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Evaluation of Pavement Condition and Remaining Service Life on the Guru Tua Road Section

Sitti Rahmawati[1], Novita Pradani[2], Ratnasari Ramlan[3]

[1,2,3]Departement of Civil Engineering, Faculty of Engineering Tadulako University, Central Sulawesi, Indonesia

ABSTRACT: The Guru Tua Road Section is a provincial road with a length of 3.96 km, serving as a connecting infrastructure between Sigi Regency and Palu City. Pavement conditions at several points are experiencing damage and causing uncertainty regarding the estimated remaining service life. This research aims to determine the condition of the road pavement to specify the type of handling, and to analyze the road's remaining service life. The evaluation of the functional condition of the road uses the International Roughness Index (IRI), Present Serviceability Index (PSI), and Surface Distress Index (SDI) methods, while the analysis of the remaining service life uses the AASHTO 1993 method. The research results indicate that the pavement condition of the Guru Tua Road Section is considered moderate, with an average IRI value of 4.595. Meanwhile, the average service function of the road is poor, with a PSI (Equation I) value of 1.205 and a PSI (Equation II) value of 1.232. Furthermore, the road pavement condition based on the average SDI value of 27.875 is good. The results of the remaining service life analysis of the Guru Tua Road section indicate that the pavement service life will end in the 8th year (2033), which is two years earlier than the planned design life, representing a reduction of 22,72 %.

KEY WORDS: Guru Tua Road, IRI, SDI, PSI, Remaining Service Life

I. INTRODUCTION

Roads are land transportation infrastructure that play a crucial role in ensuring connectivity between regions, as well as facilitating the distribution of goods, services, and people for various purposes, including economic, social, and cultural activities. Along with the increasing economic demands and rapid mobility of society, traffic volumes on roads continue to rise, which in turn intensifies the load borne by road infrastructure (Sutrisno et al., 2023). Road infrastructure subjected to high and repetitive traffic loads will experience a decline in quality, which can be identified through deterioration of pavement surface conditions, both structurally and functionally, leading to various forms of damage (Pradani et al., 2016).

Figure 1. Pavement Deterioration on the Guru Tua Road Section

The Guru Tua Road Section is a provincial road with a length of approximately 3.96 km, located in Sigi Biromaru District, Sigi Regency. This road serves a strategic function as a connecting infrastructure between Sigi Regency and Palu City. In addition to supporting daily community mobility, the Guru Tua Road also functions as one of the main access routes for sand-transport trucks, due to its proximity to the sand mining area along the Palu River.

Based on preliminary field surveys, pavement conditions at several locations along this road section have experienced various forms of damage, as illustrated in Figure 1. These conditions potentially pose safety risks to road users; therefore, a comprehensive analysis of pavement conditions is required to determine appropriate and sustainable maintenance strategies. Road condition assessment should be conducted periodically, considering both structural and functional aspects. The resulting pavement condition values serve as the basis for determining suitable treatment measures, whether in the form of routine maintenance, periodic maintenance, or upgrading/reconstruction.

Evaluation of the functional condition of road pavements can be carried out using the International Roughness Index (IRI) and the Present Serviceability Index (PSI) methods (Tho'atin et al., 2016). The IRI represents an assessment of pavement condition based on surface roughness, while the PSI evaluates the level of pavement serviceability, with its analysis also relying on surface roughness parameters. In addition, pavement condition evaluation can be performed using the Surface Distress Index (SDI) method, which assesses various types of surface distress, including crack width and area, number of potholes, and wheel ruts or grooves (Yastawan et al., 2021).

In this study, the evaluation approach combines pavement condition assessment methods based on surface roughness indices with observations of actual surface distress occurring in the field. This integrated approach is expected to provide a more accurate and comprehensive evaluation of pavement conditions. Pavement deterioration also introduces uncertainty in estimating the remaining service life of the pavement structure. Remaining service life refers to the estimated period during which the pavement can continue to function before reaching an unacceptable condition based on surface condition evaluation (Nainggolan, 2025). To predict the end of the pavement's remaining service life, the analysis is conducted using the AASHTO 1993 method, based on traffic data.

The objectives of this study are to evaluate the pavement condition of the Guru Tua Road Section based on the International Roughness Index (IRI), Present Serviceability Index (PSI), and Surface Distress Index (SDI) methods, to determine appropriate pavement damage treatment measures to be applied on the Guru Tua Road Section based on the results of the pavement condition evaluation, and to analyze and predict the remaining service life of the Guru Tua Road Section using the AASHTO 1993 method based on traffic data.

II. METHODS

A. International Roughness Index (IRI)

The roughness parameter is utilized in road management to identify the level of pavement deterioration along a road section. The IRI is calculated based on the cumulative vertical movements (upward and downward) of the road surface along the longitudinal profile, divided by the length of the measured section (Suwandi, 2021).

Table 1. Relationship Between Pavement Condition and IRI–SDI Indicators

IRI	SDI			
	< 50	50-100	100-150	>150
< 4	Good	Moderate	Minor Damage	Severe Damage
4-8	Moderate	Moderate	Minor Damage	Severe Damage
8-12	Minor Damage	Minor Damage	Minor Damage	Severe Damage
>12	Severe Damage	Severe Damage	Severe Damage	Severe Damage

Source: Bina Marga, 2011

In this study, the IRI values were obtained from a surface roughness survey conducted on the Guru Tua Road Section using a roughometer.

B. Present Serviceability Index (PSI)

Road surface roughness can be evaluated using the Surface Index (IP), which is calculated based on the measured road surface profile. This index is also known as the Present Serviceability Index (PSI).

