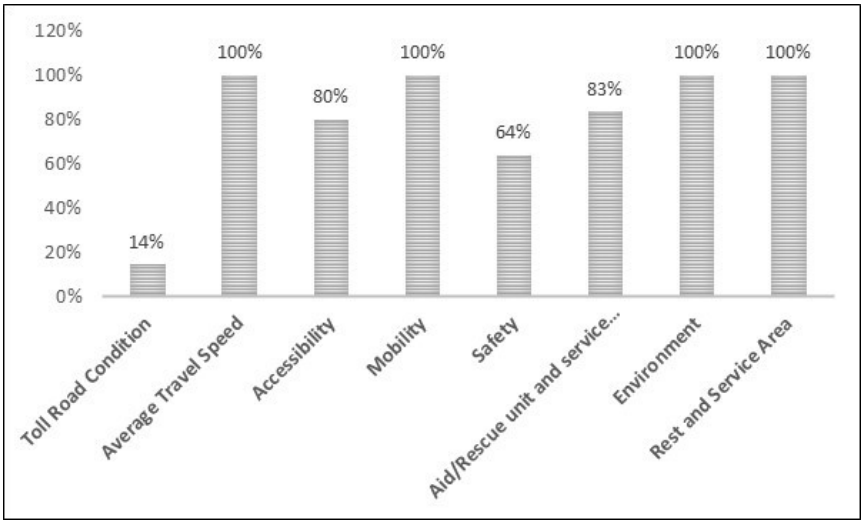

Figure 1. Percentage of criteria fulfillment

Table 6. Comparison results with minimum service standards of toll roads for toll roads condition

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
1	Toll road condition		Main pavement		
		Roughness	>0.33 mm	0.62 mu 0.63 mu	Fulfilled
		Ruggedness	Rigid pavement and flexible pavement ($|R| \leq$4.0 m/km)	3.47 m/km 3.38 m/km	Fulfilled
		Absence of hole	100%	97.37%	Not fulfilled
		Rutting	No rutting 100%	98.94%	Not fulfilled
		Crack	No crack 100%	99.08%	Not fulfilled
			Drainage		
		Absence of deposit	Functions and benefits 100%	81.08%	Not fulfilled
		Channel cross-section	Functions and benefits 100%	99.08%	Not fulfilled
			Median		
		Curb	Functions and benefits 100%	67.74%	Not fulfilled
		Median concrete barrier (MCB)	Functions and benefits 100%	96.88%	Not fulfilled
		Guard rail	Functions and benefits 100%	81.82%	Not fulfilled
		Wire rope	Functions and benefits 100%	None	Not fulfilled
			Roadside		
		Absence of hole	100%	99.07%	Not fulfilled
		Rutting	No rutting 100%	98.39%	Not fulfilled
		Crack	No crack 100%	97.59%	Not fulfilled

Figure 1 depicts the percentage of criteria fulfillment for the toll road minimum service standards in the Padaleunyi section. Among the eight criteria, only four met the standards in their entirety: average travel speed, mobility, environment, rest, and service area. The criterion with the lowest percentage of standard fulfillment was toll road conditions, meeting only 2 out of the 14 benchmarks. Comparison results with minimum service standards of toll roads for Toll roads condition as can be seen in Table 6 to Table 13. Thus, the achievement of minimum service

standards for toll road conditions reached a mere 14% of the expected level. Specifically, the only criteria that were met were the roughness and roughness of the main pavement. Conversely, the requirements of having no holes, rutting, and cracks on the main road pavement, as well as proper roadside conditions, were not fulfilled. Furthermore, improvements are needed in all drainage conditions. The median condition, encompassing the curb, median concrete barrier (MCB), guard rail, and wire rope, also fell short of meeting the standards. An example illustrating the presence of cracks and pothole damage on the main road and shoulder pavement is showcased in Figures 2-3.