The Present Serviceability Index (PSI) represents an assessment of the level of pavement surface serviceability (Present Serviceability Rating) and is a modified form of the original index developed by Paterson in 1987 (as cited in Anugrah, 2021). The PSI value is obtained using a mathematical formula, as presented in Equation (1).

$$\text{PSI} = 5 + 0{,}6046\ X^3 - 2{,}2217\ X^2 - 0{,}0434\ X \quad \ldots\ldots\ldots\ldots (1)$$

Remarks:

X = Log (1 + SV)

SV = 2,2704 IRI^2

SV = *Slope Variance*

PSI = *Present Serviceability Index*

IRI = *Internasional Roughness Indeks, m/km*

According to the book *Prediction of Distress in Flexible Pavements* (Wiyono, 2009), the PSI value is calculated using Equation (2).

$$\text{PSI} = 5{,}03 - 1{,}9 \text{ Log } (1 + \text{SV}) - 0{,}01\sqrt{(C+P)} - 1{,}38(RD)^2 \ldots (2)$$

Remarks:

PSI = *Present Serviceability Indeks*

SV = *Slope Variance*

C+P = Total Area of Cracking and Patching (m²)

RD = *Rut Depth* (Inch)

Table 2. Relationship Between Road Serviceability and Surface Index (IP / PSI)

Suface Index (IP / PSI)	Road Serviceability
4- 5	Very Good
3-4	Good
2-3	Fair
1-2	Poor
0-1	Very Poor

Source: Sukirman, 1994

C. Surface Distress Index (SDI)

The Surface Distress Index (SDI) is a road performance scale obtained from visual observations of pavement distress occurring in the field (Suwandi, 2018). The SDI calculation is performed cumulatively based on the types and extent of pavement damage. According to Bina Marga (2011), the results of pavement distress condition assessment are used to determine appropriate road treatment measures, including routine maintenance, periodic maintenance, and upgrading or reconstruction.

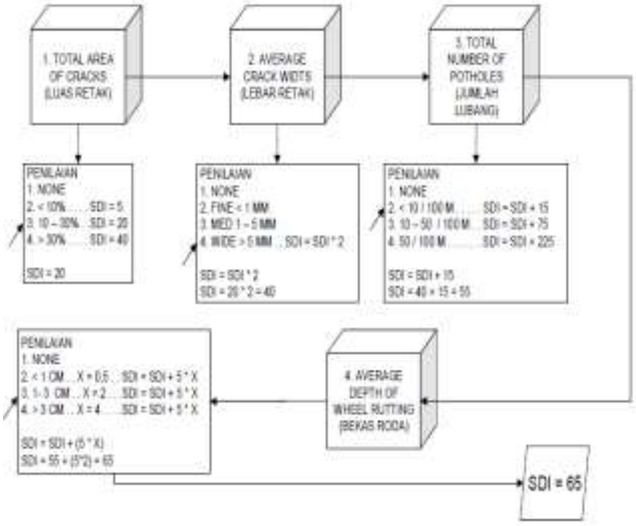

Figure 2. Example of SDI Calculation Procedure
Source: Bina Marga, 2011

Table 3. Relationship Between Pavement Maintenance Recommendations and SDI and IRI Values

IRI	SDI			
	< 50	**50-100**	**100-150**	**>150**
<4	Routine Maintenance	Routine Maintenance	Periodic Maintenance	Upgrading /Reconstruction
4-8	Routine Maintenance	Routine Maintenance	Periodic Maintenance	Upgrading /Reconstruction
8-12	Periodic Maintenance	Periodic Maintenance	Periodic Maintenance	Upgrading /Reconstruction
>12	Upgrading /Reconstruction	Upgrading /Reconstruction	Upgrading /Reconstruction	Upgrading /Reconstruction

Source : Bina Marga, 2011

D. Remaining Service Life (AASHTO 1993)

Pavement service life is the planned period during which a pavement is expected to optimally carry traffic loads without experiencing significant deterioration within a specified time frame. However, in practice, pavement segments constructed at the same time may exhibit different remaining service lives, highlighting the importance of conducting a remaining service life analysis (Hafudianyah, 2024).

The remaining pavement life is one of the main objectives of roadway capacity evaluation based on the AASHTO (1993) approach. This evaluation determines the percentage of remaining pavement life for the road section under study. The design life factor is subsequently calculated using the equation presented in Equation (3).

$$RL = 100\left[1 - \left(\frac{Np}{N2}\right)\right] \quad \text{...} (3)$$

Remarks :
RL = Remaining pavement service life (%)
Np = Total traffic that has passed over the pavement, derived from CESAL values
N2 = Total traffic at the end of the pavement service life according to the planned design, obtained from CESAL

The parameters used as considerations for calculating the remaining pavement service life are as follows:

a. Design Life

According to the 2024 pavement design manual, the design life for new flexible pavements is set at 20 years. Meanwhile, the design life for any maintenance or rehabilitation of flexible pavements is a minimum of 10 years.

b. Traffic Growth Factor (i)

$$i = \left(\frac{LHR_n}{LHR_1}\right)^{\frac{1}{n}} - 1 \quad \text{...} (4)$$

Remarks :
i = Traffic growth factor
n = Year n
LHR_1 = LHR (Average Daily Traffic) in the initial year
LHR_n = LHR in year n

To determine the average daily traffic (LHR) from year to year over the design life, the following formula is used:

$$LHR_n = LHR_1(1 + i)^n \quad \text{..} (5)$$

Traffic growth over the design life is calculated using the cumulative growth factor, as expressed by the following formula:

$$R = \frac{(1+0{,}1i)^{UR} - 1}{0{,}01i} \quad \text{...} (6)$$

Remarks :
R = Traffic growth multiplication factor
i = Annual traffic growth rate
UR = Design life (years)

Table 4. Traffic growth rate factor, i (%)

	Jawa	**Sumatera**	**Kalimantan**	**Rata-Rata Indonesia**
Arteri & Perkotaan	4,80	4,83	5,14	4,75
Kolektor Rural	3,5	3,5	3,5	3,5
Jalan Desa	1	1	1	1

Source: Indonesian Pavement Design Manual, 2024

c. Direction and Lane Distribution Factors

In the Indonesian Pavement Design Manual 2024, traffic loads on the design lane are expressed in cumulative standard axle loads (ESA), taking into account the direction distribution factor (DD) and lane distribution factor (DL). For two-way roads, the direction distribution factor (DD) is generally assumed to be 0.50.