The condition of the main line pavement exhibits variability, with some sections being overlaid and in excellent condition while others could benefit from further enhancement. The road surface has experienced significant wear and tear, despite the application of patches to many areas. Numerous cracks, grooves, longitudinal cracks, and holes are present, with longitudinal cracks being particularly common in the joint area between adjacent pavement layers. According to Wahidin [17], both newly built roads and newly restored roads (overlays) experience a decrease in structural function over time. Additionally, damage can occur due to the interaction of friction between vehicles and the road pavement, such as sudden braking at high speeds [17, 18]. Such damage weakens the asphalt pavement structure, leading to pavement deformation and the subsequent occurrence of pavement roughness. The presence of pavement roughness negatively impacts vehicle performance and traffic safety.

Table 7. Comparison results with minimum service standards of toll roads for average travel speed

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
2	Average travel speed	Average travel speed in normal condition	More than 40 km/h (inner-city) More than 60 km/h (outer-city)	61.31 km/h -	Fulfilled -

Table 8. Comparison results with minimum service standards of toll roads for mobility

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
3	Mobility	Traffic problem handling speed	30 minutes per observation cycle	20.92 minutes	Fulfilled
			Maximum 30 minutes per service unit required	7.10 minutes	Fulfilled
		Handling of stalled vehicles			
		Highway patrol handling speed	Towing to the nearest repair shop using an official and free crane service (inner-city)	100% (Towing of stalled vehicle: 1,048 ×)	Fulfilled
			Towing to the nearest workshop Towing to the nearest repair shop using an official and free crane service (outer-city)	-	-
		Crane vehicle handling speed	Handling and enforcement of traffic obstacle	22.03 minutes	Fulfilled
			Arrive at the scene within 30 minutes	18.75 minutes	Fulfilled

Regarding safety criteria, compliance was achieved to a rate of only 64%, ranking second lowest among the evaluated criteria. The criteria for signs, road markings, guide posts, kilometer benchmarks, and hectometer benchmarks were met. However, the criteria for public street lighting, anti-glare measures, right-of-way fences, and safety fences were not fulfilled. Public street lighting on the Padaleunyi Toll Road is limited to a few areas, such as the office, toll booths, and selected turns. Furthermore, some of the installed lights are non-functional and

Table 9. Comparison results with minimum service standards of toll roads for safety

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
4	Safety	Signage	Total 100% and effectiveness > 80%	Total 1743 unit; Mean 97.30%	Fulfilled
		Road markings	Total 100% and effectiveness > 80%	Total 35,885 m; Mean 98.50%	Fulfilled
		Guide post	Total 100% and effectiveness > 80%	Total 17,982 unit; Mean 85.57%	Fulfilled
		Kilometer sign	Functions and benefits 100%	Total 42 pcs; Mean 98.48%	Fulfilled
		Hectormeter sign	Functions and benefits 100%	Total 336 pcs; Mean 88.19%	Fulfilled
		Other facilities			
		Public street lighting	Lights on	Total 592 units; Mean 95.25%	Not fulfilled
		Anti-glare	Availability 100%	None	Not fulfilled
		Right-of-way fences	Availability 100%	Total 33,021 units; Mean 96.64%	Not fulfilled
		Safety fences	Availability 100%	Total 48,295 units; Mean 97.69%	Not fulfilled
		Accident handling	Free evacuation to hospital	Accident Total 53x	Fulfilled
			Free evacuation to towing pool	Accident Total 112x	Fulfilled

Table 10. Comparison results with minimum service standards of toll roads for environment

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
5	Environment	Cleanliness (inside toll Right-of-way, operational office, and toll booth)	No trash, well taken care of, clean	100%	Fulfilled
		Plants	Does not interfere with toll road functions	100%	Fulfilled
		Grasses	Grass height <30 cm	100%	Fulfilled

await replacement. This condition renders toll roads vulnerable to security and safety risks, particularly during nighttime travel. The extensive damage to the guard rail, despite its primary function of minimizing collision risks and preventing vehicles from falling from heights [19], further exacerbates safety concerns. Figure 4 demonstrates the absence of a right-of-way fence limiting pedestrian access to the toll road, resulting in the use of this location for picking up and dropping off bus passengers. Such circumstances increase the likelihood of accidents on the highway.