Table 5. Lane Distribution Factor (DL)

Number of lanes per direction	**commercial vehicles in the design lane (%)**
1	100
2	80
3	60
4	50

Source: Indonesian Pavement Design Manual, 2024

d. Vehicle Damage Factor (VDF)

The Vehicle Damage Factor (VDF) consists of two types: VDF4 (exponent 4) for pavement design using the mechanistic-statistical approach (AASHTO, 1993) and VDF5 (exponent 5) for pavement design using the mechanistic-empirical approach related to asphalt concrete fatigue. The VDF values are provided in the Indonesian Pavement Design Manual 2024.

Table 6. VDF Values for Sulawesi (Gorontalo, Central Sulawesi, Southeast Sulawesi)

Condition		Vehicle category		
		6A	6B	7A2
VDF4	Faktual	0,5	0,9	16,9
	Normal	0,5	0,4	4,9
VDF5	Faktual	0,4	0,9	34,0
	Normal	0,4	0,4	6,6

Source : Indonesian Pavement Design Manual, 2024

e. Cumulative Equivalent Single Axle Load (CESAL)

Cumulative Equivalent Single Axle Load (CESAL) is the cumulative total of design traffic axle loads on the design lane over the pavement's design life, calculated as follows using the VDF for each vehicle.

$$\mathrm{CESAL} = (\Sigma \mathrm{LHR}_{\mathrm{JK}} \times \mathrm{VDF}_{\mathrm{JK}}) \times 365 \times \mathrm{DD} \times \mathrm{DL} \times \mathrm{R} \text{ .... } (7)$$

Remarks :

LHRJK = Average daily traffic for each type of commercial vehicle (vehicles per day)
VDFJK = Vehicle Damage Factor (VDF) for each type of vehicle
DD = Direction distribution factor
DL = Lane distribution factor
CESAL = Cumulative equivalent single axle load over the design life
R = Cumulative traffic growth multiplication factor

III. RESULTS AND DISCUSSION

This study utilized both primary and secondary data. The primary data consisted of IRI values and pavement distress data obtained through direct surveys on the Guru Tua Road section. The road has a total length of 3.96 km and is divided into 40 segments, each with a uniform length of 100 m, allowing for a detailed and standardized evaluation of pavement conditions. Meanwhile, the secondary data were obtained from available official sources. In this study, the secondary data included LHR data acquired from the Bina Marga Office of Central Sulawesi Province and the study area map obtained from Google Earth.

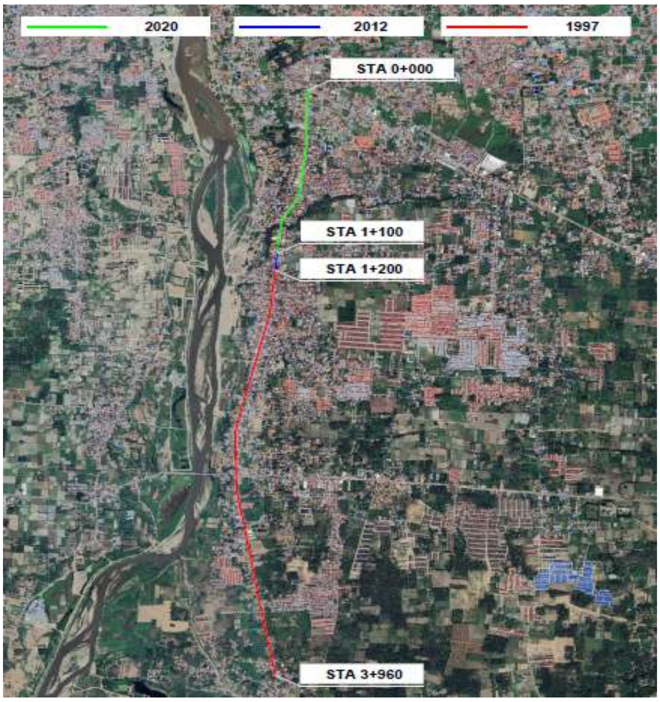

Figure 3. History of Maintenance on Guru Tua Road

Based on the figure 3, the segment from STA 0+000 to STA 1+200 is well-maintained, having undergone rehabilitation in 2012, followed by an overlay on STA 0+000 to STA 1+100 in 2020 using Asphalt Concrete-Wearing Course (AC-WC), reflecting a commitment to preventive maintenance on the initial segment. In contrast, the segment from STA 1+200 to STA 3+960 was last treated in 1997 with a Hot Rolled Sheet (HRS) pavement, indicating a lack of significant maintenance for over two decades. This suggests that the segment from STA 1+100 to STA 3+960 has exceeded its pavement service life.

In this study, an analysis was conducted to assess the pavement condition using the International Roughness Index (IRI), Present Serviceability Index (PSI), and Surface Distress Index (SDI). Based on the IRI and SDI values, the appropriate type of pavement treatment was determined. Additionally, a remaining service life analysis was performed to estimate the year in which the treatment would be required.

A. Pavement Condition Analysis

a. Analysis of the International Roughness Index (IRI) Method

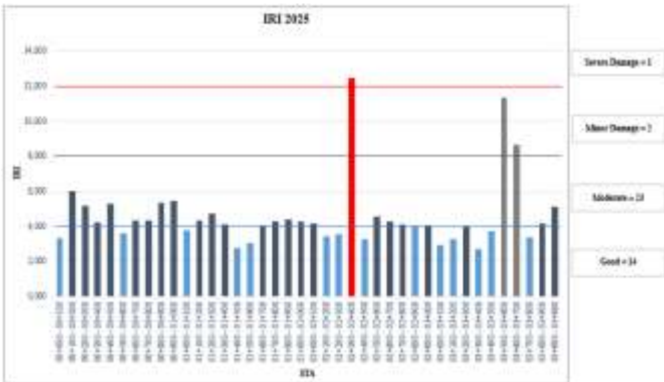

Figure 4. IRI Values of the Guru Tua Road Section

The pavement condition analysis based on IRI values shows varying conditions, with 14 segments classified as good, 23 segments as fair, 2 segments as lightly distressed, and 1 segment as severely distressed. The severely distressed segment, identified by very high IRI values between STA 02+300 and STA 02+400, indicates significant discomfort and potential hazards for road users. The severely distressed pavement condition is illustrated in Figure 5.

Figure 5. Severe Distress Condition at STA 02+300 – STA 02+400

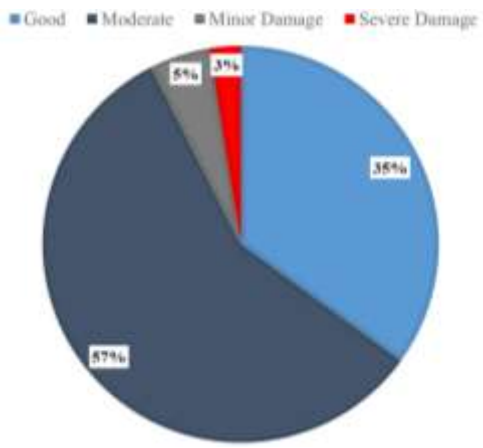

Figure 6. Percentage of Road Conditions Based on IRI Values

Based on IRI values, the condition of the Guru Tua Road section is classified into Good, Moderate, Minor Damage, and Severe Damage categories. The analysis shows that 35% of the road falls under the Good category, indicating that approximately one-third of the road section remains suitable for use without major maintenance. The Moderate category has the largest proportion at 57%, suggesting that most of the road is beginning to experience quality deterioration. Meanwhile, the Minor Damage category accounts for 5%, indicating a small portion of the road exhibiting surface distresses such as cracks or potholes that require prompt repair. Although the Severe Damage category represents only 3%, it is critical because segments in this category require rehabilitation or reconstruction to ensure road user safety and comfort.

b. Analysis of the Present Serviceability Index (PSI) Method

In this study, the PSI method analysis employed two equations: Equation I, developed by Paterson (1987), and Equation II, developed by Wiyono (2009).

- PSI Method Using Equation I (Paterson, 1987)

The following presents the analysis results using the PSI method based on Equation II :

Table 7. Road Service Function Based on PSI Value Using Equation I

STA	SV	X	PSI	Level of Service
00+000-00+100	25,055	1,416	2,201	Fair
00+100-00+200	82,198	1,920	1,006	Poor
00+200-00+300	61,179	1,794	1,263	Poor
00+300-00+400	40,836	1,622	1,666	Poor
00+400-00+500	63,751	1,811	1,225	Poor
00+500-00+600	29,147	1,479	2,031	Fair
00+600-00+700	42,804	1,642	1,616	Poor
00+700-00+800	42,883	1,642	1,615	Poor
00+800-00+900	64,161	1,814	1,220	Poor
00+900-01+000	67,684	1,837	1,171	Poor
01+000-01+100	32,561	1,526	1,909	Poor
01+100-01+200	42,528	1,639	1,623	Poor
01+200-01+300	50,967	1,716	1,439	Poor
01+300-01+400	37,701	1,588	1,750	Poor
01+400-01+500	17,245	1,261	2,624	Fair
01+500-01+600	21,051	1,343	2,398	Fair
01+600-01+700	37,646	1,587	1,752	Poor
01+700-01+800	41,610	1,630	1,646	Poor
01+800-01+900	44,035	1,654	1,587	Poor
01+900-02+000	41,902	1,632	1,639	Poor
02+000-02+100	39,310	1,605	1,706	Poor
02+100-02+200	26,323	1,437	2,145	Fair
02+200-02+300	28,871	1,475	2,042	Fair
02+300-02+400	351,296	2,547	0,467	Very Poor
02+400-02+500	23,996	1,398	2,250	Fair
02+500-02+600	47,334	1,684	1,513	Poor

02+600-02+700	41,106	1,624	1,659	Poor
02+700-02+800	37,850	1,589	1,746	Poor
02+800-02+900	35,621	1,564	1,811	Poor
02+900-03+000	36,885	1,578	1,775	Poor
03+000-03+100	19,266	1,307	2,499	Fair
03+100-03+200	23,893	1,396	2,254	Fair
03+200-03+300	36,417	1,573	1,788	Poor
03+300-03+400	16,797	1,250	2,654	Fair
03+400-03+500	30,897	1,504	1,967	Poor
03+500-03+600	292,169	2,467	0,449	Very Poor
03+600-03+700	169,249	2,231	0,559	Very Poor
03+700-03+800	25,693	1,426	2,172	Fair
03+800-03+900	39,442	1,607	1,702	Poor
03+900-03+960	59,378	1,781	1,291	Poor
Average			**1,696**	**Poor**

- PSI Method Using Equation II (Wiyono, 2009)

Based on the damage survey conducted on the Guru Tua road section, no rut depth was observed along this segment. The following presents the analysis results using the PSI method based on Equation II :