This research aligns with the findings of study [20], emphasizing the critical role of toll road conditions and safety in enhancing overall safety on toll roads. Notably, the Cipularang toll road, included in the Padaleunyi Toll Road sample, stands out as one of Indonesia's most accident-prone toll roads [21]. Consequently, addressing infrastructure damage and ensuring prompt repairs to toll road facilities become essential measures for meeting toll road development criteria. Regular monitoring and evaluation of toll road performance are also necessary to maintain satisfactory operational standards. Given that the Padaleunyi Toll Road has now reached half its planned lifespan, urgent actions are needed to improve toll road conditions, including patching potholes and cracks, to support the safety of toll road users. Additionally, immediate attention should be given to enhancing road markings by rectifying blurred or faded markings. Ensuring the provision of effective rescue and emergency services is of paramount importance [20, 22].

Table 11. Comparison results with minimum service standards of toll roads for Aid/rescue unit and service assistance

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
6	Aid/Rescue unit and service assistance	Ambulance	1 unit per 25 Km or at least 1 unit if<25 Km (equipped with first aid standards and paramedics)	2 units	Fulfilled
		Towing vehicles	Average daily traffic>100,000 vehicles per day: 1 unit per 5 km or at least 1 unit if<5 km, if more than 1 towing unit is available, a tow with a capacity of 25 tons must be available at least 1 unit	6 units	Not fulfilled
		Highway patrol (PJR)	Average daily traffic>100,000 vehicles per day: 1 unit per 15 km or at least 1 unit if<15 km Average daily traffic>100,000 vehicles per day: 1 unit per 20 km or at least 1 unit if<20 km	6 units	Fulfilled
		Toll road patrol (Operator)	1 unit per 15 km or minimum 2 units if >15 km	3 units	Fulfilled
		Rescue vehicle	1 unit per 50 km or minimum 1 units if <50 km (equipped with rescue equipment)	2 units	Fulfilled
		Information system (should be read clearly and without giving glare)	Traffic condition information and communication (banners, boards, virtual message sign (VMS), toll info phone number)	9 units	Fulfilled

Table 12. Comparison results with minimum service standards of toll roads for accessibility

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
7	Accessibility	Average transaction speed	Max 5 seconds	4.02 seconds	Fulfilled
			Max 9 seconds	7.89 seconds	Fulfilled
		Automatic toll gate			
		Average transaction speed	Max 4 seconds	3.87 seconds	Fulfilled
			Max 5 seconds	4.62 seconds	Fulfilled
		Number of vehicle queues	Maximum 10 vehicles per substation	More than 10 vehicles per substation	Not fulfilled

5 Conclusion

The fulfillment of the minimum service standards for the Padaleunyi Toll Road was evaluated, encompassing a measurement of 53 criteria. Out of these criteria, only 35 met the established standards, resulting in a fulfillment rate of 66.04%. It is evident that the physical condition of the toll road requires significant improvement in order to achieve the minimum service standards. This improvement is essential to enhance the comfort, safety, and cost-effectiveness for toll road users, including reduced vehicle operating costs and time savings. Consequently, it is imperative to formulate a prompt corrective action plan to enhance the overall performance of the toll road.

Table 13. Comparison results with minimum service standards of toll roads for rest and service area

No	Service substance	Minimum service standard		Measurement results (Mean)	Compliance with minimum standards
		Benchmark	**Indicator**		
8	Rest and service area	Road condition	All road surfaces at the rest area. No holes, cracks and breaks	100%	Fulfilled
		On/Off Ramp	The road surface at the entrance and exit of the rest area. No holes, cracks and breaks	100%	Fulfilled
		Toilet	Operational 100%, clean, free	100%	Fulfilled
		Vehicle parking	Operational 100%, clean, in order, free Forbidden to park on the on/off ramp	100%	Fulfilled
		Illumination	Operational 100%	100%	Fulfilled
		Refueling station	Operational 100%	100%	Fulfilled
		Public workshop	Operational 100%	100%	Fulfilled
		Place to eat and to drink	Operational 100%	100%	Fulfilled

Figure 2. Longitudinal cracks and holes in the main line pavement at km 135

Figure 3. Damage at km 128

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Figure 4. Absence of right-of-way fence

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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