Table. 8 Road Service Function Based on PSI Value Using Equation I

STA	Cracking (m2)	Patching (m2)	PSI	Level of Service
00+000-00+100	0,000	0,000	2,340	Fair
00+100-00+200	18,270	3,700	1,335	Poor
00+200-00+300	72,340	19,880	1,526	Poor
00+300-00+400	188,140	5,400	1,810	Poor
00+400-00+500	4,900	0,000	1,566	Poor
00+500-00+600	11,400	0,000	2,186	Fair
00+600-00+700	0,000	0,000	1,911	Poor
00+700-00+800	0,000	0,000	1,910	Poor
00+800-00+900	0,000	0,000	1,583	Poor
00+900-01+000	1,700	0,000	1,527	Poor
01+000-01+100	0,000	0,000	2,131	Fair
01+100-01+200	1,290	0,000	1,905	Poor
01+200-01+300	2,800	10,440	1,734	Poor
01+300-01+400	8,730	0,135	1,984	Poor
01+400-01+500	2,700	0,000	2,617	Fair
01+500-01+600	3,680	1,540	2,455	Fair
01+600-01+700	2,200	0,735	1,997	Poor
01+700-01+800	2,400	0,000	1,918	Poor
01+800-01+900	1,350	0,000	1,877	Poor
01+900-02+000	6,850	0,000	1,902	Poor
02+000-02+100	9,500	0,000	1,949	Poor
02+100-02+200	5,100	0,200	2,278	Fair
02+200-02+300	1,800	0,000	2,214	Fair
02+300-02+400	31,050	0,000	0,135	Very Poor
02+400-02+500	7,300	0,000	2,347	Fair
02+500-02+600	3,300	0,000	1,812	Poor
02+600-02+700	7,900	0,000	1,916	Poor
02+700-02+800	4,730	0,000	1,988	Poor
02+800-02+900	1,400	0,000	2,047	Fair
02+900-03+000	5,400	0,000	2,008	Fair
03+000-03+100	26,670	2,640	2,493	Fair
03+100-03+200	5,460	4,090	2,347	Fair
03+200-03+300	11,400	3,210	2,003	Fair
03+300-03+400	1,900	1,150	2,637	Fair
03+400-03+500	7,200	4,550	2,139	Fair
03+500-03+600	148,300	1,850	0,220	Very Poor
03+600-03+700	53,100	1,800	0,717	Very Poor
03+700-03+800	11,500	0,862	2,285	Fair
03+800-03+900	21,000	2,910	1,928	Poor
03+900-03+960	11,200	10,250	1,600	Poor
Average			**1,882**	**Poor**

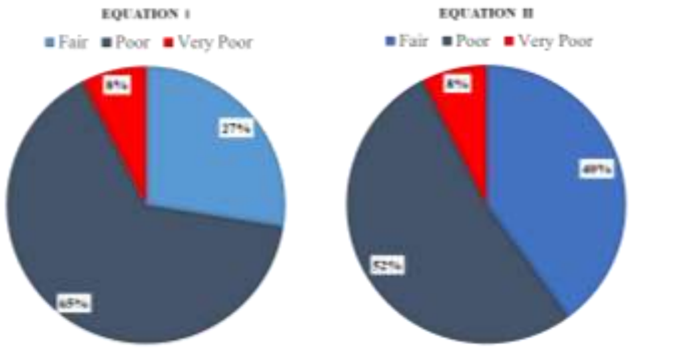

Figure 7. Percentage of Level of Service

Based on the analysis using the PSI method with Equation I, out of a total of 40 segments analyzed, 11 segments were classified as having a fair level of service, accounting for 27%, while 26 segments fell into the poor category, representing 65%, and 3 segments were classified as very poor, representing 8%. Meanwhile, based on the analysis using the PSI method with Equation II, 16 segments (40%) were classified as fair, 21 segments (52%) as poor, and 3 segments (8%) as very poor in terms of road service level.

Figure 8. Level of Service Based on Equations I and II

Overall, the condition of the Guru Tua road section indicates that it has not yet provided an optimal level of service to users. The highest PSI value only reached approximately 2.5 on a scale of 5, indicating that the service level is still moderate to poor. More critical conditions were observed at two critical points, namely STA 02+400–02+500 and STA 03+600–03+700, where the PSI values dropped close to 0.

c. Analysis of the Surface Distress Index (SDI) Method

The following presents the results of the damage survey conducted on the Guru Tua road section, which will be used for analysis using the SDI method :

Table 9. Road Damage Survey Results on the Guru Tua Road Section

STA	Crack Area (%)	Crack Width (mm)	Number of Potholes	Rut Depth (mm)
00+000-00+100	0,00	0	0	0
00+100-00+200	2,81	9 - 11	0	0
00+200-00+300	11,13	7 - 13	4	0
00+300-00+400	28,94	10 - 32	2	0
00+400-00+500	0,75	8	1	0
00+500-00+600	1,75	9 - 20	0	0
00+600-00+700	0,00	0	1	0
00+700-00+800	0,00	0	0	0
00+800-00+900	0,00	0	0	0
00+900-01+000	0,26	10	0	0
01+000-01+100	0,00	0	1	0
01+100-01+200	0,20	10 - 20	2	0
01+200-01+300	0,62	21	15	0
01+300-01+400	1,94	10 - 13	0	0
01+400-01+500	0,60	9	2	0
01+500-01+600	0,82	10 - 12	2	0
01+600-01+700	0,49	11	3	0
01+700-01+800	0,53	10	0	0
01+800-01+900	0,30	9	0	0
01+900-02+000	1,52	10	3	0
02+000-02+100	2,11	9 - 12	0	0
02+100-02+200	1,13	9 - 10	0	0
02+200-02+300	0,40	5	0	0
02+300-02+400	6,90	7 - 25	12	0
02+400-02+500	1,62	10 - 12	0	0
02+500-02+600	0,73	10 - 30	0	0
02+600-02+700	1,76	6 - 20	1	0
02+700-02+800	1,05	7 - 18	1	0
02+800-02+900	0,31	11	0	0
02+900-	1,20	6 - 10	0	0

03+000				
03+000-03+100	5,93	9 - 20	2	0
03+100-03+200	1,21	5 - 12	2	0
03+200-03+300	2,53	10 - 12	5	0
03+300-03+400	0,42	7 - 13	4	0
03+400-03+500	1,60	9 - 20	2	0
03+500-03+600	32,96	17 - 30	3	0
03+600-03+700	11,80	10 - 30	1	0
03+700-03+800	2,56	9 - 12	0	0
03+800-03+900	4,67	10 - 12	2	0
03+900-03+960	4,15	10	2	0

The following presents the analysis results using the SDI method :

Table 10. Pavement Condition Based on SDI Values

STA	SDI 1	SDI 2	SDI 3	SDI 4	SDI	Road Condition
00+000-00+100	0	0	0	0	0	Good
00+100-00+200	5	10	0	0	10	Good
00+200-00+300	20	40	55	0	55	Moderate
00+300-00+400	20	40	55	0	55	Moderate
00+400-00+500	5	10	25	0	25	Good
00+500-00+600	5	10	25	0	25	Good
00+600-00+700	0	0	15	0	15	Good
00+700-00+800	0	0	0	0	0	Good
00+800-00+900	0	0	0	0	0	Good
00+900-01+000	5	10	0	0	0	Good
01+000-01+100	0	0	15	0	15	Good
01+100-01+200	5	10	25	0	25	Good
01+200-01+300	5	10	85	0	85	Moderate
01+300-01+400	5	10	0	0	10	Good
01+400-01+500	5	10	25	0	25	Good
01+500-01+600	5	10	25	0	25	Good
01+600-01+700	5	10	25	0	25	Good
01+700-01+800	5	10	25	0	25	Good
01+800-01+900	5	10	25	0	25	Good
01+900-02+000	5	10	25	0	25	Good
02+000-02+100	5	10	25	0	25	Good
02+100-02+200	5	10	25	0	25	Good
02+200-02+300	5	10	25	0	25	Good
02+300-02+400	5	10	85	0	85	Moderate
02+400-02+500	5	10	25	0	25	Good
02+500-02+600	5	10	25	0	25	Good
02+600-02+700	5	10	25	0	25	Good
02+700-02+800	5	10	25	0	25	Good
02+800-02+900	5	10	25	0	25	Good
02+900-03+000	5	10	25	0	25	Good
03+000-03+100	5	10	25	0	25	Good
03+100-03+200	5	10	25	0	25	Good
03+200-03+300	5	10	25	0	25	Good
03+300-03+400	5	10	25	0	25	Good
03+400-03+500	5	10	25	0	25	Good
03+500-03+600	40	80	95	0	95	Moderate
03+600-03+700	20	40	55	0	55	Moderate
03+700-03+800	5	10	0	0	10	Good
03+800-03+900	5	10	25	0	25	Good
03+900-03+960	5	10	25	0	25	Good
Average					**27,875**	**Good**

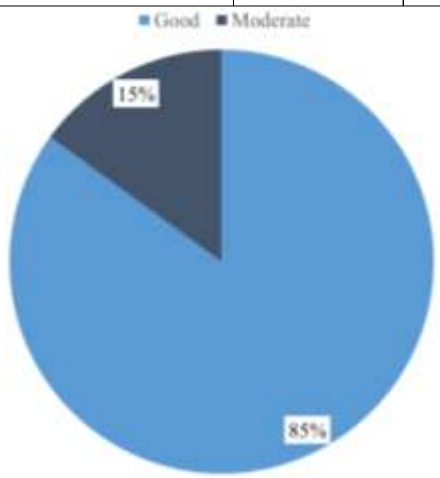

Figure 9. Percentage of Road Condition Based on SDI Values

The analysis of the pavement condition of the Guru Tua road using the Surface Distress Index (SDI) method indicates that the condition varies across segments, although overall it remains generally in good to fair condition. Based on the SDI calculations, approximately 85% of the segments fall into the good category, indicating that the majority of the pavement surface is still serviceable and does not require major maintenance. However, around 15% of the segments are classified as fair, suggesting the onset of surface distresses such as cracks and potholes that may affect the comfort and safety of road users.

B. Pavement Condition Based on IRI and SDI Values

Table 11. Road Condition and Maintenance Recommendations

STA	IRI 2025	SDI 2025	Road Condition	Maintenance
00+000-00+100	3,322	0	Good	Routine Maintenance
00+100-00+200	6,017	10	Moderate	Routine Maintenance
00+200-00+300	5,191	55	Moderate	Routine Maintenance
00+300-00+400	4,241	55	Moderate	Routine Maintenance
00+400-00+500	5,299	25	Moderate	Routine Maintenance
00+500-00+600	3,583	25	Good	Routine Maintenance
00+600-00+700	4,342	15	Moderate	Routine Maintenance
00+700-00+800	4,346	0	Moderate	Routine Maintenance
00+800-00+900	5,316	0	Moderate	Routine Maintenance
00+900-01+000	5,46	0	Moderate	Routine Maintenance
01+000-01+100	3,787	15	Good	Routine Maintenance
01+100-01+200	4,328	25	Moderate	Routine Maintenance
01+200-01+300	4,738	85	Moderate	Routine Maintenance
01+300-01+400	4,075	10	Moderate	Routine Maintenance
01+400-01+500	2,756	25	Good	Routine Maintenance
01+500-01+600	3,045	25	Good	Routine Maintenance
01+600-01+700	4,072	25	Moderate	Routine Maintenance
01+700-01+800	4,281	25	Moderate	Routine Maintenance
01+800-01+900	4,404	25	Moderate	Routine Maintenance
01+900-02+000	4,296	25	Moderate	Routine Maintenance
02+000-02+100	4,161	25	Moderate	Routine Maintenance
02+100-02+200	3,405	25	Good	Routine Maintenance
02+200-02+300	3,566	25	Good	Routine Maintenance
02+300-02+400	12,439	85	Severe Damage	Reconstruction
02+400-02+500	3,251	25	Good	Routine Maintenance
02+500-02+600	4,566	25	Moderate	Routine Maintenance
02+600-02+700	4,255	25	Moderate	Routine Maintenance
02+700-02+800	4,083	25	Moderate	Routine Maintenance
02+800-02+900	3,961	25	Good	Routine Maintenance
02+900-03+000	4,029	25	Moderate	Routine Maintenance
03+000-03+100	2,913	25	Good	Routine Maintenance
03+100-03+200	3,244	25	Good	Routine Maintenance
03+200-03+300	4,005	25	Moderate	Routine Maintenance
03+300-03+400	2,72	25	Good	Routine Maintenance
03+400-03+500	3,689	25	Good	Routine Maintenance
03+500-03+600	11,344	95	Minor Damage	Periodic Maintenance
03+600-03+700	8,634	55	Minor Damage	Periodic Maintenance
03+700-03+800	3,364	10	Good	Routine Maintenance
03+800-03+900	4,168	25	Moderate	Routine Maintenance
03+900-03+960	5,114	25	Moderate	Routine Maintenance
Average	**4,595**	**27,875**	**Moderate**	**Routine Maintenance**

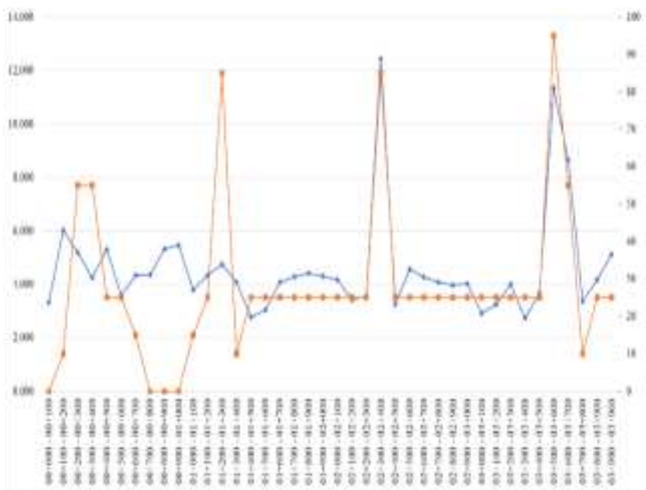

Figure 10. International Roughness Index (IRI) and Surface Distress Index (SDI) Values

The combined analysis of IRI and SDI values reveals significant variation in pavement conditions along the Guru Tua Road. The highest IRI value (12.439) was observed at STA 02+300–02+400, indicating very poor ride quality, accompanied by a high SDI value (85) that reflects severe surface distress. Meanwhile, the highest SDI value (95) occurred at STA 03+500–03+600, indicating more severe surface damage, with the IRI value (11.344) also classified as lightly damaged. Overall, the worst pavement conditions were identified at STA 02+300–02+400 and STA 03+500–03+600, as indicated by the consistently high IRI and SDI values at these segments.

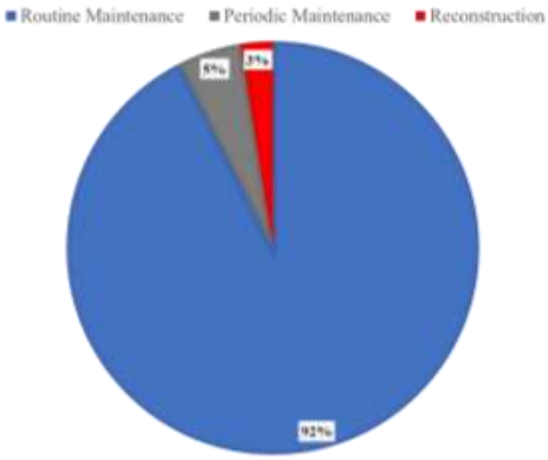

Figure 11. Percentage of Maintenance for the Guru Tua Road Section

The combined IRI–SDI analysis shows that 92% of the road segments require only routine maintenance, 5% need periodic maintenance, and 3% require reconstruction. This confirms that the integration of IRI and SDI provides a reliable basis for prioritizing pavement maintenance strategies.

C. Remaining Service Life Analysis

The first step in the remaining service life analysis is to determine the traffic growth rate based on the available Average Daily Traffic data

Table 12. Average Daily Traffic of the Guru Tua Road Section

Vehicle Classification	Average Daily Traffic (vehicles/day)		
	2023	2024	2025
6A	47	54	344
6B	80	89	123
7A2	15	18	12

Source : Bina marga office of Central Sulawesi Province

The analysis was performed under desaign and actual conditions. Design Average Daily Traffic was estimated using the design traffic growth factor from MDPJ 2024, while actual Average Daily Traffic projections were calculated using growth factors derived from field traffic data.

Table 13. Average Daily Traffic of the Guru Tua Road Section

Vehicle Classification	I (%)		*R*	
	Design	Actual	Design	Actual
6A	3,5	-11,07	10,02	9,95
6B	3,5	24,73	10,02	10,11
7A2	3,5	-6,67	10,02	9,97

Table 14. Average Daily Traffic Design After Maintenance

Year	Vehicle Classification			Cumulative
	6A	6B	7A2	
2025	34	123	12	200
2026	35	127	12	207
2027	36	132	13	214
2028	38	136	13	222
2029	39	141	14	230
2030	40	146	14	238
2031	42	151	15	246
2032	43	156	15	254
2033	45	162	16	263
2034	46	168	16	273
2035	48	174	17	282

Table 15. Average Daily Traffic Actual After Maintenance

Year	Vehicle Classification			Cumulative
	6A	6B	7A2	
2025	34	123	12	200
2026	30	153	11	234
2027	27	191	10	278
2028	24	239	10	334
2029	21	298	9	406
2030	19	371	8	497
2031	17	463	8	612
2032	15	578	7	756
2033	13	720	7	937
2034	8	996	5	1218
2035	7	1242	4	1518

After calculating the annual average daily traffic after treatment, the next step is to determine the cumulative equivalent standard axle load (CESAL). The CESAL calculation was conducted for two conditions, namely the design condition and the actual condition.

Table 16. Design Cumulative Equivalent Single Axle Load (CESAL)

Year	Vehicle Classification			Cumulative
	6A	6B	7A2	
2025	31.074	202.346	370.693	604.113
2026	32.161	209.428	383.668	625.257
2027	33.287	216.758	397.096	647.141
2028	34.452	224.345	410.994	669.791
2029	35.658	232.197	425.379	693.234
2030	36.906	240.324	440.268	717.497
2031	38.198	248.735	455.677	742.610
2032	39.535	257.441	471.626	768.601
2033	40.918	266.451	488.133	795.502
2034	42.351	275.777	505.217	823.345
2035	43.833	285.429	522.900	852.162

Table 17. Actual Cumulative Equivalent Single Axle Load (CESAL)

Year	Vehicle Classification			Cumulative
	6A	6B	7A2	
2025	30.871	204.290	369.002	604.163
2026	27.453	254.803	344.402	626.658
2027	24.413	317.806	321.441	663.661
2028	21.710	396.388	300.012	718.110
2029	19.307	494.399	280.011	793.717
2030	17.169	616.645	261.344	895.157
2031	15.268	769.117	243.921	1.028.306
2032	13.578	959.290	227.659	1.200.527
2033	12.074	1.196.485	212.482	1.421.041
2034	7.602	1.663.569	141.655	1.802.826

2035	6.761	2.062.432	132.211	2.201.404

Based on the CESAL data, the deterioration and remaining service life of the Guru Tua Road section were analyzed under both the design and actual conditions over a 10-year period, from 2025 to 2035, in accordance with the design life of the road improvement specified in MDPJ 2024.

Table 18. Remaining Service Life of the Pavement (Design Condition)

Planned service life	Year	CESAL	Cumulative CESAL	Remaining Life (%)
0	2025	-	-	100,00
1	2026	625.257	625.257	91,48
2	2027	647.141	1.272.399	82,65
3	2028	669.791	1.942.190	73,52
4	2029	693.234	2.635.424	64,07
5	2030	717.497	3.352.921	54,29
6	2031	742.610	4.095.531	44,17
7	2032	768.601	4.864.132	33,69
8	2033	795.502	5.659.634	22,84
9	2034	823.345	6.482.978	11,62
10	2035	852.162	7.335.140	0,00

Table 19. Remaining Service Life of the Pavement (Actual Condition)

Planned service life	Year	CESAL	Cumulative CESAL	Remaining Life (%)
0	2025	604.163	604.163	91,76
1	2026	626.658	1.230.821	83,22
2	2027	663.661	1.894.482	74,17
3	2028	718.110	2.612.592	64,38
4	2029	793.717	3.406.309	53,56
5	2030	895.157	4.301.466	41,36
6	2031	1.028.306	5.329.772	27,34
7	2032	1.200.527	6.530.299	10,97
8	2033	1.421.041	7.951.340	-8,40
9	2034	1.802.826	9.754.166	-32,98
10	2035	2.201.404	11.955.570	-62,99

Based on the analysis results, under the design condition, the pavement was designed with a service life of 10 years; therefore, the remaining service life gradually decreases from 100% in 2025 to 0% in 2035. This steady decline reflects ideal performance in accordance with design assumptions, where cumulative traffic loading (CESAL) and pavement deterioration occur as planned. In contrast, under the actual condition, the remaining service life decreases more rapidly, lasting only until the seventh year (2032) and reaching negative values in the eighth year. This indicates that the pavement has exhausted its service life earlier than planned due to higher actual traffic volumes as well as less favorable construction quality and environmental conditions.

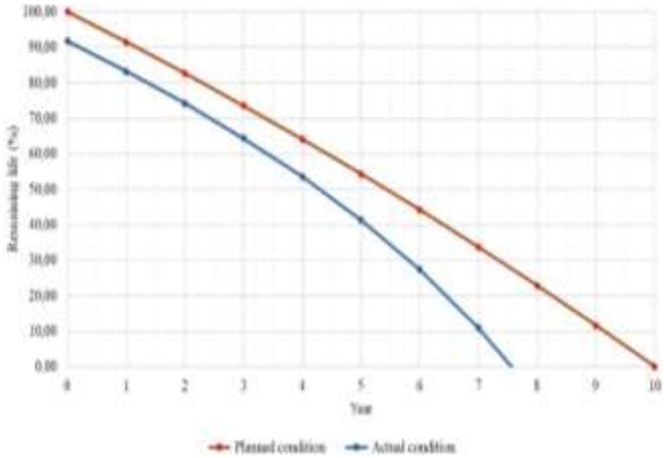

Figure 12. Remaining Service Life of the Pavement

The Remaining Service Life graph of the Guru Tua Road illustrates a comparison between the design condition (red line) and the actual condition (blue line) over a 10-year period. The red line represents the initial design prediction in accordance with MDPJ 2024, in which the remaining service life decreases uniformly and reaches 0% at the end of the tenth year. In contrast, the blue line reflects actual field conditions, where the pavement reaches 0% remaining service life at approximately the beginning of the eighth year, with a reduction of 22.72%. This indicates that the service life of the Guru Tua Road is exhausted earlier than planned, resulting in an estimated reduction of about two years compared to the design life. These findings highlight the need for greater attention to discrepancies between design assumptions and real-world conditions, as well as the importance of implementing timely and well-planned maintenance strategies to ensure that the pavement achieves the intended 10-year service life in accordance with MDPJ 2024.

IV. CONCLUSIONS

This study assessed pavement condition, maintenance requirements, and remaining service life of the Guru Tua Road using the IRI, PSI, SDI, and AASHTO 1993 methods. The IRI analysis classified 35% of road segments as good, 57% as moderate, 5% as minor damaged, and 3% as severe damaged, with the highest IRI value of 12.439 recorded at STA 02+300–02+400, indicating extreme roughness and elevated safety risk. The PSI results showed suboptimal serviceability, with 27–40% of segments categorized as fair, 52–65% as poor, and 8% as very poor, including critical segments with PSI values approaching zero. The SDI method classified 85% of segments as good and 15% as moderate, but was less sensitive to severe deterioration due to its reliance on pothole counts without considering size or depth. Based on the combined IRI–SDI assessment, 92% of segments require routine maintenance, 5% periodic maintenance, and 3% rehabilitation or reconstruction. Using the AASHTO 1993 method, the remaining service life under design conditions (MDPJ 2024) decreased gradually from 100% in 2025 to 0% in 2035, whereas under actual conditions it reached 0% around the eighth year (2033), representing an approximate two-year reduction in service life and a 22.72% decline due to higher actual traffic loading and external factors, underscoring the need for timely maintenance and periodic monitoring to achieve the intended 10-year service life.

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